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# Development of a unified training and assessment simulation program for anesthesia and intensive care


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Thèse de doctorat de Sociologie et Sciences de l'Education

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# Titre : Développement d'un programme unifié de simulation pour la formation et l'évaluation en anesthésie-réanimation


## Résumé

### Contexte
L'anesthésie-réanimation (AIC) a besoin de formations et d'évaluations sommatives basées sur les compétences correspondant à l'exercice clinique. La simulation, intégrée dans l'approche d'éducation médicale basée sur les compétences, occupe une part importante de la formation en AIC, en particulier pour les compétences techniques et non techniques. S'adapter aux évolutions pédagogiques et des connaissances médicales est une nécessité mais consomme des ressources humaines et du temps. Construire et entretenir un programme commun de formation et d'évaluation par la simulation en AIC à l'échelle d'un pays – ou plus – pourrait être une solution. Cette thèse a pour objectif de poser les bases du développement un tel programme.

### Méthode
Au travers de trois études, nous avons successivement :

- Décrit l'état des lieux de la formation par la simulation en AIC en France en 2021 pour déterminer la faisabilité d'un programme national de simulation en AIC en France.
- Rassemblé les éléments clés des connaissances de la littérature sur l'évaluation sommative en simulation en santé pour déterminer s'il est possible de l'intégrer dans un programme de formation en simulation.
- Décrit les similitudes et différences entre les référentiels pédagogiques de internes (résidents) en AIC de l'Union Européenne, des USA, et du Canada pour déterminer s'il est possible de construire un cœur de référentiel de compétences partagé entre ces régions.

### Résultats
Les résultats des deux premières études montrent qu'il est possible de développer un programme de simulation commun en AIC à l'échelle d'un pays (la France) et qu'il semble possible d'y intégrer l'évaluation sommative. Le taux élevé de similitudes entre les référentiels pédagogiques en AIC de l'UE, des USA et du Canada valide la faisabilité théorique d'un cœur de référentiels de compétences partagés entre ces régions.

### Conclusion
Une stratégie pour développer un programme unifié de formation et d'évaluation par la simulation en AIC à l'échelle d'un pays (la France) est faisable et attendue. La première étape de cette stratégie a été réalisée avec cette thèse : établir l'état des lieux sur lequel se baser pour construire un futur programme commun de formation et d'évaluation par la simulation en AIC. Etendre une telle stratégie à l'échelle internationale est théoriquement faisable mais fait encore face de nombreux obstacles et défis.



### Mots-clés
Formation médicale, éducation médicale basée sur les compétences, simulation, évaluation sommative, anesthésie-réanimation

# Title: Development of a unified simulation training and assessment program for anesthesia and intensive care


## Abstract

### Background
Excellent anesthesia and intensive care (AIC) requires competency-based training and summative assessments relevant to clinical practice. Simulation, as part of the competency-based approach to medical education, is an important part of AIC training, both for clinical and behavioral/communication skills. Adapting to changes in education and evidence-driven medical practice is a necessity but consumes human resources and time. Building and maintaining a unified AIC simulation training and assessment program at the level of a country - or region, or internationally - could be a solution. The objective of this thesis is to propose a strategy for developing such a program and to assess its feasibility.

### Method
Through three studies, we have successively:

- Described the current simulation-based education and assessment of AIC in France in 2021 to determine the feasibility of a national unified AIC simulation program (in France).
- Gathered key elements of knowledge from the literature on summative assessment with simulation in healthcare to determine the feasibility of integrating it into a specialty's simulation training program (in this case AIC).
- Described the similarities and differences between the educational requirements for AIC residents in the European Union, the United States, and Canada to determine if it is possible to build a core of shared competency repositories between these regions.

### Results
The results of the first two studies show that it is possible to develop a unified AIC simulation program across a country (France) and that it is possible to integrate summative assessment. The high rate of similarity between the AIC educational repositories of the EU, the USA and Canada validates the theoretical feasibility of a core set of shared competency repository between these regions.

### Conclusion
A strategy to develop a unified AIC simulation training and assessment program on a national scale (France) is feasible and expected. The first step of this strategy has been achieved with this thesis: to map the current simulation-based education and assessment on which to build a future unified training and evaluation program in AIC simulation. Extending such a strategy on an international scale is theoretically feasible but still faces many obstacles and challenges, including assessing its desirability.



### Keywords
Medical training, competency-based medical education, summative assessment, simulation, anesthesia and intensive care

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This thesis represents the culmination of three years of work. However, it is only the beginning because I have only laid the foundations for an exciting project: the development of a unified training and assessment program in anesthesia and intensive care on a large scale. A project that - without revealing the conclusion of this thesis - will require a large collaboration of many people. Teamwork in short, as it is often the case in simulation and anesthesia. This thesis is already the result of teamwork. Multiple and different teams that each supported and assisted me in the achievement of this thesis.

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Articles #1 and #3 have been presented as abstracts at the French Society of Anesthesia and Intensive Care (SFAR) meeting in Paris (France) on September 24th and 25th, 2021.

# List of Abbreviation

ACGME: Accreditation Council for Graduate Medical Education
AIC: Anesthesia and Intensive Care
AMEE: Association for Medical Education in Europe
ANTS: Anaesthetists' Non-Technical Skills
CA: Cardiac Arrest
CBD: Competence by Design
CBME: Competency-Based Medical Education
CHERRIES: Checklist for Reporting Results of Internet E-Surveys
CNEAR: Collègue National des enseignants en Anesthésie-Réanimation
COVID19: Corna Virus Disease 2019
CPD: Continuing Professional Development
CRM: Crisis Resources Management
Crisis Resources Management
EPA: Entrustable Professional Activity
ETR: European Training Requirement
EU: European Union
GDPR: General Data Protection Regulation
IRB: Institutional Review Board
MOC: Maintenance Of Certification
MOCA: Maintenance Of Certification in Anesthesiology
NGT: Nominal Group Technique
OSCE: Objective Structured Clinical Examination
PhD: Doctor of Philosophy
PTSD: Post Traumatic Stress Disease
RAND/UCLA: Research And Development Corporation/University of California at Los Angeles
SFAR : Société Française d'Anesthésie-Réanimation
SoFraSimS: Société Francophone de Simulation en Santé
UEMS: European Union of Medical Specialists
UH: University Hospital
UK: United Kingdom
US: United States

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# Executive summary

Excellent, evidence-based anesthesia and intensive care (AIC) need relevant and representative clinical training and summative assessments to best train and select learners.[1–3] Simulation, as part of the competency-based medical education (CBME) approach, is an important part of clinical training in AIC, particularly in clinical and behavioral/communication skills.[4–6] Simulation is one efficient way to meet the need for objective and concrete formative and summative assessments within AIC because it so closely mimics clinical practice.[7–9] Building repositories of simulation-based training and assessment approaches, adapting them to the evolving knowledge, and integrating them within a training program is complex and consumes resources (e.g. experts, time). Several organizational institutions in charge of validating AIC resident training have developed and published AIC educational competency repositories.[10–14] If simulation is mentioned as a tool in those repositories, we currently have few systematic assemblies of how it is used. Assembling and describing how simulation-based education and assessment is currently used is a crucial first step in building systematic and unified simulation-based training and simulation-based assessment programs for the future.

This thesis explores three facets of AIC residency training:

1. A description of current simulation-based education and assessment in AIC in France (Article #1);
2. A description of current key principles simulation-based summative assessment in healthcare (Article #2);
3. A description of commonalities and differences in AIC residency in the European Union (EU), United States (US), and Canada (Article #3).

This thesis seeks to lay the groundwork needed for AIC residency training to move toward robust unified competency-based training and assessment. A clear description of current practices provides the starting point to map the necessary next steps to build simulation-based summative assessments of competencies for AIC residencies at a large-scale.

**Article #1: A description of current simulation-based education and assessment in anesthesia and intensive care in France**

Developing a unified AIC simulation program is a daunting task that, while it requires a lot of resources and energy, can bring many benefits. In order to develop such a program, it is first necessary to identify the baseline conditions in order to determine realistic objectives, to integrate this action into a coherent set of CBME and to design the best pathway to reach these objectives. At the scale of a country (France), this crucial step will allow for optimal progress towards the highest educational standards by rationalizing resources and efforts. The first study of this thesis confirmed the feasibility of a unified simulation program in AIC at the scale of one country (France). The simulation activity profiles identified were very homogeneous, were supported by the national training program, and should therefore allow a simple coordination to formalize a unified simulation program in AIC (France). It is now up to the institutions in charge of training residents in AIC to initiate the concrete development.

**Article #2: Summative assessment with simulation in healthcare: key principles for practice**

Integrating summative assessment into simulation-based competencies training programs is a logical extension of the advanced integration of simulation into the CBME approach. This evolution is based on the fact that simulation more closely replicates the demands of clinical practice than written or verbal tests of knowledge.[8] To implement simulation-based competency assessment, we need to have an overview to guide practice with such principles of the key principles of summative assessment in simulation. An overview does not exist as such in the literature. Determining the type of evidence for the use of summative assessment in simulation is essential for program designers and trainers. The second study in this thesis maps the knowledge of summative assessment in simulation and provides sufficient data to support the its use in healthcare education curricula. This overview of the key principles of summative assessment in simulation combined with the feasibility of a unified national AIC simulation program (France) implies that it is conceivable to integrate summative assessment in simulation into a unified national AIC training program in France.

**Article #3: A description of the commonalities and differences in anesthesiology residency in the European Union, the United States, and Canada**

The adaptation of curricula to the constant evolution of programs, and medical and pedagogical innovations is resource-intensive.[15,16] These medical and pedagogical innovations in AIC are shared across country borders. An international approach (EU, US, and Canada) targeting a shared core of AIC competencies would help both to homogenize practices and to rationalize

the use of resources needed for adaptations. A baseline assessment of the similarities and differences between the pedagogical repositories for the EU, US and Canada is needed to consider the feasibility of a shared international curriculum of AIC pedagogical objectives.[11,12,14] The third study in this thesis shows a high level of concordance in AIC learning objectives between the EU, US and Canada. This implies that a shared curriculum of AIC competencies between the EU, US and Canada is theoretically feasible and would cover a large majority of the objectives of the current curricula.

**Implications of the three studies**

Combining the results of the three studies in this thesis, we have arguments to say:

- That a unified simulation program in AIC can be designed on a country scale (France). (Article #1)
- That knowledge of the key principles of summative assessment in simulation should allow for its inclusion in a unified national simulation program to develop a unified simulation training and summative assessment program in AIC. (Article #2)
- That there are sufficient similarities between the AIC educational repositories of the EU, US and Canada to develop a shared international AIC educational objectives program. (Article #3)

We can therefore consider designing an international unified curriculum for AIC simulation training based on an international shared curriculum of AIC educational objectives and to integrate summative assessment in simulation. Strong political and strategic will as well as human and financial resources would be necessary to develop such a unified international curriculum for training and summative assessment in AIC simulation. However, the studies reported here provide favorable evidence of the feasibility of such an undertaking.

This thesis lays the groundwork for two important areas of future research: the further development of knowledge in summative assessment in healthcare and the development of a unified training program and summative assessment in AIC simulation. The first area can come to feed the second one later on. On the basis of the data gathered through this thesis, we believe that we have taken a modest step forward towards a better understanding of the place that simulation can have in training and summative assessment in AIC. We are now in a position to move concretely towards the development of a unified AIC simulation program, regionally, nationally, or internationally.

# Résumé substantiel

Une formation en anesthésie-réanimation excellente et fondée sur des données probantes nécessite une formation clinique et des évaluations sommatives pertinentes et représentatives afin de former et de sélectionner au mieux les apprenants.[1–3] La simulation, en tant qu'élément de l'approche de l'enseignement médical basé sur les compétences, est une partie importante de la formation clinique en anesthésie-réanimation, en particulier en ce qui concerne les compétences cliniques et comportementales/de communications.[4–6] La simulation est un moyen efficace de répondre au besoin d'évaluations formatives et sommatives objectives et concrètes dans le cadre de l'anesthésie-réanimation, car elle reproduit de très près la pratique clinique.[7–9] La constitution de référentiels de formation et d'évaluation fondés sur la simulation, leur adaptation à l'évolution des connaissances et leur intégration dans un programme de formation sont complexes et consomment des ressources (par exemple : des experts, du temps). Plusieurs institutions officielles chargées de valider la formation anesthésie-réanimation des résidents ont élaboré et publié des référentiels de compétences pédagogiques en anesthésie-réanimation.[10–14] Si la simulation est mentionnée comme un outil dans ces référentiels, nous disposons actuellement de peu de descriptions systématiques de la manière dont elle est utilisée. Rassembler et décrire la façon dont la formation et l'évaluation fondées sur la simulation sont actuellement utilisées est une première étape cruciale dans l'élaboration de programmes systématiques et unifiés de formation et d'évaluation fondées sur la simulation pour l'avenir.

Cette thèse explore trois facettes de la formation des résidents en anesthésie-réanimation :

1. Une description de l'enseignement et de l'évaluation actuels basés sur la simulation en anesthésie-réanimation en France (Article #1) ;
2. Une description des principes clés actuels de l'évaluation sommative basée sur la simulation dans le domaine des soins de santé (Article #2) ;
3. Une description des points communs et des différences dans la formation des résidents en anesthésie-réanimation en Union européenne, aux États-Unis et au Canada (article 3).

Cette thèse vise à jeter les bases nécessaires pour que la formation des résidents en anesthésie-réanimation évolue vers une formation et une évaluation solides et unifiées basées sur les compétences. Une description claire des pratiques actuelles constitue le point de départ pour

définir les prochaines étapes nécessaires à l'élaboration d'évaluations sommatives des compétences basées sur la simulation pour les formations des résidents anesthésie-réanimation à grande échelle.

**Article #1 : Description de l'enseignement et de l'évaluation fondés sur la simulation en anesthésie-réanimation en France.**

Le développement d'un programme unifié de simulation en anesthésie-réanimation est une tâche ardue qui, bien qu'elle exige beaucoup de ressources et d'énergie, peut apporter de nombreux avantages. Afin de développer un tel programme, il est d'abord nécessaire d'identifier les conditions de base afin de déterminer des objectifs réalistes, d'intégrer cette action dans un ensemble cohérent de l'enseignement médical basé sur les compétences et de concevoir la meilleure voie pour atteindre ces objectifs. A l'échelle d'un pays (la France), cette étape cruciale permettra une progression optimale vers les plus hauts standards éducatifs en rationalisant les ressources et les efforts.

Une enquête électronique anonyme fermée, approuvée par un comité d'éthique, a été soumise aux directeurs de programmes de résidence en anesthésie-réanimation et aux directeurs de programmes de simulation en anesthésie-réanimation en France de janvier à février 2021. Le taux de participation était de 31/31 (100%) avec 29 centres affiliés à un hôpital universitaire. Tous les centres avaient des activités de simulation en anesthésie-réanimation. La formation des résidents était organisée pour 94% des centres. Les utilisations de la simulation étaient la formation (100%), la recherche et le développement (61%), les tests de procédures ou d'organisation (42%) et l'évaluation sommative (13%). La formation interprofessionnelle par simulation pleine échelle existait dans 90 % des centres. La formation aux procédures avant les soins aux patients était effectuée toujours pour 16%, le plus souvent pour 45%, parfois pour 29% et rarement ou pas pour 10% des centres. Des patients simulés étaient utilisés dans 61% des cas. Des thèmes principaux ont été identifiés pour les compétences procédurales, la formation par simulation peine échelle et la formation par simulation avec patients standardisés. L'activité de simulation a été perçue comme étant en augmentation pour 68% des centres. Les centres ont exprimé le désir de participer au développement puis à l'utilisation d'un programme national unifié de simulation en anesthésie-réanimation.

La première étude de cette thèse a confirmé la faisabilité d'un programme unifié de simulation en anesthésie-réanimation à l'échelle d'un pays (la France). Les profils d'activités de simulation identifiés étaient très homogènes, étaient soutenus par le programme national de formation, et

devraient donc permettre une coordination simple pour formaliser un programme unifié de simulation en anesthésie-réanimation (France). Il appartient maintenant aux institutions en charge de la formation des résidents en anesthésie-réanimation d'initier le développement concret.

**Article #2 : Évaluation sommative avec la simulation dans les soins de santé : principes clés pour la pratique**

L'intégration de l'évaluation sommative dans les programmes de formation aux compétences fondées sur la simulation est une extension logique de l'intégration avancée de la simulation dans l'approche de l'enseignement médical basé sur les compétences. Cette évolution est basée sur le fait que la simulation reproduit plus fidèlement les exigences de la pratique clinique que les tests écrits ou oraux de connaissances.[8] Pour mettre en œuvre l'évaluation des compétences fondée sur la simulation, nous devons avoir une vue d'ensemble pour guider la pratique avec des principes clés pour l'évaluation sommative en simulation. Une vue d'ensemble n'existe pas en tant que telle dans la littérature. La détermination du type de preuve pour l'utilisation de l'évaluation sommative en simulation est essentielle pour les concepteurs de programmes et les formateurs.

À l'aide d'une technique de groupe nominal, 34 experts ont défini des thèmes pour clarifier l'utilisation de l'évaluation sommative en simulation, répondant aux questions pratiques des formateurs pour les guider dans leur pratique éducative. Chaque thème a été exploré par un sous-groupe sur la base d'une revue de la littérature « état de l'art » avec une technique d'échantillonnage en boule de neige. L'objectif était d'identifier les principes clés et les recommandations potentielles pour les orientations futures. Les résultats ont été contrôlés de manière croisée entre les sous-groupes et examinés par un comité d'experts indépendants. Les thèmes pouvaient être classés en trois grandes catégories. La première catégorie était celle pour laquelle il existe des preuves dans la littérature qui permettent de bien comprendre le sujet. Des recommandations basées sur ces preuves peuvent être proposées. La deuxième catégorie concernait les cas où les données de la littérature fournissent des orientations mais doivent être complétées. Des recommandations avec un niveau de preuve limité complété par l'opinion d'experts peuvent être proposées et des recherches doivent être entreprises. La troisième catégorie était celle pour laquelle il n'existe pratiquement aucune donnée dans la littérature. Des idées et/ou des avis d'experts peuvent être proposés et des recherches doivent être entreprises. Sept thèmes ont été retenus : "Qu'est-ce qui peut être évalué en simulation ?", "Outils

d'évaluation pour l'évaluation sommative", "Conséquences de l'évaluation sommative", "Scénarios pour l'évaluation sommative", "Débriefing, vidéo et recherche pour l'évaluation sommative", "Formateurs pour l'évaluation sommative", et "Mise en œuvre de l'évaluation sommative dans la simulation en soins de santé". Ensemble, ils donnent un aperçu de ce qui est connu et peut être fait avec une certitude relative, et de ce qui est inconnu et nécessite probablement des recherches supplémentaires.

La deuxième étude de cette thèse fait le point sur les connaissances de l'évaluation sommative en simulation et fournit des données suffisantes pour soutenir son utilisation dans les programmes d'enseignement des soins de santé. Cet aperçu des principes clés de l'évaluation sommative en simulation combiné à la faisabilité d'un programme national unifié de simulation en anesthésie-réanimation (France) implique qu'il est concevable d'intégrer l'évaluation sommative en simulation dans un programme national unifié de formation en anesthésie-réanimation en France.

**Article 3 : Description des points communs et des différences dans la formation des résidents en anesthésie-réanimation dans l'Union européenne, aux États-Unis et au Canada.**

L'adaptation des curriculums à l'évolution constante des programmes et aux innovations médicales et pédagogiques exige beaucoup de ressources.[15,16] Ces innovations médicales et pédagogiques en anesthésie-réanimation sont partagées par-delà les frontières. Une approche internationale (Union Européenne, États-Unis et Canada) ciblant un noyau commun de compétences en anesthésie-réanimation contribuerait à la fois à homogénéiser les pratiques et à rationaliser l'utilisation des ressources nécessaires aux adaptations. Une évaluation initiale des similitudes et des différences entre les référentiels pédagogiques de l'Union Européenne, des États-Unis et du Canada est nécessaire pour envisager la faisabilité d'un programme international commun d'objectifs pédagogiques en anesthésie-réanimation.[11,12,14]

Au moyen de deux tours d'analyse de contenu, nous avons comparé qualitativement les référentiels de compétences de formation en anesthésie-réanimation publiées pour l'Union européenne (The European Training Requirement), les États-Unis (ACGME Milestones) et le Canada (CanMEDS Competence By Design), en nous concentrant sur les similitudes et les différences de représentation (premier tour) et d'accentuation (deuxième tour) afin de générer des hypothèses sur les solutions pratiques concernant les normes éducatives internationales. Nous avons cartographié les similitudes et les divergences entre les trois référentiels. Le premier

tour a révélé que 93 % des compétences étaient communes aux trois référentiels. Les principales différences entre l'European Training Requirement, les US Milestones, et le Competence by Design concernaient la médecine d'urgence. Le deuxième tour a montré que plus de 30 % des compétences étaient mises en valeur de la même manière, à l'exception notable des compétences non techniques en anesthésie (European Training Requirement), des compétences plus granulaires dans des situations spécifiques d'anesthésie (Competence by Design) et du professionnalisme et des pratiques comportementales (US Milestones).

La troisième étude de cette thèse montre un haut niveau de concordance des objectifs d'apprentissage en anesthésie-réanimation entre l'Union Européenne, les États-Unis et le Canada. Cela implique qu'un programme commun de compétences en anesthésie-réanimation entre l'Union Européenne, les États-Unis et le Canada est théoriquement réalisable et couvrirait une grande majorité des objectifs des programmes actuels.

**Implications des trois études**

En combinant les résultats des trois études de cette thèse, nous avons des arguments pour dire :

- Qu'un programme unifié de simulation en anesthésie-réanimation peut être conçu à l'échelle d'un pays (France). (Article #1)
- Que la connaissance des principes clés de l'évaluation sommative en simulation devrait permettre de l'inclure dans un programme national unifié de simulation afin de développer un programme unifié de formation et d'évaluation sommative en anesthésie-réanimation. (Article 2)
- Qu'il existe suffisamment de similitudes entre les référentiels pédagogiques en anesthésie-réanimation de l'Union Européenne, des États-Unis et du Canada pour développer un programme international commun d'objectifs pédagogiques en anesthésie-réanimation. (Article #3)

Nous pouvons donc envisager de concevoir un programme international unifié pour la formation par simulation en anesthésie-réanimation basé sur un programme international partagé d'objectifs pédagogiques en anesthésie-réanimation et d'intégrer l'évaluation sommative à la simulation. Une forte volonté politique et stratégique ainsi que des ressources humaines et financières seraient nécessaires pour développer un tel programme international unifié pour la formation et l'évaluation sommative en simulation en anesthésie-réanimation.

Cependant, les études rapportées ici fournissent des preuves favorables de la faisabilité d'une telle entreprise.

Cette thèse jette les bases de deux domaines importants de recherche future : l'approfondissement des connaissances en matière d'évaluation sommative dans le domaine des soins de santé et le développement d'un programme unifié de formation et d'évaluation sommative en simulation en anesthésie-réanimation. Le premier domaine peut venir alimenter le second par la suite. Sur la base des données recueillies dans le cadre de cette thèse, nous pensons avoir fait un modeste pas en avant vers une meilleure compréhension de la place que la simulation peut avoir dans la formation et l'évaluation sommative en anesthésie-réanimation. Nous sommes maintenant en mesure d'avancer concrètement vers le développement d'un programme unifié de simulation en anesthésie-réanimation, au niveau régional, national ou international.

# Introduction

Health care curricula, including within anesthesia and intensive care (AIC), need relevant and representative clinical training and summative assessments to best train and select learners.[1–3] Simulation, as part of the CBME approach, is an important part of clinical training in AIC, particularly in clinical and behavioral/communication skills.[4,5] Simulation is one efficient way to meet the need for objective and concrete formative and summative assessments within AIC [7,9] because it so closely mimics clinical practice.[8] Building repositories of simulation-based training and assessment approaches, adapting them to the evolving knowledge, and integrating them within a training program is complex and consumes resources (e.g. experts, time).[15,16] Several organizational institutions in charge of validating AIC resident training have developed and published AIC educational competency repositories. These repositories serve individual countries (e.g. US, Canada, UK, Denmark)[10–13] or broader regions such as Europe, which includes several countries.[14] In these repositories, simulation is mentioned as one possible pedagogical tool for teaching and assessing mastered competencies. Published training programs developed in simulation on AIC themes (e.g. crisis situations) are not obviously linked to competency repositories. Developing a unified large-scale training and summative assessment program in AIC simulation is currently out of reach, as little data have been gathered.

Building a unified large-scale training and summative assessment strategy with simulation in AIC requires mapping the contours of current practice, including what is feasible, valid, validated about using simulation in training, and developing an action plan to implement this strategy.

**Article #1: A description of current simulation-based education and assessment in anesthesia and intensive care in France**

First, we need to assess how a large-scale, simulation-based, unified program can be implemented in AIC. For this purpose, the outlines of a simulation teaching program must be drawn and associated with the AIC skills and teaching repository. There is a difference between the teaching competency repository – which is global - and the simulation teaching repository or program – which is local.[17] The latter involves adapting and applying practical simulation-

related teaching concepts and simulators to achieve the competencies recommended in the competency repository. In the perspective of a large-scale unified strategy, it is necessary to identify the broadest shared core competencies that can be included in the simulation repository. To maximize success of such an approach, it is necessary to start by analyzing the current situation. What skills are currently being taught, and how are they approached? This fundamental step determines the distance to be covered and the possibilities of establishing a unified AIC simulation program. Clearly identifying the starting point allows us to set goals more precisely, and more importantly, to identify the path to move toward these goals. Without knowing where we are starting from it is complicated to choose the best path to reach our destination. The construction of a unified program for large-scale teaching of AIC through simulation requires a detailed inventory of the existing situation.

**Article #2: Summative assessment with simulation in healthcare: key principles for practice**

Second, we need to address the simulation-based summative assessment question.[7] If we wish to incorporate a summative assessment dimension to this large-scale unified teaching strategy with AIC simulation, we must additionally define the elements of summative assessment in simulation as precisely as possible. It is this step that allows us to build parts of the educational program corresponding to summative assessment. We need to identify what evidence is already established and what remains uncertain or lacking regarding using summative assessment in simulation. Thus, we need to describe the key principles, among other things, what can be assessed, the assessment conditions, the tools, and the validity of the findings to inform the various stakeholders.

**Article #3: A description of the commonalities and differences in anesthesiology residency in the European Union, the United States, and Canada**

Third, to build a unified large-scale training and assessment strategy for AIC simulation, we need to develop a strategic implementation action plan. This action plan will include several successive steps. The first step in this action plan is identifying the structural or geographic units to which this large-scale unified strategy for teaching and assessment with AIC simulation can be applied. At the country level, this will depend on whether programs are nationally standardized or run by federal or local organizations. Regionally, programs may be common or

have enough similarities to be compatible with a large-scale shared strategy. EU, as a region, is already involved in developing a shared set of competencies in AIC for all its nations.[14] Similarly, the US has a unified repository of competencies in AIC at the federal level.[12] Because of their shared history of medical development,[18] North America and EU may represent an interesting regional combination in a search for a larger geographic group with sufficiently high commonality between AIC competency repositories to consider developing an AIC simulation competency repository. Thus, we need to compare AIC residency competency repositories from UE, US and Canada to characterize their commonalities and differences. Those commonalities will map the shared core of competencies serving as a ground base to develop an international shared curriculum of AIC educational objectives; essential to develop a unified curriculum for AIC simulation training.

Achieving this first step of the action plan will help identify the driving regional forces concerned that can be mobilized for constructing and realizing the next stages of the action plan. This will determine the geographical and organizational perimeter within which it is possible to build a unified large-scale teaching and summative assessment strategy with AIC simulation.

There are different benefits expected from building such a strategy.[19] Pedagogical benefits, organizational benefits and benefits for care comprise a few.[20] Some of these benefits are linked and intertwined and may be realized quickly or unfold over a longer time period.[21,22] First of all, a common strategy allows optimizing the pedagogical engineering means (human resources) implemented for designing and maintaining simulation training. This will limit design redundancy and free up expert time to further develop other avenues, and can save time and money.[19] Another benefit is improving quality of the teaching provided and received. With a smaller curriculum to independently design, each expert unit can deepen and enrich their development of the limited number of competencies for which it is responsible. The trainers can spend more time mastering the training courses to improve the quality of the teaching delivered, as they will not be responsible for designing the training courses. If the training courses are carried out via a unified repository, itself built from good clinical practice guidelines, this also contributes to homogenizing high-quality CBME. The educational quality provided and received should logically be reflected in the quality of care provided to patients, as competency assessments are conducted within the AIC simulation programs. As health knowledge is constantly evolving at an ever-increasing pace, it is necessary to adapt teaching to new clinical recommendations. Sharing the workload of updating simulation education as

part of a large-scale strategy would facilitate adapting CBME to the changing knowledge of evidence-based medicine. Finally, a large-scale unified strategy for simulation teaching and assessment in AIC would be a vehicle for improving educational, clinical, and research interoperability among the parties involved in this joint effort.

# Research question

To build a unified large-scale training and assessment strategy with simulation in AIC, we need to gather some data. These data must allow us to better comprehend how to develop a unified simulation training and summative assessment program in AIC within a larger educational context, and will inform us of the feasibility of such a project. To facilitate this understanding and develop a robust evidence-based argument, we proceeded in three steps.

First, we will investigate the feasibility of a unified simulation program in AIC. Focusing on a single country (France) with a structured training in AIC, we will evaluate the current status of simulation in AIC and what resources and supports are in use. (**Part 1**) This information can allow us to consider how feasibly a unified training program can be built, and will lay the foundations for a unified summative assessment program. This inventory is essential to provide us with a foundation for building a repository of competencies in simulation, which answers both the pedagogical needs (what is done) and the theoretical needs (repository of competencies). Both also inform our capacity to realize this goal.

Second, we will investigate the current simulation-based summative assessment key principles in healthcare and the remaining fields to be explored. (**Part 2**) Within CBME, the full integration of simulation in the AIC curriculum implies a focus on summative assessment in addition to formative assessment. In view of the important stakes involved, we must rigorously and clearly define the summative assessment practices of what can be used, proven and validated; and of what we remain uncertain and needs supporting evidence or caution before being used, and a healthy awareness of the limits.

The combination of the results of these first two steps will allow us to consider the possibility of a unified training program in simulation in AIC integrating the summative assessment on a national scale (France). Because summative assessment is naturally high stakes, our efforts along with the human and financial resources needed for developing and validating such training and summative assessment programs are critically important. Expanding our populations of programs, trainers, and learners using simulation in these ways would increase the means made available to carry out such a joint program. In addition to expanding the base

of instructors and learners, the quality of simulation cases designed would likely be much higher, as cognitive resources for each program would be reinvested into developing one or two rigorous, piloted standardized cases rather than needing to create 20 cases (where quality may be constrained or sacrificed). This requires identifying other countries or regions that meet the previously defined criteria and have a sufficiently similar set of AIC skills for a unified core of simulation skills. This brings us to the third step.

Third, aiming toward realizing a large-scale unified simulation program strategy, we will investigate the extent of similarities and differences in the educational objectives of the AIC competency frameworks between different regions: the EU, the US and Canada. (**Part 3**) Europe and North America share a history of medical development and innovation.[18] It is reasonable to assume a number of similarities in the training applied in these three regions. Determining these similarities and differences in competency frameworks will allow for the precise identification of the core competencies that could be taught and summatively assessed through simulation on a much larger scale. This step will make it possible - if it is conclusive - to widen the populations concerned and the means that can be mobilized. This would be a strong argument in favor of the feasibility of building a unified large-scale teaching and assessment strategy with simulation in AIC.

# Methods

In this section we will describe in detail the princeps of the methods used for the three articles which compose this thesis, what was done, as well as the justifications of the choices of these methods.

## Literature reviews

The purpose of a literature review is to position the work carried out in a context in order to determine:

- The state of the art of existing knowledge and work,
- The knowledge gaps to be filled,
- The contribution made by the work carried out to the subject studied,
- The articulation of the work carried out with existing work.

We therefore conducted a literature review for the three articles that make up this science thesis as well as for the science thesis itself. Different types of literature reviews exist. Grant and Booth in 2009 propose a typology of literature reviews of 14 types of reviews and their methodology.[23] This descriptive work was completed by Booth et al in a book entitled "*Systematic approaches to a successful literature review*" whose second edition dates from 2016. **Table 1** presents description of the literature review used and the justification of the choice we made based on Booth et al recommendations.[24] The term “literature review” is an umbrella that cover different type of literature reviews including one specific named “literature review” which is different from other (scoping or systematic reviews). **Appendix 1** summarize the description and features of fourteen referenced literature review as described by Booth in 2016.[24]

**Table 1: Type of literature reviews done for each work with description (from Booth 2016) and rationale for choice.**[24]

| Work | Type of review | Description | Justification of choice |
|---|---|---|---|
| **Article #1**<br>A description of current simulation-based education and assessment in anesthesia and intensive care in France | Literature review | *Examines recent or current literature. Can cover wide range of subjects at various levels of completeness and exhaustivity. May include research findings.*[24] | We conducted a literature review to determine what was already known about the description of the use of simulation in an anesthesiology curriculum, what remained to be explored, and how our work related to that. |
| **Article #2**<br>Summative assessment with simulation in healthcare: key principles for practice | Rapid review | *Assesses what is already known about policy or practice issue.*[24] | We conducted a rapid review to determine the scope of the question posed to the nominal group and to provide framework elements from the literature to inform the initial thinking of the nominal group. An exhaustive or in-depth approach was not necessary at this stage of the work. |
| | State-of-the-art review | *Addresses current matters. May offer new perspectives on issue or point out area for further research.*[24] | The nominal group narrowed the question posed to seven themes. Each of these themes was to explored in detail in order to establish an up-to-date state of knowledge. The choice of a state-of-the-art review was based on the need to have an overview of recent and updated elements without repeating a systematic history when this was not of interest. This review approach was associated with a "snowball" strategy. |
| **Article #3**<br>A description of the commonalities and differences in anesthesiology residency in the European Union, the United States, and Canada | Literature review | *Examines recent or current literature. Can cover wide range of subjects at various levels of completeness and exhaustivity. May include research findings.*[24] | We conducted a literature review to determine what was already known about the comparison of educational objectives between different anesthesia-resuscitation curricula, what remained to be explored, and how our work was situated in relation to this. |
| **PhD**<br>Development of a unified training and assessment simulation program for anesthesia and intensive care | Literature review | *Examines recent or current literature. Can cover wide range of subjects at various levels of completeness and exhaustivity. May include research findings.*[24] | We conducted a literature review to determine what was already known about the use of simulation for the assessment of competencies in anesthesia training, what remained to be explored, and how our work compared to that. |

# E-Surveys for article #1

**E-survey's characteristics in general and in our case**

Bennett (2020) reviewed Web based surveys - recommendations for their design and interpretation in 2020 and the current guidelines are those proposed by Eseynbach and Wyatt in a series of articles in the early 2000s.[25] whose elements are consistent with the text book of Callegaro[26]: "*An online survey corresponds to the systematic collection of data by sending a standardized electronic questionnaire via the internet or email to a target population whose size is more or less known for the purpose of quantitative analysis.*" (adapted from Callegaro[26])

Respondent and organizational characteristics conducive to conducting an online survey as described by Eysenbach 2002[27] are as follows. Regarding study respondents, they must be internet users, willing to participate in the study, representative of the population, and their contacts are known or easily accessible. In our study, the respondents were the AIC program teaching coordinators or the AIC simulation program leaders. Their positions ensured a sufficient level of Internet literacy. Their involvement in teaching, the subject of the study, the importance of the data for the community and their center, and the commitment to communicate the results to them were powerful motivators. Their contact was available via the networks and mailing lists of the learned societies supporting the research: *Société Francophone de Simulation en Santé* (SoFraSimS) and *Collègue National des enseignants en Anesthésie-Réanimation* (CNEAR). Concerning the organizational aspects of the study, the criteria described by Eysenbach 2002[27] are a limited budget for the realization of a study and sufficient technical internet skills available, the possibility of controlling multiple responses from the same participant, the possibility of carrying out a test of validity and reliability of the study in the pilot phase, and a willingness to collect the data quickly In our study, we did not have identified funding but had access to web-based survey tools and sufficient expertise in these tools. These tools allowed for the control of multiple responses (cookies and IP) and the pilot testing of the study. Finally, it was necessary to collect data over a short period of time in order to take a snapshot at a given time of the use of simulation in anesthesia and intensive care in France; the dynamics of evolution of the elements collected were not known.

Eysenbach (2002) indicates that the results of online studies are comparable with those obtained with other data collection methods (mail surveys, face-to-face interviews).[27] The main biases

of an online survey are the difficulty in determining the response rate, respondent selection bias (non-representativeness, self-selection), and multiple entries from the same respondent.[27] These biases are strongly related to the "open-ended" nature of a survey. In our study, the survey was closed and targeted on a given population whose size (number of centers) was known. The response rate was therefore easily accessible, there was no risk of selection bias, and the technical tool made it possible to control the risk of multiple entries.

**Why we choose to do an e-survey**

Based on the arguments developed by Wyatt,[28] we chose to do an e-survey in order to quickly gather the most exhaustive data on the resources available and the use of simulation in AIC in France at a given time. The geographical dispersion and the high workload of the respondents required a tool that could adapt to their availability. The web tool allowed to gather this information in an anonymous and asynchronous way, adapting to the availability of the respondents (possibility to interrupt, save and resume the survey) and integrating the data in a directly analyzable form (spreadsheet). The absence of dedicated funding and access to contacts via the networks of learned societies were arguments in favor of this data collection method.

**Implementation**

We created items for the survey based on a previous survey I made in 2017 on simulation centers activities and resources in France (personal data), and on the report on simulation done for the French *Haute Autorité de Santé* in 2012.[29] The preparation, implementation and reporting are presented in the method section of the article " A description of current simulation-based education and assessment in anesthesia and intensive care in France" and were done according to the CHERRIES checklist.[30]

# Consensus Methods for article #2

**What are the main consensus methods?**

The main consensus methods are the Delphi method, the nominal group technique and the RAND/UCLA method. The purpose of using a consensus method is to measure and establish consensus agreement based on expert opinion on a particular issue. The principle is based on the idea that a reliable and specific answer can be obtained based on agreement among experts.[31] The interest is in drawing on a wide range of skills, knowledge and experience through the experts, which can fuel discussions and produce syntheses and possibly new ideas. Humphrey-Murto et al. produced a synthesis of the use of consensus methods in medical education research in 2017 in which the methods are described and recommendations on their use are made.[32] Below are extended quotations from Humphrey-Murto (2017) on the Delphi method, the nominal group technique and the RAND/UCLA.

> ***Delphi***
>
> *The Delphi technique was initially described by the RAND Air Force Corporation in America in the 1950s (Murphy et al. 1998).*[33]
>
> *The Delphi method includes the following stages: identifying a research problem, selecting participants, developing a questionnaire of statements, conducting anonymous iterative postal or email questionnaire rounds, collecting individual and group feedback between rounds and summarizing the findings (Jones & Hunter 1995; Murphy et al. 1998; Campbell et al. 2001).*[33–35] *This process is repeated until the best possible level of consensus is reached, or until a predetermined number of rounds have been completed. Participants never meet or interact directly in the classically- described Delphi method (Murphy et al. 1998)*[33] *(see Table 1 available online as Supplemental Material).*
>
> *The initial identification of the research problem usually involves a group of experts who share an interest in seeking solutions or recommendations to a particular problem.*
>
> *Round 1 of a Delphi involves mailing out the survey to expert participants who rank their agreement with each statement, and may be allowed to add new items to the list. The number of participants in the Delphi has ranged from 4 to 3000 (Campbell et al. 2001).*[35] *In some Delphi studies, there is no initial questionnaire development;*

*instead, the initial round is for idea generation from the participants. This is very relevant when little is known about a particular topic.*

*Between rounds, the research team collates the rankings and the anonymous collated results are sent back to participants for review. The quantitative data might include the mean, median and/or frequency distribution for each item. Participants would usually be able to see their ranking relative to other participants, and have an opportunity to re-rank the items. In some studies participants would also be asked to provide written feedback when their views differed substantially from the others. The list of items and participants may vary for each round. In some studies, the entire list of items would be sent for each round, while in others only those items in which there was a lack of agreement would be re-sent.*

*The benefits of the Delphi method include the potential inclusion of a large number of participants who are geographically dispersed, and clearly are favored for international research. It is relatively inexpensive and avoids undue dominance by specific individuals by providing the greatest degree of anonymity but may limit discussion and debate.* (Humphrey-Murto 2017 p. 2)

***Nominal group technique (NGT)***

*The NGT was developed by Delbecq and Van de Ven in the 1960s (Murphy et al. 1998, p. 3).*[33]

*The NGT shares several features of the Delphi, but in contrast is a structured face-to-face interaction usually involving 5–12 participants. It is often used for item generation and provides an opportunity for discussion (Jones & Hunter 1995).*[34]

*The steps are outlined in Table 1. The research team formulates a nominal question and gathers a panel of expert participants. Unlike the Delphi, a literature review is not always completed at this time, but background information is provided to the participants. The participants meet face to face and respond to the nominal question by recording his/her ideas independently and privately. These ideas are then shared with the group in a round-robin format, with each participant sharing one item from their list. These ideas are recorded by a facilitator who documents the responses until all participants have no more original ideas. Often, a flip chart or list of the responses is posted for all to see. The facilitator then leads a group discussion where each idea is discussed in turn, with similar ideas grouped together, and clarification provided. In some settings, the process may end here.*

*Usually, however, individuals then vote privately on the items and results are then fed back to the group in aggregate (anonymously). Further discussion and voting may take place (Murphy et al. 1998).*[33] *The entire process may last from 1.5 to up to 6 hours (Campbell et al. 2001).*[35] *A facilitator is required to effectively run the session. Advantages of the NGT include the generation of a larger number of ideas and the potential for discussion and debate. Limitations include a smaller number of participants than the Delphi, and the potential for dominant participants to unduly influence the group.* (Humphrey-Murto 2017 p. 2)

***RAND/UCLA appropriateness method (RAND/UCLA)***

*The RAND/UCLA method was developed to enable the measurement of the overuse and underuse of medical and surgical procedures (Fitch et al. 2001)*[36]*. The concept of appropriateness refers to the fact that the expected health benefits should exceed the expected negative consequences. RAND/UCLA has also been referred to as a hybrid of the Delphi and NGT.*

*Like Delphi, it begins with identification of a research problem, completion of a literature search, and development of a questionnaire of statements, which is sent out to participants. The questionnaire might involve a list of specific clinical scenarios or indications of patients who may present for a certain treatment. Participants also receive background information (literature review, definitions). In the first round, participants do not meet face-to-face; instead, they rank each item individually via email or mailed survey. In the original description, for each indication, the participants rate the benefit-to-harm ratio of the procedure on a scale of 1–9, where 1 means that the expected harms greatly outweigh the expected benefits, and 9 means that the expected benefits greatly outweigh the expected harms. A middle rating means that the harms and benefits are about equal for the patient described (Fitch et al. 2001)*[36]*. Like the NGT, the next step involves a face-to-face meeting where collated results are fed back to each individual member of the group. The participants have an opportunity to discuss their ratings, in light of how other participants have voted after which private voting occurs again. Consensus should not be forced and the outcome may lead to a classification of "appropriate", "uncertain", or "inappropriate". A common scale used is median scores in the 1–3 range are classified as inappropriate, 4–6 range as uncertain and 7–9 range as appropriate. A rating of uncertain would also be allocated if there*

> *was disagreement; in other words, all participant ratings did not fall within any 3-point range (Fitch et al. 2001).*[36] *The number of participants has traditionally been 9, large enough for diversity of representation yet small enough to allow discussion. The RAND/UCLA method is not intended for idea generation and assumes there is supporting data available to create the initial questionnaire of a highly structured list (Fitch et al. 2001).*[36] *As with the NGT an effective facilitator is required. Table 2 highlights some of the key differences between the methods.* (Humphrey-Murto 2017 p. 3)

**What we did: a modified Nominal Group Technique**

We followed the best practice recommendations proposed by Humphrey-Murto et al. for the methodologically rigorous conduct of a consensus method in research in medical education (**Appendix 2**).[32] We conducted a modified NGT method (**Table 2 Consensus Group Methods Comparison**). The purpose of this modified NGT was to identify themes to explore to clarify the use of summative assessment during simulation, answering trainers' practical enquires to guide them in their education practice.

First, the research question was formulated during a discussion at the 2018 SoFraSimS conference. The main conclusions were to address the increases in interest in using summative assessment, its informal uses, and consideration for use in official programs in healthcare education; the group identified that these important areas had no current guidelines. To reduce gaps in knowledge, the SoFraSimS' board commissioned a group coordinator to lead a work group on these topics. The work group's mission was to identify the "state of the play," or landscape of simulation used for summative assessments, the existing knowledge base, and potentially experts' recommendations.

Second, the group coordinator conducted an initial, non-exhaustive preparatory rapid literature review[24] to serve as a knowledge base for the working group's reflections and to help identify the topics to be explored. This rapid literature review was available on a common online document library (Zotero®) that the group members completed as they researched and discussed. The group coordinator was a physician, practicing and training trainers in simulation for 11 years, having trained almost a thousand trainers over 4 continents and training residents monthly. He is involved and board member of the SoFraSimS and has previously led 2 workgroups for establishing guidelines for the society SoFraSimS.

Third, based on the research topic and the preparatory rapid literature review the following question was posed to the group members: *"What are the questions to address for understanding and developing the use of summative assessment with simulation?"*

**Table 2: Consensus group methods comparison for Delphi, Nominal Group Technique and the Modified Nominal Group Technique we applied.**

The cells with grey background share the same mains characteristics. In bold are the specifics differences between the reference NGT and the modified NGT we made.

| **Stages in Consensus Group Methods**<br>*Grey color refers to similarities et and bold to differences* | | |
|---|---|---|
| **Delphi** | **Nominal Group** | **Modified NGT applied** |
| Identify a research problem | Identify a research problem | Identify a research problem |
| Complete a systematic literature search | Not systematic: Complete a literature search | Not systematic: Complete a literature search |
| Develop a questionnaire of statements for participants | Formulation of the nominal question | Formulation of the nominal question |
| Prepare background information for participants | Prepare background information for participants | Prepare background information for participants |
| Select participants (4-thousands) | Usually 5-12 | Select participants (34) |
| Round 1 mail or email questionnaire | **Face to face** meeting where nominal question is presented | **Video conference** meeting where nominal question is presented |
| Collect asynchronously individual and group feedback by research team via interview, email, remote survey; new items may be added | Round robin idea generation via the process of **synchronous, in-person** feedback from individual group members, recording each idea in turn, in multiple rounds | Round robin feedback from individual group members to record each idea **asynchronously online via email exchanges over a 6-week period**; idea generation |
| | Group discussion of each idea in turn for clarification at the **face-to-face** meeting | Group discussion of each idea in turn for clarification at **video conference** meeting |
| Round 2 mail or email questionnaire with individual and group feedback for anonymous re-ranking | Round 2; individual **synchronous, in-person** voting on ideas | Round 2; **asynchronous and anonymous online** individual voting on ideas |
| Continue iterative process of feedback by **mail or email** and re-ranking until complete | Continue iterative process of feedback and re-ranking until complete | Continue iterative process of feedback by **survey system** and re-ranking until complete (4 rounds) |

Fourth, the group of NGT participants was formed through a call for volunteers. The selection criteria for the group members were that the participants be people involved in simulation as trainers, training program designers, or program's directors with experience in the field of healthcare simulation. They were already, or would be, confronted with the issue of summative assessment in simulation. The members were therefore competent in simulation with a particular interest and involvement in the topic of summative assessment in simulation. The workgroup's members were recruited among volunteer simulation healthcare instructors in French speaking countries. There were 34 experts (12 women and 22 men) from 3 countries (Belgium, France, Switzerland). Twenty-three were physicians and 11 were nurses, while 12 total had academic positions. All were experienced trainers in simulation for more than 7 years and were involved or responsible for initial training or continuing education programs with simulation.

Fifth, the first two stages of the NGT (generations of ideas and round robin) facilitated by the group coordinator took place simultaneously asynchronously online via email exchanges over a 6-weeks period. We asked group members, based on the literature provided, to reflect on the question asked and to formulate proposals for questions/themes to explore. These proposals were sent to the group coordinator who regularly synthesized them and sent back to the whole group the updated status of the questions/themes while preserving the anonymity of the contributors and asking them to check the accuracy of the synthesized elements. The third step of the NGT (clarification) was carried out during a 2-hours video conference session. All members were able to discuss the proposed ideas, group ideas by themes and make the necessary clarifications. As a result of this step, 24 preliminary questions were defined as a basis for the fourth step (**Article 2, Supplemental Digital Content 1**). The fourth step of the NGT (the rating) consisted of four distinct asynchronous and anonymous online rounds that led us to a final set of themes with related sub-questions (**Article 2, Supplemental Digital content 2**). All rating rounds followed similar validation rules. We kept items (either questions or themes) with more than 70% approval ratings by participants. For those items with 30-70% approval, we reformulated and resubmitted in the next round, and discarded items with less than 30% approval. We discussed discrepancies and achieved final ratings with complete agreement for all items. For each round we sent reminders to reach a minimum participation rate of 80% of the members.

Finally, the outcome of our modified NGT process resulted in the identification of seven themes to explore in order to have a clearer idea of what is known and what would need to be explored about the use of simulation in summative assessment.

**Table 3** summarizes our modified NGT step-by-step with the description, benefits and limitations for each of the step. Our consensus method (modified NGT) had the recommended features.[33,34,37] First, anonymity was respected in the idea generation phase (step 1) and in the rating phase because only the coordinator received the emails and returned the proposed ideas, and the rating system used (SurveyMonkey®) guaranteed the anonymity of the answers. Second, iterations were performed in the idea generation phase until new ideas were exhausted and in the rating phase until a consensus was reached. Third, participants were provided with control feedback as the coordinator regularly sent a status report of the discussions with the comments and questions received; likewise with the results of the rating. Fourth, statistical group response was updated and disseminated after each of the 4 rating iterations. Finally, the interactions were structured and coded in their direction (participants to coordinator and between participants) according to the different phases of the NGT process.

**Why we chose this methodology**

We have realized a modified NGT that borrows characteristics from the Delphi method; another consensus method. The modifications compared to the classical description and the justifications for their implementation are the following. The interactions did not take place face to face due to the geographical dispersion of the participants over several countries and the context of the COVID19 pandemic. Interactions were conducted by email (asynchronous interactions) and by video conference (synchronous interactions). From our point of view, this allowed for more interaction time interspersed with individual reflection time, which may have been beneficial for the idea generation and round robin processes (step 1 and 2 of the NGT). We also believe that asynchronous remote interactions may have reduced one of the limitations of the NGT; namely the overriding influence of one or more participants on the group's thinking. Working remotely also made it possible to recruit a wider panel of experts, thus reducing one of the limitations of the NGT by broadening the expertise and perspectives brought by the participants. The duration of the NGT was eight weeks, unlike a traditional face-to-face session which is limited to a few hours. The reflections and discussions were able to proceed without time pressure or limitations.

**Table 3: Step-by-step description of the modified Nominal Group Technic (NGT) used in article #2 with description benefits and limitations for each of the step.**

| Steps | Description | Benefits | Limitations |
|---|---|---|---|
| **Step 1: research question formulation** | The research question was formulated during a discussion at the 2018 SoFraSimS conference | Involved a simulation large community of practice and the society<br>Adress a topic of interest for a community<br>Populate the work to come and help to recruit participants | |
| **Step 2: preparative literature review** | The group coordinator conducted an initial, non-exhaustive preparatory rapid literature review[24] | This rapid review served as a knowledge base for the working group's reflections and helped identify the topics to be explored. | A shortcoming in this rapid review was at risk to misorient the group. However, the whole group screened again the literature. |
| **Step 3: Formulation of the nominal question** | Based on the research topic and the preparatory rapid literature review the following question was posed to the group members: *"What are the questions to address for understanding and developing the use of summative assessment with simulation?"* | The nominal question was broad enough to let the group free of developing innovative orientation of work; and, at the same time, gave clear directions: understanding and future development. | The hidden side of the broad question is the risk of dispersion of the participants during the discussion. However, this is usual at this stage of a nominal group technic. |
| **Step 4: NGT participants recruitment** | The NGT's participants was formed through a call for volunteers. The selection criteria were that the participants be people involved in simulation as trainers, training program designers, or program's directors with experience in the field of healthcare simulation. They were already, or would be, confronted with the issue of summative assessment in simulation. | The recruitment of volunteers implied the participants were interested to the topic and increased the likelihood of their implication until the end of the NGT. Their skills in simulation, and preview experience or willing to use summative assessment in simulation ensure a degree of expertise related to the nominal question.<br>The online process of our modified NGT allowed to included everyone. | No background check was formally done on the participants experience.<br>No representation equity regarding profession, academic position or country was organized. |

| | | | |
|---|---|---|---|
| **Step 5: NGT application in 4 steps** | Generations of ideas and round robin (first two steps) facilitated by the group coordinator took place asynchronously online via email exchanges over a 6-weeks period.<br><br>Clarification (third step) was carried out during a 2-hours video conference session. Twenty-four preliminary questions were defined as a basis for the fourth step.<br><br>The rating (fourth step) consisted of four distinct asynchronous and anonymous online rounds of voting on the 24 questions. The rating led to a final set of seven themes with related sub-questions. | Mixing generation of ideas and rounds robin over a 6-weeks period allowed to maximize the reflection time and the circulation of ideas. It also gave more time to extend literature review according to the orientation of the reflection.<br><br>Regular feedback along the 6-weeks period facilitated and made the discussion and clarification efficient.<br>Video conference allowed two simultaneous communications channels: voice/video and chat. It has allowed to capture every contribution without major interruption of the discussion.<br><br>The process allowed more time for reflection and succeeded in achieving an agreement for all the questions. | Lack of dedicate common time for the round robin may have disturbed participants unfamiliar with NGT. However, the group coordinator gave and asked for feedback weekly, and was available for guidance.<br><br>With long period of time among generation of ideas, round robin and clarification, participants may have lost some ideas or details if they had not taken note of it.<br>With the spread of the NGT over the time, important contributors to generation of ideas and round robin may have not able to join for the clarification. That could not happen to a classic -face-to-face) NGT.<br><br>The process may have limited the discussion between the different rounds of voting, limiting the clarification that some participants should have wished to provided. However, comments were possible and gave as feedback by the group coordinator with each rounds' results. |
| **Step 6: NGT outcome** | Identification of seven themes to explore about the use of simulation in summative assessment | Definition of a clear and circumscribed investigation perimeter, appropriate for more in-depth targeted research. | Risk of having left out elements related to the initial question. Nevertheless, because of the nominal group technique, these elements would probably be incidental or of relative importance. |

We believe that the modifications made to the classical NGT process, inspired by the Delphi method (asynchronous, remote and distributed features), allowed us to reduce the limitations of the NGT and to take advantage of the benefits of the Delphi method: increase the number of participants, recruitment over a large geographical area, mitigation of the risk of dominant participants, low cost, increase the possibilities of discussion and debate. This methodological choice therefore seemed appropriate to achieve our goal of identifying the themes to be explored to clarify the use of summative assessment during simulation, answering trainers' practical enquires to guide them in their education practice.

# Content analysis for article #3

This methodological description of content analysis was synthesized from White & Marsh's article "*Content Analysis: A Flexible Methodology*." of 2006[38] and Krippendorff's book "*Content analysis: an introduction to its methodology*." 4th Ed of 2018.[39] Content analysis is a method of text analysis derived from research on large-scale communications in the 1950s based on the "sender / message / receiver" model. Content analysis is a flexible method that can be used alone or in combination with other methods to address questions about the information contained in documents.

**What is a content analysis?**

The definition of content analysis proposed by Krippendorff is: "*a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use*.".[39] The idea of inference is central to content analysis. On the basis of analytical constructs or rules of inference, conclusions are built from analyzed documents. Krippendorff specifies that analytical constructs can be derived from (1) existing theories or practices; (2) the experience or knowledge of experts; and (3) previous research.[39] The successive steps of a well-conducted content analysis (at least for a quantitative content analysis) should allow its reproduction by other researchers, thus validating its validity and reliability.

**Which data are analyzable with a content analysis?**

The selection of data should answer the research questions or validate the hypotheses. The selection of working documents should ideally include the three elements of the "sender / message / receiver" model or at least elements relevant to the research question.

Beaugrande and Dressler propose the following criteria to identify a document suitable for content analysis: cohesion, coherence, intentionality, acceptability, informativity, situationality, and intertextuality.[40]

Neuendorf proposes a typology of document based on recipients and context: individual messaging, interpersonal and group messaging, organizational messaging, and mass messaging.[41]

The selection of the data must allow a certain consistency in units of analysis to facilitate the study. This can be achieved by identifying units for sampling, collection, analysis and reporting.

Sampling and collection are done pragmatically while data analysis is guided by the research question.

**Content analysis description**

The successive steps of a quantitative content analysis are as follows:[38]

1. Establish hypothesis or hypotheses
2. Identify appropriate data (text or other communicative material)
3. Determine sampling method and sampling unit
4. Draw sample
5. Establish data collection unit and unit of analysis
6. Establish coding scheme that allows for testing hypothesis
7. Code data
8. Check for reliability of coding and adjust coding process if necessary
9. Analyze coded data, applying appropriate statistical test(s)
10. Write up results

There are two types of content analysis: quantitative and qualitative. Both can be mixed. Both share many common elements. Krippendorff identifies the following four common determinants: (1) sampling in the sense of selecting what is relevant; (2) unitize text/item (determine units of analysis); (3) contextualize the meaning in light of what researchers know about the circumstances surrounding the text; and (4) have specific research questions in mind.[39]

**What we did**

It is reasonable to assume that there is some degree of similarity in the practice of anesthesia around the world. This also suggests that there may be some similarity in the teaching of anesthesia. However, to our knowledge, there is no data to support this reasoning. As Europe and North America have a common history of medical development,[18] we chose to focus on those regions with a reasonable chance of having sufficient points of comparison. We therefore conducted a quantitative content analysis with the objective of determining the similarities and differences between the competency frameworks for anesthesia residencies between the European Union, the USA and Canada. The methodology applied followed the one written by

White and Marsh in order to maximize the reproducibility, validity and reliability of the work performed.[38]

The three researchers involved in the content analysis were each from one of the three regions of the European Union, the United States and Canada. All three were familiar with their region's repository and the clinical practice of anesthesia (context) in their region. English - the language of the analyzed repositories - was their native language for two of them and the third was fluent. The researchers' experience and knowledge allowed them to make inferences from the analyzed repositories to make comparisons and associations in order to determine differences and similarities in the educational objectives of the anesthesia residencies.

We identified each region's current governance setting standards for anesthesiology residency education, which included: the European Board and Section of Anesthesiology working under the auspices of the European Union of Medical Specialists (UEMS); the Accreditation Council for Graduate Medical Education (ACGME) for the United States; and the Royal College of Physicians and Surgeons of Canada. These were the European Training Requirement (ETR) in Anesthesiology,[14] the ACGME Program Requirements and the ACGME Milestones for US,[12] and the Anesthesiology Competencies within Competence by Design (CBD) for Canada.[11] The standards are described in the method part of article #3 "*First steps towards international competency goals for residency training: A qualitative comparison of 3 regional standards in anesthesiology*." The three standards follow the "sender / message / receiver" model. The "senders" are the authorities issuing the standards. The "messages" contained in the repositories are the descriptions of the competencies to be taught by the programs and mastered by the residents. The "receivers" are those responsible for organizing the anesthesia resident training programs; and indirectly the anesthesia residents themselves. Each of the repositories met the criteria of Beaugrande and Dressler.[40] Namely, the repositories:

- were written as a coherent whole (cohesion);
- had an understandable meaning (coherence);
- were intended to convey a set of professional competences (intentionality);
- were acceptable to the recipients since they were issued by their representatives (acceptability);
- provided detailed explanations of the professional competences (informativity);
- were situated in their temporal and cultural contexts (situationality);

- were consistent with previous versions of the frameworks (intertextuality).

Each of the competencies of the different repositories was considered as an independent item or unit of analysis. The items from each repository were entered into a cross-tabulation with the other repositories' items. The similarities and differences between the repositories were thus identified through the different cross-tabulations (Round 1). The cross-tabulations provided both numerical data (percentage of similarities/differences) and qualitative data (non-shared competencies). We discuss among researchers the non-shared competencies to understand the translation in clinical practice, and the potential reasons for those observed differences. The identification of the relative importance given to the competencies was obtained by taking the elements validated as shared and by discussing among the researchers the items' practical applications and implications. The results were synthesized in the form of tables and figures. All source data, cross-tabulations, discussion notes and results were cross-checked. External experts reviewed the final results with access to all the data. The different steps of the content analysis performed are summarized in **Table 4**.

**Why we chose this methodology**

The choice of a content analysis method was based on the need to extract data from written documents - the anesthesia residency competency repositories - and to express them in results that are partly quantified and can be summarized in the form of tables. These presentations of results allow for accessible comparisons, understanding of similarities and differences, and serve as a basis for future works. Future works could be joint developments based on similarities or gap-filling based on identified differences.

**Table 4: Description of the 10 steps of content analysis performed for the article #3 "*First steps towards international competency goals for residency training: A qualitative comparison of 3 regional standards in anesthesiology.*"**

| Content analysis steps | What we did |
|---|---|
| 1. Establish hypothesis or hypotheses | Our hypothesis was: There is a significant degree of similarity between the anesthesiology residency training frameworks for the EU, US and Canada. |
| 2. Identify appropriate data (text or other communicative material) | EU: The European Training Requirement in Anesthesiology[14]<br>US: The ACGME Program Requirements and the ACGME Milestones[12]<br>Canada: The Anesthesiology Competencies within Competence by Design[11] |
| 3. Determine sampling method and sampling unit | Use of all the three repositories' content |
| 4. Draw sample | Not applicable |
| 5. Establish data collection unit and unit of analysis | Data collection unit for analysis were based on the competencies' items, using the ETR as the reference comparison, given that it had the greatest number of competencies. |
| 6. Establish coding scheme that allows for testing hypothesis | We considered each of the ETR, US Milestones, and CBD competencies as a distinct item. |
| 7. Code data | We entered each of the ETR, US Milestones, and CBD competencies into a Microsoft Excel spreadsheet to serve as each region's repository of competencies. Each competency item was reviewed by the investigator representing that region and compared (cross tabulation) with the other regions' competencies to determine congruence.<br>For the first round of analysis, we identified whether each competency item was represented in either of the other repositories. The second round of analysis sought to determine the relative importance or emphasis of specific skill sets in each country's repository, using each repository as a reference for the other two to ensure full consideration of all competencies. Competency items were identified as having equal or different levels of importance, or "emphasis" between repositories based on how they were presented within the repository (i.e., competency items which were singled out and treated in-depth as unique competencies were interpreted as more emphasized than ones which were only briefly mentioned). |
| 8. Check for reliability of coding and adjust coding process if necessary | Check for reliability was performed by cross-checking among researchers, discussion and external experts' review.<br>We Adjusted coding by consensus. Consensus was achieved universally between researchers through discussions, with minimal instances of disagreement. |
| 9. Analyze coded data, applying appropriate statistical test(s) | We used descriptive statistics to quantitatively present congruency and emphasis of competencies between the repositories. |
| 10. Write up results | We presented results with tables and figures. |
| European Union (EU); United States of America (US); The Anesthesiology Competencies within Competence by Design (CBD); The European Training Requirement (ETR); The ACGME Program Requirements and the ACGME Milestones (US Milestones); | |

# Part 1: Feasibility of a unified simulation training program in Anesthesia and Intensive Care

## Introduction to Article #1

We can envision many important benefits to a unified simulation training program in AIC on a national scale (France). This would increase the homogenization of teaching, facilitate the dissemination of practical teaching of skills, and competency-based assessment methods. This evolution corresponds to the most recent criteria of quality in teaching aiming at bringing training closer to real clinical practice.[8] The ultimate goal is to improve the quality of care delivered to patients. For organizations and trainers responsible for implementing the courses, a unified program represents savings in human and financial resources.[19] As the design effort is pooled, it is reasonable to expect to have a quality and/or scope of simulation training program equivalent or superior to what could be produced in isolation, for a reduced cost. The savings thus made can be reinvested in the development of parts of the programs that have not been done until now due to a lack of resources or in the teaching itself. The pooling, increasing de facto the human resources coordinated on the same objective, it becomes easier to proceed to the regular adaptations necessary to the constant evolution of knowledge. This allows us to provide a training program that is up to date with the latest scientific data. Finally, a unified simulation training program in AIC facilitates interoperability and collaboration between centers, allowing the development of educational projects, research and even clinical action in network.

A first step in creating a unified AIC simulation training program is to assess its feasibility and desirability. To determine feasibility, it is necessary to evaluate what is already being done, the degree of similarity in what is already being done in the different centers, and the extent of the convergence effort needed for an evolution from a center-specific program to a unified program. Desirability is assessed by the perceived usefulness and willingness to adhere to a unified AIC

simulation training program. If feasibility and desirability are sufficient to confirm the viability of the project, the next step is to determine the current baseline from which the unified program will be built. This step is essential to determine both realistic and plausible characteristics for the joint program to achieve, and to identify the pathway to the final program. Knowing where you are starting from is essential to determine where you are going and which pathway to follow. Knowing the baseline state also supports the development of the common agenda and facilitates adoption if it is inspired by what is already being done.

The objective of this survey is therefore to answer simultaneously two questions that are complementary and vital for the continuation of the project: its feasibility (similarity of existing and desirability of a unified program) and the identification of the baseline.

This survey is carried out with the French community of AIC residency program directors and AIC simulation program directors because I am an anesthesiologist doing simulation for 12 years in France with a good knowledge of the environment and the evolution of simulation in AIC in France over the last years. In France, as in other countries, training with simulation has become more and more important in the last few years for the AIC specialty and the AIC residents first year's curriculum includes a precise description of what must be taught. The French Society of Anesthesia and Intensive Care (SFAR) adopted simulation early on (e.g. integration in meeting, expert recommendations) and the French-speaking Society for Simulation in Healthcare (SoFraSimS) includes a significant number of anesthesiologists (e.g. the two presidents since its creation). These two societies are therefore strongly involved in simulation in AIC and bring an important support to this project.

Article #1 presents the results of this survey on current simulation-based education and simulation-based assessment in AIC in France.

# Article #1

## A description of current simulation-based education and assessment in anesthesia and intensive care in France

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**Short title:** Description of simulation in anesthesia in France

## Abstract

### Background

Simulation plays an integral role in many competency-based medical education curricula. It is mostly used for training and formative assessment. If simulation is to play a significant role in summative assessment of clinical readiness in the future, then fair, comprehensive and rigorously designed simulation programs will be required. To implement these rigorous designs, we need to know where we are starting; what is the current "state of play" of simulation-based education and assessment? To illustrate the feasibility of answering this question, we describe the current simulation-based education and simulation-based assessment in anesthesia and intensive care (AIC) in France.

### Method

An IRB-approved, online anonymous closed electronic survey was submitted to AIC residency program directors and AIC simulation program directors in France from January to February 2021. The survey consisted of 68 questions across 5 sections: centers' characteristics, curricular characteristics, courses' characteristics, instructors' characteristics, and simulation perceptions and perspectives.

### Results

The participation rate was 31/31 (100%) with 29 centers affiliated with a university hospital. All centers had AIC simulation activities. Resident training was organized for 94% of centers. Simulation uses were training (100%), research and development (61%), procedural or organizational testing (42%) and summative assessment (13%). Interprofessional full-scale simulation training existed for 90% of centers. Procedural training prior to patients' care was performed always for 16%, most often for 45%, sometimes for 29% and rarely or not for 10% of centers. Simulated patients were used for 61%. Main themes were identified for procedural skills, full-scale and simulated patient simulation training. Simulation activity was perceived as increasing for 68% of centers. Centers expressed a desire to participate in developing and then using a national unified AIC simulation program.

### Conclusion

Based on our findings in AIC, we demonstrated that a baseline description of simulation activities, which is the first step in a strategy to develop a unified simulation training program in a discipline, was achievable. We now have a clearer perspective on who, what, how and when simulation for AIC is used. This approach provides useful clues to develop a comprehensive and meaningful program matching existing expectations and closing the identified gaps.

**Trial registration:** not applicable.

**Keywords:** Internship and Residency, Curriculum, Simulation, Education, Anesthesia, Competency-Based Education

**Word count:** 3492

## Introduction

Developing and positioning residency education and assessment to prepare clinicians for practice and verify that readiness is a daunting task. This complicated work requires adopting and adapting evidence-based clinical and education practices into the design of acute care residencies. This work puts substantial demands on program directors, education teams, and accrediting bodies. This task demands time and resources, and may direct attention away from other aspects of program oversight. [1–3]

Every healthcare discipline needs integrated simulation within their competency-based medical education (CBME) strategy,[4,5] since simulation plays an important role in teaching fundamental skills, both technical and non-technical.[6,7] In most healthcare disciplines, simulation is already at play for teaching and sometimes for formative assessment.[4,8–10] A growing emphasis on competency-based assessment of resident trainees makes simulation even more attractive as an educational modality, as training and assessments can be reliably standardized.[9–11] Developing a comprehensive simulation program could bring many

benefits for teaching and assessment.[9,12] However, it is too resources-intensive to develop at a small-scale. The concept has been proven in Canada for the 17 anesthesiology and intensive care (AIC) programs but remains to be proven as feasible at a larger scale.[10]

While Chiu et al. have taken the initial steps, there are limited data available to produce a large-scale strategy at a discipline level.[10] Without clear baseline knowledge, we are in the dark, unable to build a meaningful and efficient strategy to create a comprehensive and deliberate simulation program integrated within CBME, which would additionally provide trainees and programs with necessary assessments (both formative and summative).

An accurate appraisal of the baseline educational practices using simulation in any discipline (e.g. AIC) will provide a starting point to map the terrain needed to move forward strategically to implement simulation, via robust skill development and assessment processes to support CBME. A unified approach to adapting these curricula may optimize resources and results within a single discipline (e.g. AIC). The time and resources saved through a comprehensive approach will benefit educational and scientific societies, institutions, programs directors, and education teams.[13] Starting from a common ground instead of reinventing assessments independently will allow these groups to invest their efforts in either developing or adopting a homogeneous core of guidelines, with a focus on practical training and assessment tools (both formative and summative), as well as making adaptations as necessary.[10] This study aims to demonstrate the feasibility of this first strategic step to develop a unified simulation training in a healthcare discipline by defining the baseline use by major academic teaching centers, using surveys targeted at AIC residency training in France.

## Method

### Design

The design and results of this survey are reported based on the guidelines for reporting Results of Internet E-Surveys (CHERRIES).[14] The survey was an anonymous closed purposive survey designed to be completed by current AIC residency program directors and/or AIC simulation program directors from the simulation centers related to 30 University Hospitals in

France. One answer was expected for each center; Paris had 3 centers, and thus 3 responses, whereas all other cities had only one center.

**IRB (Institutional Review Board) approval and informed consent process**

The survey was reviewed by French Society for Anesthesiology and Intensive Care IRB on December 12, 2020 (Ref IRB 00010254-2020-240, chairperson Pr. JE Bazin) and was ruled exempt. Registration of the survey was reviewed by the information technology service at the University of Caen Normandy and was compliant with the European General Data Protection Regulation (Ref TG_RECHERCHE_POPULATION_00-20190705-01R1). Participants were given information about the research scope and aims, the length of the survey (approximately 20 minutes), and data confidentiality, as well as the scope of their own participation and their rights to withdraw their participation. Completion of the survey implied that participants had read and understood this information and had consented to participate in the research. Participation was anonymous, in that participants were not asked for any personal identifying characteristics. Participants were asked to identify their institutional affiliation, to control whether multiple responses were recorded from a single simulation center. Raw data was stored in the LimeSurvey platform [15] within the University of Caen Normandy data center and was accessible only to the researcher (CB) who programmed the survey and downloaded the unidentifiable anonymous results for analysis. If any identifiable data were provided in free-text qualitative responses, these were redacted prior to analysis.

**Development and pretesting**

The survey design emerged from discussion among the research team regarding the use of simulation for AIC training in France, specifically for AIC residents. Questions were constructed by CB and reviewed by the survey development team (AB, ML, JP), drawing on their combined experiences as AIC physicians, simulation educators, and researchers. A draft survey consisting of 64 questions across 5 sections was created and circulated to the research team for validation and review, and questions continued to be iteratively refined. The final survey consisted of 68 questions across 5 sections: centers' characteristics, curricular characteristics, courses' characteristics, instructors' characteristics, and simulation perceptions

and perspectives. Before being distributed to participants, the survey was piloted by the survey development team and four similar subjects of the targeted population recruited among the development team's network. Usability and technical functionality were assessed and adapted during the pilot phase.

**Recruitment process and description of the sample having access to the questionnaire**

The survey was distributed as a "closed survey", which targeted AIC residency program directors and AIC simulation program directors from the simulation centers related to UH in France: Amiens, Angers, Besançon, Bordeaux, Brest, Caen, Clermont-Ferrand, Dijon, Grenoble, La Réunion, Lille, Limoges, Lyon, Marseille, Martinique, Montpellier, Nancy, Nantes, Nice, Nîmes, Paris (3), Pointe-à-Pitre, Poitiers, Reims, Rennes, Rouen, Saint-Etienne, Strasbourg, Toulon, Toulouse, and Tours.[16] These participants were asked to provide one answer for their center. Using existing educational AIC (National College of AIC teachers; CNEAR) and simulation societal networks (French Speaking Society for Simulation in Healthcare; SoFraSimS), the targeted population was directly contacted and received individualized links for the survey in January and February 2021, over a period of 6 weeks.

**Survey administration**

The survey was administered using LimeSurvey (LimeSurvey GmbH), a free and open source on-line statistical survey web application hosted at the University of Caen Normandy. The survey was voluntary and participants could choose to exit the survey at any time. The survey was endorsed and supported by the French National Society of AIC (SFAR), the National College of AIC teachers (CNEAR), and the French Speaking Society for Simulation in Healthcare (SoFraSimS). As an option (and separate from their answers), participants could choose to receive the survey results. This and the endorsement could be seen as incentives for participants. The survey link was open for responses over a 6-week period. To prevent biases, when possible, items' order within the questions were randomized by the survey system. Survey design utilized adaptive questioning to ensure that participants answered questions relevant to their center and activities when possible. The survey had a total of 68 questions with 9 to 21 questions displayed per page throughout 5 pages. A completeness check was performed using

LimeSurvey before the questionnaire was distributed. Survey completeness was checked after each page of the survey was submitted. Mandatory unanswered questions were highlighted. All questions provided a non-response option such as “not applicable” or “I do not know” to ensure that all participants could select an option that matched their knowledge or situation. A back button was included in the survey design to allow respondents to review and change their answers throughout the survey.

**Response rate**

The participation rate was calculated by dividing the number of centers completing the survey by the total number (33) of simulation centers related to the 30 University Hospitals in France. A correction in the number of centers (31) was performed because one UH simulation center was scheduled to open in 2022 (Point-à-Pitre) and two UH simulation centers sharing the same program provided one answer for the both (Montpellier and Nîmes). Completion rate was calculated by dividing the number of respondents who completed the entire survey by the total number of respondents who started the survey by advancing past the informed consent page. To maximize the response rate, centers with incomplete responses in the database were sent a reminder email at 3 weeks and were called by phone at 5 weeks.

**Preventing multiple entries from the same individual**

Individual respondents were prevented from taking the survey more than once using a functionality in LimeSurvey, which used cookies to assign a unique identifier to each respondent to prevent multiple survey completions by a single respondent. IP addresses were not collected as part of the dataset. The log file was analyzed for identification of multiple entries from the same center. The first completed entry was considered as the one valid for the center and kept for analysis; any later entries were to be discarded.

**Data analysis**

Only completed questionnaires were analyzed. Questionnaires submitted with an atypical timestamp below 12 minutes were to be excluded. The 12 minutes cut-off point was determined during the pilot phase as the fastest answering time performed by testers who were broadly aware of the questionnaire's content. No statistical corrections (such as weighting responses) were performed.

## Results

The participation rate was 31/31 (100%). Results are reported with absolute number of centers and percentages using denominators of centers for which the question was relevant. No duplicated entries were received.

### Centers' characteristics

Among the 31 responders, 29 were directly linked to a university hospital (UH), one was a military hospital (Toulon) and one was a foundation-related private hospital (in Paris). All the 30 French UHs had a simulation center except one (opening scheduled for 2022), and Paris UH had two. Two geographically close UHs had a shared AIC program and provided one response for their center. Centers' characteristics regarding their physical layout, affiliations and national certification are presented in **Appendix 1**.

### AIC simulation Activities

All 31 (100%) responders had simulation activities in AIC. In situ simulation training, structured training (meaning the center had a formal curriculum through which residents progressed), training frequencies, and simulation uses are presented in **Figure 1**. The median calendar year [min-max] of starting AIC residency training was 2013 [2005-2019].

### Courses' characteristics

There was procedural training for AIC residents in 29 (94%) centers. Frequency and hurdles to procedural training are presented in **Figure 2 a) and b)**. All 31 (100%) responders reported full-scale simulation training for AIC residents, and 28 (90%) had developed interprofessional simulation. The personnel associated with interprofessional full-scale simulation training

including AIC residents are presented in **Figure 2 c)**. Nineteen (61%) of centers had simulated patient (SP) training for AIC residents. The people involved as SPs are described in **Figure 2 d)**.

**Curricular characteristics**

Simulation curricular characteristics, development, and pedagogical strategies are described in **Figure 3**.

**Instructors' characteristics**

Descriptions of simulation instructors for AIC are presented in **Table 1**, including number of instructors per center, instructors' training, and instructors' professional time allocated for simulation training.

**Perceptions and perspectives for the simulation centers**

Perceptions of AIC simulation activities' evolution, and training programs' maturation are presented in **Figure 4 a)**. **Figure 4 b)** shows accelerators for developing simulation AIC activities identified for 22 (71%) centers, and hurdles identified for 30 (97%). **Table 2** summarizes agreement rated with a Likert-scale from 1 "Totally disagree" to 5 "Totally agree" on statements regarding interest in a national simulation training program and using summative assessment in AIC.

**Simulation uses**

The simulation modalities and uses presented in **Figure 5** show that all modalities are principally used for training. **Table 3** summarizes simulation modalities distributed by residency year and the median time allocated for each modality by residency year. Ranked frequencies for teaching the 16 most commonly taught procedural skills out of 56 total skills (**Supplemental Digital Content 1**) and the 16 most commonly taught full-scale simulation themes out of 34 themes (**Supplemental Digital Content 2**), are presented in **Table 4**, along with the 4 common teaching themes for simulated patients.

We also accrued data on senior (e.g., attending anesthesiologist-level) programs and they are presented in **Supplemental Digital Content 3**.

## Discussion

If we refer to Rogers' concept of "diffusion of innovation" (considering simulation use as the innovation in CBME), adopters are educational and scientific societies, institutions, programs directors, education teams and to a certain degree, the learners.[17] For adopters to support and promote innovation, it should provide advantages, be compatible with existing systems and be efficient. The first step of the "diffusion of innovation" is to achieve the baseline knowledge – which we have been able to gather for simulation in AIC. Now we know what technical skills and full-scale-scenarios are the most taught in AIC. This baseline knowledge is essential to build the proof of effectiveness. For simulation in AIC, effectiveness is judged by whether the learners acquire the skills and includes factors such as what are their instructors' training (which we collected) and what pedagogical principles are applied (which we have not yet fully assessed). Both baseline knowledge and proof of effectiveness need to be accurately assessed: "From where are we starting with simulation?" Baseline measures provide additional benefits. First, they provide the starting point for the journey to map the pathway for an ideal simulation program. Second, if we aim to establish guidelines, matching will help these new guidelines be successful because people will be more likely to accept them if they are inspired by and built upon their own field experiences. These stakeholders can then inform what guidelines will be acceptable and help diffuse that innovation. Third, the wisdom of the crowd may tell what is ultimately needed.[18] For example, we found a high interest in using simulation for summative assessment, yet many centers had no formalized programs for doing this. Through the centers' feedback, a clear next step would be to develop simulation-specific summative assessment guidelines. Fourth, in the implementation process, baseline measures help to (i) set realistic goals and measure progress towards them; (ii) maintain accountability and inform others of what differences the project is making; and (iii) inform and motivate stakeholders to focus on certain issues and increase their engagement in the process.

With a high response rate (100%), our results are comprehensive and reliable, and our conclusions are suitable for the French AIC simulation community. This proof of concept demonstrates that a baseline assessment is achievable and valuable at a national level for a given healthcare discipline. We believe this approach may be reproduced for other disciplines and can determine the common ground upon which to build coordinated simulation programs. The value of this approach is reinforced by the reported high rates of organization, structured curricula,

and involvement of program directors in AIC resident simulation training. It gives a promising base for further development, systematization and implementing assessment methods (both formative and summative). Because we found high homogeneity among the collected data, we hypothesize there is room for a common simulation program.

If we analyze the data concerning different simulation modalities, we observe an important rate of full-scale in situ simulation (**Figures 1 and 5**). This calls for further deeper exploration to understand motivations and benefits, because full-scale simulation in situ requires complex organization and resources. [19] One explanation we can offer is the link between in situ simulation and interprofessional training. [19–21] In situ simulation may offer simpler access to interprofessional training since different professions are on site and it is not necessary to organize to bring them together in a simulation center. If this is the case, we can assume that it is the interprofessional training that leads to the in situ. This would be confirmed by the observed high rate of interprofessional training, itself suggesting an important awareness and training objectives of human factor and non-technical skills. A second hypothesis is that the in-situ environment provides opportunities to uncover or test latent problems that would not emerge in a completely simulated environment. [22–24] Regardless of motivation, strategies could be shared nationally between centers for ways in which in situ simulation could be more successful.

On another note, simulated patients are moderately used and there is a large heterogeneity in their background (**Figure 2 b**). Questions on simulated patients' training deserve further development because of the important possible issues with training outcomes, efficiency, and participants' psychological consequences. Due to the high technical level of AIC training, the range of situations requiring simulated patients may be limited, and it may be different for other disciplines.

Procedural training is widely used but only few centers reach the objective of "never first procedure on a patient without prior training in simulation" (**Figure 2 a**). This is mostly reported to be related to organizational and AIC instructor human resources. With a large dispersion in the number of instructors, identifying a minimum number and ratio of instructors to trainees may help to develop and apply programs. Generalizing procedural training prior to caring directly for patients is certainly a priority development area for ethical, safety, quality, and efficiency reasons in healthcare.[7] This would be true for every discipline, and reveals there is

opportunity for unified and standardized training programs across areas sharing the same requirements.

The use of simulation was mostly full-scale and procedural simulation for training (**Figure 5**). Procedural training seemed to be particularly important in the first year of residency, and full-scale seemed important throughout the residency years. The procedural themes were essentially around airway, emergency procedures and locoregional anesthesia. This logically follows the French regulation governing AIC first years' program for simulation training which emphasized procedural training. [25] This continues along the residency with more complex technical skills and procedures introduced later in residency. Full-scale simulation, as a vector for developing non-technical skills, is more distributed along the residency.

As a side observation, the significant level of senior (e.g., attending/consultant anesthesiologist) training signals the perceived importance and engagement with continuing education with simulation. (**Supplemental Digital Content 3)** This is promising for needed follow-up after graduation. Simulation is a concrete, close to real life training that is likely well adapted for practicing healthcare staff training and future recertification.[26] Knowing the high rate of increase in new knowledge healthcare is facing,[27] simulation may be a perfect match for some needs in continuing education.

In terms of pedagogical concepts, innovative pedagogical approaches such as mastery learning [28–30] and peer-to-peer teaching [31–33] are known and partially used. That can be seen as a proof of feasibility or acceptability for these techniques. However, there is room for larger implementation and research into knowing how these newer innovative teaching techniques may help with human resources optimization objectives and competency assessment.

Finally, as reported in a similar survey in US,[34] there was interest and readiness expressed for a national program **(Table 2**), calling for its development and foretelling a potential easy adoption. Experience from Canada, proved that a national simulation program in AIC can be feasible.[10] These are promising data in light of our objective to prove the feasibility of a baseline description of simulation use in AIC as a first step toward the development and application of a unified program. We can hope that may also be true for other disciplines.

*Limitations*

Our work has some limits that must be underlined. First, our survey was self-declarative (not externally observed and validated) and there was no control on data reported. However, the anonymity, the support from national societies and institutions, and the credentials of the responders led us to believe they responded honestly. Second, we attempt to prove the concept of doing a baseline assessment of state of play for simulation in a discipline as a first step of developing a large unified program. It appeared to work for AIC but it remains to be confirmed for other disciplines, as specific effects for AIC could not be excluded. Third, simulation modalities are evolving quickly in France, as the OSCEs (objectives standardized clinical examinations) are promoted as mandatory for the national medical exam of 2023. Therefore, one might guess that relational simulation and procedural simulation that are often used during OSCE will take a bigger influence in France soon.

## Conclusion

This work provides a baseline description of simulation-based education and simulation-based assessment in AIC in France that can be used as a starting point for future development of curricula or assessment. The relatively homogeneous core of pedagogical objectives and conceptualization of simulation programs is promising. It is likely there will be acceptance of and benefits to a unified large-scale program that helps with human resources and organization which are highlighted as principal limits to development.[13] A ready-to-use simulation program, saving time for conception, may allow one to focus on the teaching. Such a program may help to reach the essential patient safety objective “Never perform a first procedure on a patient without prior (simulation) training”, and to generalize and homogenize the precious human factor training resources.

AIC illustration proved that step one of a unified blueprint for simulation training is accessible. Based on this state of play, a unified blueprint seems feasible, viable and desirable; which are assets for its adoption. What is observed in AIC should reasonably be reproduced in other disciplines to efficiently and relevantly integrate simulation in Graduate Medical Education and Continuing Medical Education.

**List of abbreviations**

AIC: Anesthesia and Intensive Care
CBME: Competency-Based Medical Education
CHERRIES: Checklist for Reporting Results of Internet E-Surveys
IRB: Institutional Review Board
OSCE: Objective Structured Clinical Examination
UH: University Hospital

## Declarations

### Ethics approval and consent to participate

Not applicable

### Consent for publication

Not applicable

### Availability of data and materials

All data generated or analyzed during this study are included in this published article [and its supplementary information files] or available on reasonable request.

### Competing interests

The authors declare that they have no competing interests.

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### Authors' contributions

CB helped with study conception and design, data contribution, data analysis, data interpretation, writing, visualization, review and editing. RDM helped with study design

refinement, data contribution, data interpretation, writing, review and editing. JWR and DB helped with data interpretation, writing, and review and editing. AB, ML and JP helped with study conception and design, data review and editing. BP, and JP helped with review and editing. All authors read and approved the final manuscript.

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**Figure 1: In situ simulation training, structured training (meaning the center had a formal curriculum through which residents progressed), training frequencies, and simulation uses for the 31 responding centers.**

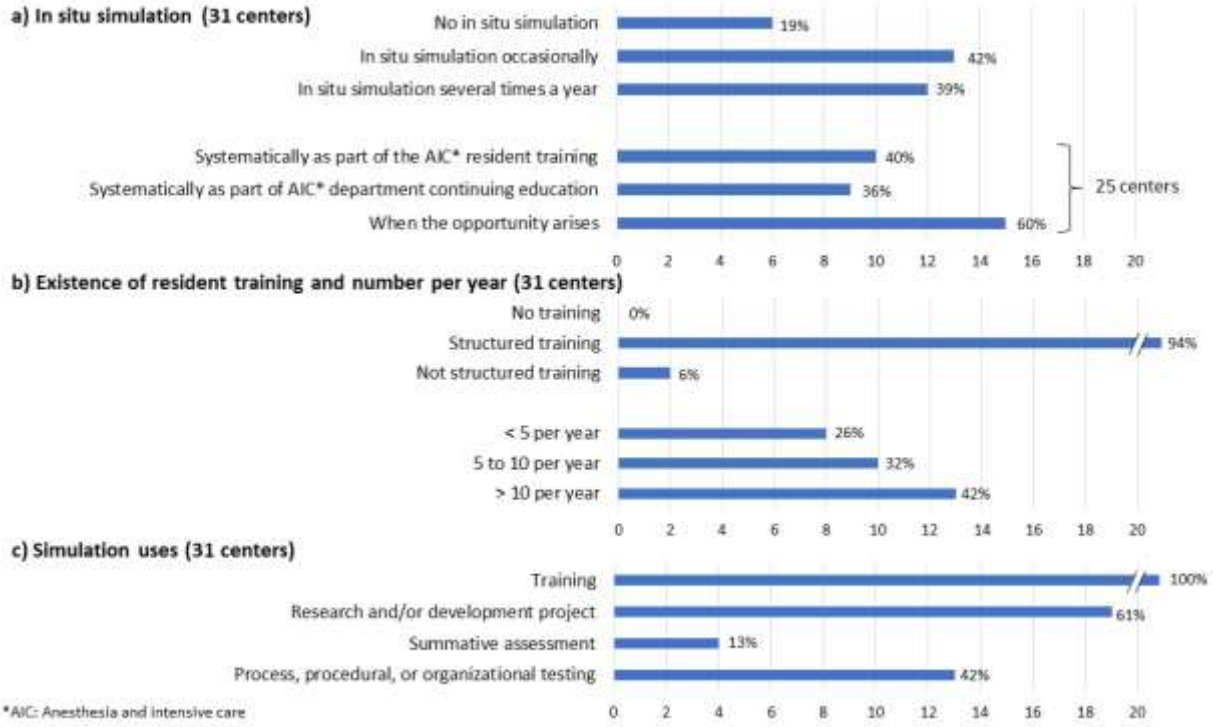



**Figure 2: Resident's training in specific technical skills prior to applying those skills in patient care (a) and hurdles for not having training prior to patient care (b). Personnel associated with AIC residents in interprofessional full-scale simulation training (c). People involved as simulated patient for AIC residents training (d).**

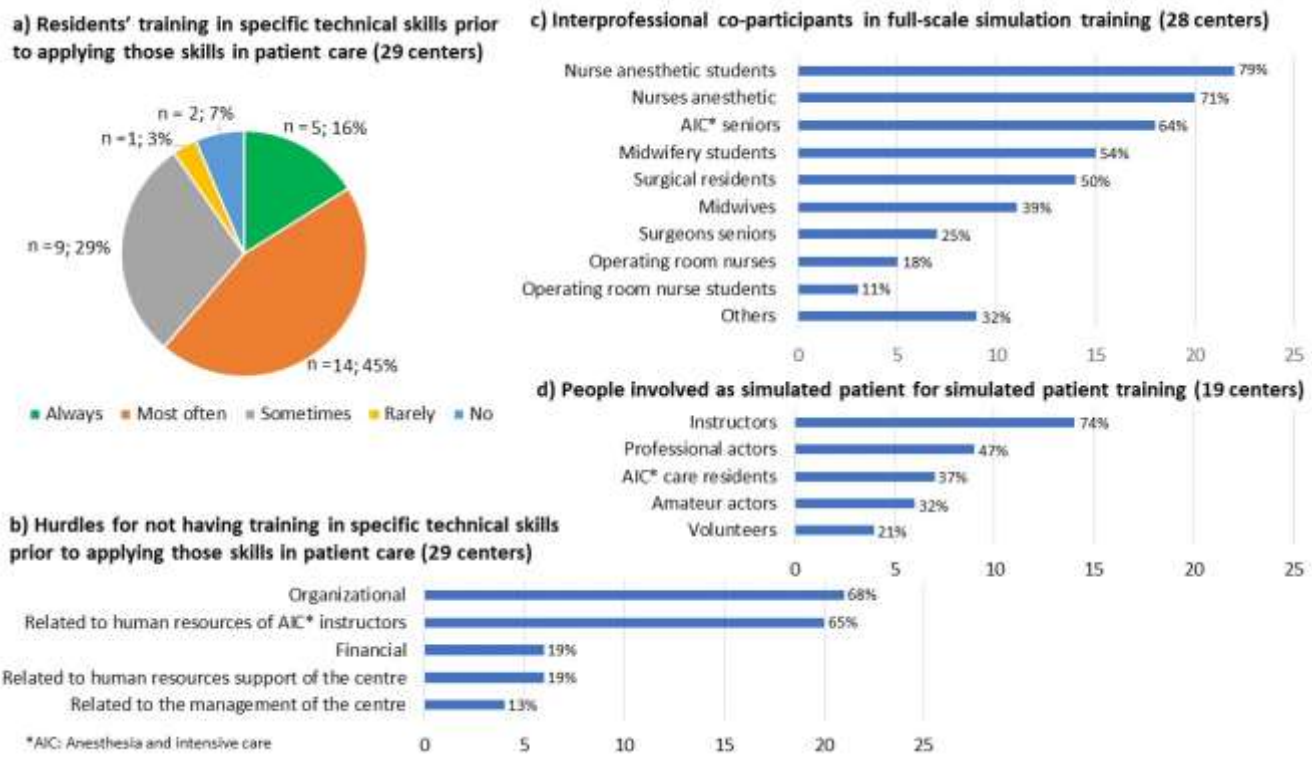


**Figure 3: Simulation curricular characteristics, development, and pedagogical strategies.**

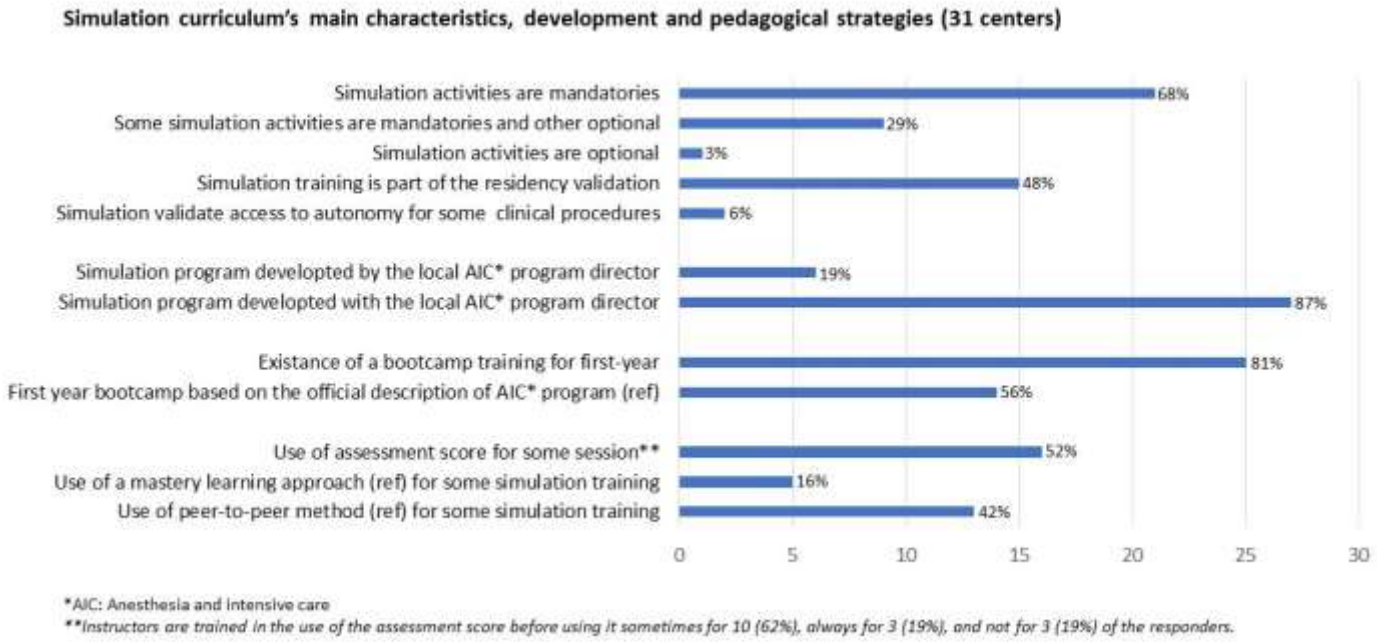



**Table 1: Simulation instructors' characteristics.**

| Instructors' characteristics | Results |
|---|---|
| • Number of AIC* instructors in the center | 7 [2-27] |
| • Number of centers with at least one instructor who graduated with simulation instructor training | 30 (97) |
| • Number of instructors who graduated with simulation instructor training per center | 4 [0-14] |
| • Number of centers with at least one instructor who graduated with university diploma in simulation | 29 (94) |
| • Number of instructors who graduated with a university diploma in simulation per center | 2 [0-15] |
| • Number of centers with at least one instructor having part time dedicated to simulation | 23 (74) |
| • Number of instructors per center having part time dedicated to simulation | 2 [1-12] |
| • Number of AIC instructor full-time equivalents dedicated to the simulation center | 0.5 [0.1-3.0] |
| • Number of centers having instructors who were not AIC who conducted training alone (excluding sim technicians and instructors for interprofessional training) | 5 (16) |
| • Professions are: - Anesthetic nurse | 2 (40) |
| - Surgeon | 1 (20) |
| - Other physician(s) | 3 (60) |

*AIC: anesthesia and intensive care
Results are in median [min-max] or number (percentage)

**Figure 4: Perceptions of AIC simulation activities' evolution, and training programs' maturation (a). Accelerators for developing simulation AIC activities (22 centers), and hurdles for developing simulation AIC activities (30 centers) (b).**

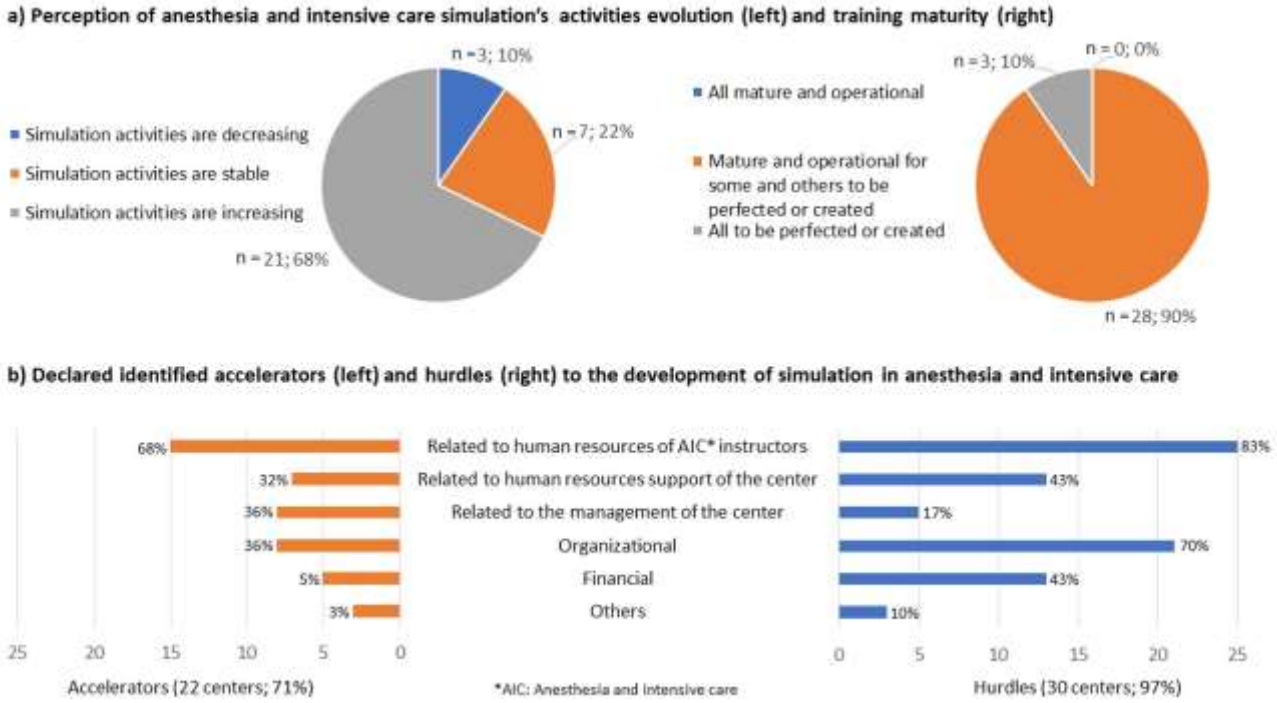



**Table 2: Perspectives on national simulation training program and summative assessment in anesthesia and intensive care.**

| Statement | Likert scale** |
|---|---|
| • A national simulation training program in AIC* would be useful. | 4.5+/-0.9 |
| • We would use a national simulation training program in AIC* if one existed. | 4.3+/-1.0 |
| • We would be willing to participate in the development of a national simulation training program in AIC*. | 4.3+/-1.1 |
| • We are currently able (human resources, equipment and know-how) to make summative assessment in simulation. | 2.9+/-1.1 |

*AIC: anesthesia and intensive care

**Likert-scale from 1 "Totally disagree" to 5 "Totally agree"

**Figure 5: simulation modalities and uses (311 centers).**

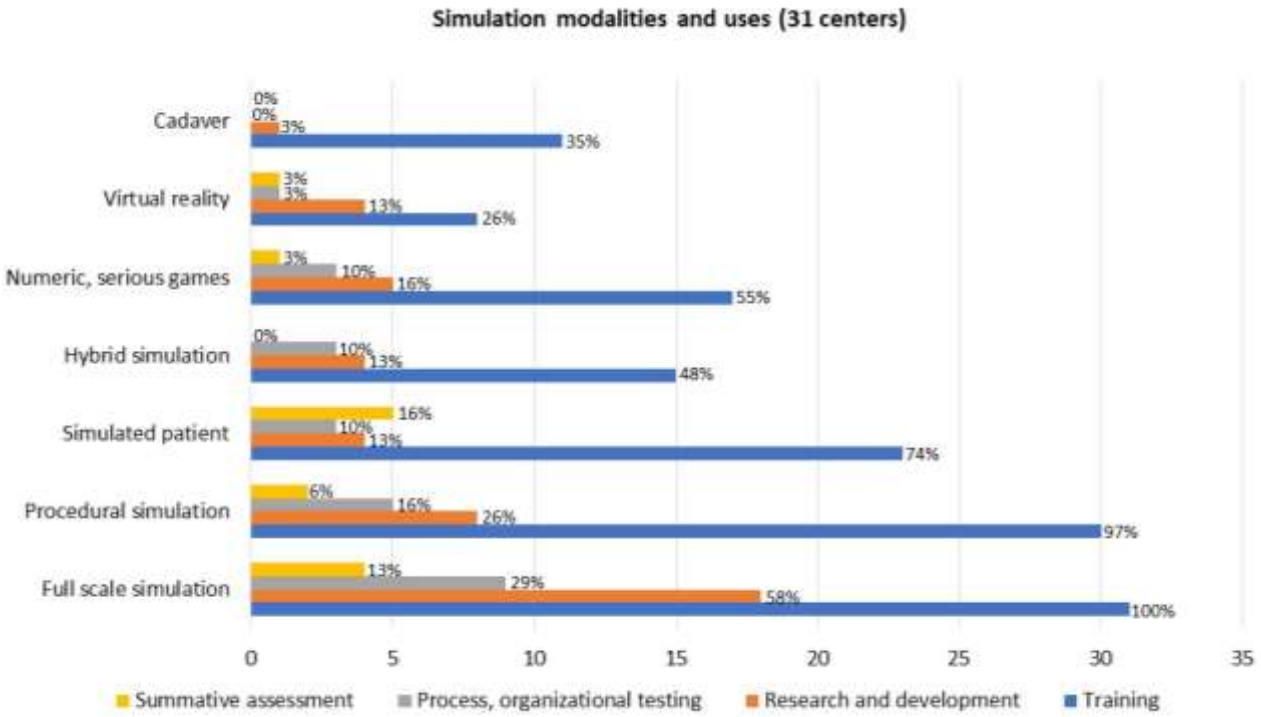



**Table 3: Simulation modalities and training time allocated: number of centers (percentage) and median time allocated (in hour) to simulation modalities per anesthesia and intensive care residency year [min-max] (among 31 centers).**

| Simulation | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Procedural training | 28 (90)<br>10 [2-16] | 13 (42)<br>8 [1-20] | 12 (39)<br>6 [1-16] | 11 (35)<br>5 [2-16] | 8 (26)<br>5 [4-16] |
| Full scale simulation | 27 (87)<br>7 [2-14] | 25 (81)<br>8 [3-24] | 28 (90)<br>8 [3-21] | 24 (77)<br>12 [3-20] | 19 (61)<br>10 [4-20] |
| Simulated patient | 13 (42)<br>4 [1-7] | 9 (29)<br>4 [1-7] | 5 (16)<br>8 [4-14] | 7 (23)<br>4 [1-8] | 7 (23)<br>4 [2-8] |
| Hybrid | 3 (10)<br>5 [2-10] | 2 (6)<br>7 [5-8] | 3 (10)<br>5 [1-8} | 4 (13)<br>5 [1-8] | 3 (10)<br>5 [1-8] |
| Numeric, serious games | 5 (16)<br>4 [2-6] | 6 (19)<br>4 [2-6] | 7 (23)<br>4 [2-6] | 4 (13)<br>4 [2-5] | 2 (6)<br>3 [2-4] |
| Virtual reality | - | - | - | 1 (3)<br>3 | - |
| Cadaver | 4 (13)<br>3 [2-3] | 2 (6)<br>2 [2-2] | 2 (6)<br>2 [1-2] | 2 (6)<br>4 [1-6] | 1 (3)<br>1 |

**Table 4: Sixteen most commonly taught procedural skills and full-scale simulation; and the four simulated patient themes according to years of training: number of centers (percentage) providing themes per anesthesia and intensive care residency year from the most to the less commonly taught.**

| Procedural skills (among 29 centers) | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | NT* |
|---|---|---|---|---|---|---|
| Difficult intubation | 12 (41) | 16 (55) | 12 (41) | 12 (41) | 6 (21) | 1 (3) |
| Tracheal intubation | 28 (97) | 5 (17) | 3 (10) | 1 (3) | 1 (3) | 2 (7) |
| External chest compressions | 27 (93) | 14 (48) | 11 (38) | 6 (21) | 6 (21) | 2 (7) |
| Management of intraosseous access | 16 (55) | 7 (24) | 4 (14) | 7 (24) | 4 (14) | 3 (10) |
| Use of defibrillators | 22 (76) | 12 (41) | 7 (24) | 3 (10) | 4 (14) | 4 (14) |
| Cricothyroidotomy | 8 (28) | 7 (24) | 8 (28) | 10 (34) | 8 (28) | 5 (17) |
| Ventilation with face mask | 25 (86) | 2 (7) | - | 1 (3) | 1 (3) | 5 (17) |
| Supraglottic device | 20 (69) | 9 (31) | 5 (17) | 3 (10) | 3 (10) | 5 (17) |
| Management of central venous access (ultrasound guided) | 20 (69) | 8 (28) | 1 (3) | - | - | 6 (21) |
| Fiberoptic intubation | 5 (17) | 10 (34) | 9 (31) | 8 (28) | 5 (17) | 6 (21) |
| Epidural anesthesia | 17 (59) | 4 (14) | 2 (7) | 1 (3) | 1 (3) | 8 (28) |
| Chest tube insertion | 13 (45) | 6 (21) | 7 (24) | 5 (17) | 4 (14) | 8 (28) |
| Mechanical / Invasive Ventilation | 16 (55) | 10 (34) | 4 (14) | 1 (3) | 1 (3) | 8 (28) |
| Spinal anesthesia | 16 (55) | 4 (14) | 2 (7) | 1 (3) | 1 (3) | 9 (31) |
| Transtracheal oxygenation | 6 (21) | 6 (21) | 7 (245) | 8 (28) | 6 (21) | 9 (31) |
| Ultrasound guidance for peripheral nerve blocks | 8 (28) | 10 (34) | 9 (31) | 2 (7) | 1 (3) | 10 (34) |
| Management of peripheral venous access | 18 (62) | - | - | - | - | 11 (38) |
| e-Fast ultrasound assessment | 5 (17) | 10 (34) | 8 (28) | 8 (28) | 4 (14) | 11 (38) |
| **Full-scale simulation themes (among 31 centers)** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **NT*** |
| Cardiac arrest - adult patient | 27 (87) | 13 (42) | 12 (39) | 8 (26) | 8 (26) | 1 (3) |
| Anaphylactic shock | 15 (48) | 19 (61) | 14 (45) | 8 (26) | 5 (16) | 2 (6) |
| Difficult tracheal intubation | 12 (39) | 14 (45) | 14 (45) | 13 (42) | 10 (32) | 2 (6) |
| Management of a trauma patient | 6 (19) | 13 (42) | 15 (48) | 15 (48) | 9 (29) | 3 (10) |
| Malignant hyperthermia | 8 (26) | 14 (45) | 15 (48) | 11 (35) | 9 (29) | 4 (13) |
| Local anesthetic systemic toxicity | 8 (26) | 17 (55) | 16 (52) | 14 (45) | 8 (26) | 4 (13) |
| Hypotension | 17 (55) | 19 (61) | 13 (42) | 8 (26) | 3 (10) | 5 (16) |
| Hemorrhagic shock | 14 (45) | 13 (42) | 16 (52) | 8 (26) | 6 (19) | 5 (16) |
| Hypoxemia | 16 (52) | 16 (52) | 14 (45) | 10 (32) | 4 (13) | 6 (19) |
| Bronchospasm | 8 (26) | 12 (39) | 9 (29) | 12 (39) | 6 (19) | 6 (19) |
| Septic shock | 2 (6) | 15 (48) | 15 (48) | 6 (19) | 4 (13) | 8 (26) |
| Obstetric hemorrhage | 3 (10) | 7 (23) | 11 (35) | 11 (35) | 6 (19) | 9 (29) |
| Cardiac arrest - pediatric patient | 4 (13) | 8 (26) | 9 (29) | 9 (29) | 5 (16) | 9 (29) |
| Laryngospasm | 6 (19) | 9 (29) | 10 (32) | 11 (35) | 4 (13) | 10 (32) |
| Cardiogenic shock | 8 (26) | 13 (42) | 13 (42) | 6 (19) | 4 (13) | 11 (35) |
| Emergency caesarean delivery | 2 (6) | 6 (19) | 11 (35) | 11 (35) | 3 (10) | 11 (35) |
| **Simulated patient simulation themes (among 19 centers)** | **Year 1** | **Year 2** | **Year 3** | **Year 4** | **Year 5** | **NT*** |
| Anesthesia consultation | 15 (79) | 6 (32) | 4 (21) | 3 (16) | 3 (16) | 2 (11) |
| Breaking bad news | 6 (32) | 3 (16) | 7 (37) | 7 (37) | 8 (42) | 3 (16) |
| Announcement of care-related damage | 3 (16) | 6 (32) | 6 (32) | 7 (37) | 8 (42) | 5 (26) |
| Announcement of a death | 3 (16) | 2 (11) | 6 (32) | 4 (21) | 7 (37) | 8 (42) |

*NT: Not Taught

**Supplemental Digital Content 1: Procedural skills themes and years of training: number of centers (percentage) providing thematic procedural skills training per anesthesia and intensive care residency year from the most to the less taught (among 29 centers).**

| Procedural skills | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | NT |
|---|---|---|---|---|---|---|
| Difficult intubation | 12 (41) | 16 (55) | 12 (41) | 12 (41) | 6 (21) | 1 (3) |
| Tracheal intubation | 28 (97) | 5 (17) | 3 (10) | 1 (3) | 1 (3) | 2 (7) |
| External chest compressions | 27 (93) | 14 (48) | 11 (38) | 6 (21) | 6 (21) | 2 (7) |
| Management of intraosseous access | 16 (55) | 7 (24) | 4 (14) | 7 (24) | 4 (14) | 3 (10) |
| Use of defibrillators | 22 (76) | 12 (41) | 7 (24) | 3 (10) | 4 (14) | 4 (14) |
| Cricothyroidotomy | 8 (28) | 7 (24) | 8 (28) | 10 (34) | 8 (28) | 5 (17) |
| Ventilation with face mask | 25 (86) | 2 (7) | - | 1 (3) | 1 (3) | 5 (17) |
| Supraglottic device | 20 (69) | 9 (31) | 5 (17) | 3 (10) | 3 (10) | 5 (17) |
| Management of central venous access (ultrasound guided) | 20 (69) | 8 (28) | 1 (3) | - | - | 6 (21) |
| Fiberoptic intubation | 5 (17) | 10 (34) | 9 (31) | 8 (28) | 5 (17) | 6 (21) |
| Epidural anesthesia | 17 (59) | 4 (14) | 2 (7) | 1 (3) | 1 (3) | 8 (28) |
| Chest tube insertion | 13 (45) | 6 (21) | 7 (24) | 5 (17) | 4 (14) | 8 (28) |
| Mechanical / Invasive Ventilation | 16 (55) | 10 (34) | 4 (14) | 1 (3) | 1 (3) | 8 (28) |
| Spinal anesthesia | 16 (55) | 4 (14) | 2 (7) | 1 (3) | 1 (3) | 9 (31) |
| Transtracheal oxygenation | 6 (21) | 6 (21) | 7 (245) | 8 (28) | 6 (21) | 9 (31) |
| Ultrasound guidance for peripheral nerve blocks | 8 (28) | 10 (34) | 9 (31) | 2 (7) | 1 (3) | 10 (34) |
| Management of peripheral venous access | 18 (62) | - | - | - | - | 11 (38) |
| e-Fast ultrasound assessment | 5 (17) | 10 (34) | 8 (28) | 8 (28) | 4 (14) | 11 (38) |
| Upper limb peripheral blocks | 8 (28) | 9 (31) | 9 (31) | 2 (7) | 1 (3) | 11 (38) |
| Lower limb peripheral blocks | 8 (28) | 9 (31) | 9 (31) | 2 (7) | 1 (3) | 11 (38) |
| Transthoracic echocardiography | 10 (34) | 13 (45) | 10 (34) | 8 (28) | 7 (24) | 11 (38) |
| Management of peripheral venous access (ultrasound guided) | 15 (52) | 6 (21) | - | - | - | 12 (41) |
| Management of arterial catheter | 16 (55) | 3 (10) | 1 (3) | - | - | 12 (41) |
| Needle/catheter decompression of the pleural space | 11 (38) | 5 (17) | 7 (24) | 5 (17) | 3 (10) | 13 (45) |
| Intubation using airway exchange catheter (e.g., reintubation) | 5 (17) | 7 (24) | 6 (21) | 4 (14) | 4 (14) | 14 (48) |
| Transesophageal echocardiography | 3 (10) | 6 (21) | 6 (21) | 7 (24) | 5 (17) | 15 (52) |
| Lung ultrasound to detect pneumothorax/pleural effusion | 5 (17) | 7 (24) | 7 (24) | 4 (14) | 2 (7) | 16 (55) |
| Administration of Blood Products | 8 (28) | 5 (17) | 6 (21) | 3 (10) | 1 (3) | 16 (55) |
| Non-Invasive Ventilation | 7 (24) | 9 (31) | 4 (14) | 1 (3) | 1 (3) | 17 (59) |
| Use of lung isolation techniques (e.g., bronchial blockers, double-lumen endotracheal tubes) | 1 (3) | 5 (17) | 8 (28) | 4 (14) | 1 (3) | 17 (59) |
| Proper patient positioning | 10 (34) | 4 (14) | 2 (7) | - | - | 17 (59) |
| Wall blocks (chest and abdomen) | 5 (17) | 8 (28) | 6 (21) | 1 (3) | 1 (3) | 17 (59) |
| Transcranial Doppler | 1 (3) | 8 (28) | 8 (28) | 7 (24) | 5 (17) | 18 (62) |
| Use of rapid transfusion device | 4 (14) | 4 (14) | 4 (14) | 3 (10) | 1 (3) | 19 (66) |
| Arterial compression and tourniquet placement | 5 (17) | 3 (10) | 4 (14) | 2 (7) | 1 (3) | 20 (69) |
| Use of blood salvage techniques/intraoperative cell salvage machines (e.g., "cellsaver") | 2 (7) | 4 (14) | 3 (10) | 2 (7) | 1 (3) | 21 (72) |
| Establishment of non-invasive and semi-invasive monitoring and collection of vitals | 7 (24) | 1 (3) | 1 (3) | 1 (3) | - | 21 (72) |
| Management and regulation of the patient's temperature | 6 (21) | 3 (10) | 1 (3) | 1 (3) | - | 21 (72) |
| Esophageal Doppler | 3 (10) | 5 (17) | 2 (7) | 1 (3) | - | 21 (72) |
| Combined spinal epidural anesthesia | 4 (14) | 2 (7) | 1 (3) | - | - | 22 (76) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Placement of immobilization | 3 (10) | 3 (10) | 2 (7) | 2 (7) | - | 22 (76) |
| Ultrasound guidance of neuraxial anesthesia | 1 (3) | 2 (7) | 2 (7) | 1 (3) | - | 24 (83) |
| Head, face and neck blocks | 1 (3) | 2 (7) | 4 (14) | 1 (3) | 1 (3) | 24 (83) |
| Fiberoptic bronchial lavage | 2 (7) | 3 (10) | 4 (14) | 1 (3) | 1 (3) | 24 (83) |
| Management of PICC line/midline catheter | 2 (7) | 1 (3) | - | 1 (3) | 1 (3) | 25 (86) |
| Epidural blood patch | 2 (7) | 2 (7) | 1 (3) | 1 (3) | 1 (3) | 25 (86) |
| Use of external pacemakers | 2 (7) | 3 (10) | 2 (7) | 2 (7) | 2 (7) | 25 (86) |
| Management of gastric tubes (placed orally or nasally) | 2 (7) | 3 (10) | 1 (3) | 2 (7) | 1 (3) | 25 (86) |
| Management of Swan-Ganz pulmonary arterial catheter | 1 (3) | 4 (14) | 2 (7) | - | - | 25 (86) |
| Caudal anesthesia | - | - | - | 3 (10) | - | 26 (90) |
| Gastric ultrasound | - | 1 (3) | 3 (10) | 2 (7) | - | 26 (90) |
| Drainage of cerebrospinal fluid and measurement of intracranial pressure | 1 (3) | 3 (10) | 2 (7) | 2 (7) | 1 (3) | 26 (90) |
| Management of urinary catheters | 2 (7) | 2 (7) | - | 1 (3) | - | 26 (90) |
| New-born advance life support and central venous access | - | - | - | - | 2 (7) | 26 (93) |
| Advance Cardiac Life Support certification | 1 (3) | - | - | - | - | 28 (97) |
| Interpretation of evoked potentials | - | - | - | - | - | 29 (100) |

**Supplemental Digital Content 2: Full-scale simulation themes and years of training: number of centers (percentage) providing thematic full-scale simulation training per anesthesia and intensive care residency year from the most to the less taught (among 31 centers).**

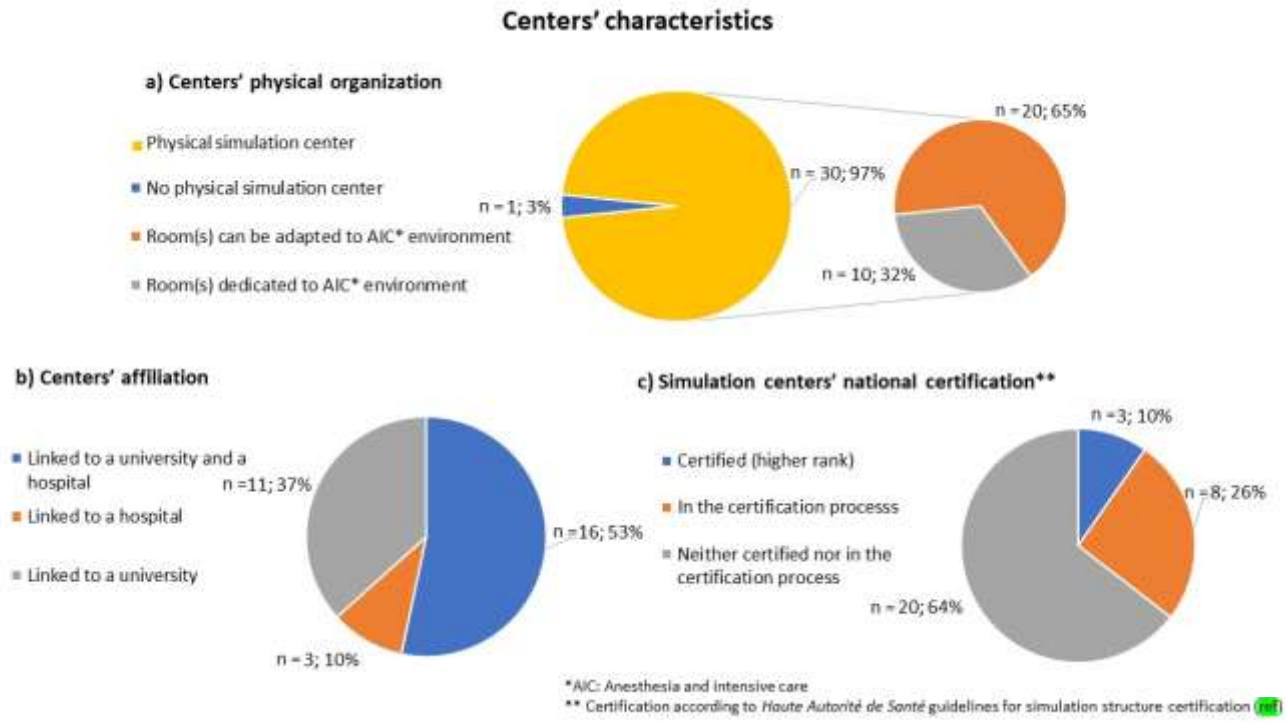
| Full-scale simulation themes | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | NT |
|---|---|---|---|---|---|---|
| Cardiac arrest - adult patient | 27 (87) | 13 (42) | 12 (39) | 8 (26) | 8 (26) | 1 (3) |
| Anaphylactic shock | 15 (48) | 19 (61) | 14 (45) | 8 (26) | 5 (16) | 2 (6) |
| Difficult tracheal intubation | 12 (39) | 14 (45) | 14 (45) | 13 (42) | 10 (32) | 2 (6) |
| Management of a trauma patient | 6 (19) | 13 (42) | 15 (48) | 15 (48) | 9 (29) | 3 (10) |
| Malignant hyperthermia | 8 (26) | 14 (45) | 15 (48) | 11 (35) | 9 (29) | 4 (13) |
| Local an aesthetic systemic toxicity | 8 (26) | 17 (55) | 16 (52) | 14 (45) | 8 (26) | 4 (13) |
| Hypotension | 17 (55) | 19 (61) | 13 (42) | 8 (26) | 3 (10) | 5 (16) |
| Hemorrhagic shock | 14 (45) | 13 (42) | 16 (52) | 8 (26) | 6 (19) | 5 (16) |
| Hypoxemia | 16 (52) | 16 (52) | 14 (45) | 10 (32) | 4 (13) | 6 (19) |
| Bronchospasm | 8 (26) | 12 (39) | 9 (29) | 12 (39) | 6 (19) | 6 (19) |
| Septic shock | 2 (6) | 15 (48) | 15 (48) | 6 (19) | 4 (13) | 8 (26) |
| Obstetric hemorrhage | 3 (10) | 7 (23) | 11 (35) | 11 (35) | 6 (19) | 9 (29) |
| Cardiac arrest - pediatric patient | 4 (13) | 8 (26) | 9 (29) | 9 (29) | 5 (16) | 9 (29) |
| Laryngospasm | 6 (19) | 9 (29) | 10 (32) | 11 (35) | 4 (13) | 10 (32) |
| Cardiogenic shock | 8 (26) | 13 (42) | 13 (42) | 6 (19) | 4 (13) | 11 (35) |
| Emergency caesarean delivery | 2 (6) | 6 (19) | 11 (35) | 11 (35) | 3 (10) | 11 (35) |
| Pneumothorax | 8 (26) | 11 (35) | 9 (29) | 3 (10) | 5 (16) | 12 (39) |
| New-born resuscitation | - | 1 (3) | 8 (26) | 10 (32) | 9 (29) | 12 (39) |
| Pre-eclampsia and eclampsia | - | 5 (16) | 10 (32) | 9 (29) | 3 (10) | 12 (39) |
| Cardiac arrest in a pregnant woman | 1 (3) | 5 (16) | 10 (32) | 8 (26) | 6 (19) | 12 (39) |
| Cardiac arrhythmias (Supraventricular and non-lethal ventricular arrhythmias, sinus bradycardia) | 7 (23) | 13 (42) | 9 (29) | 5 (16) | 3 (10) | 12 (39) |
| Embolism (venous thromboembolism, air or carbon dioxide, fat and amniotic fluid) | 3 (10) | 10 (32) | 10 (32) | 6 (19) | 4 (13) | 13 (42) |
| Management of inadvertent erroneous medication administration event (neuromuscular blockade, pressor, hypnotic, opioid, etc.) | 4 (13) | 7 (23) | 8 (26) | 7 (23) | 7 (23) | 13 (42) |
| Post-extubation respiratory distress | 4 (13) | 11 (35) | 10 (32) | 6 (19) | 3 (10) | 14 (45) |
| Unplanned extubation | 4 (13) | 9 (29) | 5 (16) | 3 (10) | 2 (6) | 16 (52) |
| Acute pulmonary oedema | 8 (26) | 10 (32) | 5 (16) | 4 (13) | 3 (10) | 16 (52) |
| Cardiac tamponade | 4 (13) | 7 (23) | 5 (16) | 3 (10) | 3 (10) | 18 (58) |
| Total spinal anesthesia | 5 (16) | 6 (19) | 7 (23) | 4 (13) | 2 (6) | 19 (61) |
| Massive aspiration event | 6 (19) | 7 (23) | 4 (13) | 2 (6) | 1 (3) | 20 (65) |
| Perioperative management of ST segment changes (including MI) | 4 (13) | 7 (23) | 4 (13) | 2 (6) | - | 21 (68) |
| Conflict management (with patients or with staff) | 2(6) | 2 (6) | 5 (16) | 6 (19) | 8 (26) | 21 (68) |
| Supply failure (oxygen or power) | 1 (3) | - | 1 (3) | 2 (6) | 3 (10) | 26 (84) |
| Transfusion reaction | 1 (3) | 1 (3) | 2 (6) | 2 (6) | 2 (6) | 26 (84) |
| OR evacuation (due to fire or environmental cause) | - | - | 2 (6) | 1 (3) | 2 (6) | 27 (87) |

**Supplemental Digital Content 3: senior (e.g. attending anesthesiologist-level) programs' characteristics.**

| Questions | Results | Answers options |
|---|---|---|
| Is there an AIC "senior"* simulation training? | 4 (13) | Yes, structured for the whole department |
| | 6 (19) | Yes, structured for specific units/AIC "senior"* |
| | 12 (38) | Yes, but not structured |
| | 9 (29) | No |
| • If yes: Since when exist an AIC "senior"* simulation training? (start year) | 2013 [00-18] | Year (median [min-max] |
| | 1 (5) | I don't know |
| • If yes: How many AIC "senior"* training sessions per year? | 12 (54) | < 5 per year |
| | 7 (32) | 5 to 10 per year |
| | 3 (14) | > 10 per year |
| • If yes : Is there interprofessional full-scall simulation training for AIC "senior"*? | 21 (95) | Yes |
| | 1 (5) | No |
| ○ If yes: The persons associated with interprofessional high-fidelity simulation training including AIC "seniors"* are: (MCQ) | 14 (67) | Residents AIC |
| | 20 (95) | Anesthetic nurses |
| | 5 (24) | Anesthetic nurses students |
| | 12 (57) | Surgeons |
| | 8 (38) | Surgical residents |
| | 12 (57) | Midwives |
| | 5 (24) | Midwifery Students |
| | 8 (38) | Operating room nurses |
| | 3 (14) | Operating room nurses students |
| | 5 (24) | Others |

*"senior" are fellows and attending anesthesiologists and intensive care physicians

**Appendix: Centers' characteristics regarding their physical layout, affiliations and national certification.**



# Discussion on Article 1

This article brings important elements on the state of the art of simulation in AIC in France and increases our knowledge on the subject. We have gathered arguments in favor of the feasibility and the necessary data for the development of a unified training program in simulation in AIC in France. Because of the completeness of the responses, the data collected are very relevant to answer the questions we have about simulation in AIC in France.

Among the results supporting feasibility, it is worth highlighting the use by all centers (since all responded) of simulation for the training of AIC residents. Simulation is widely adopted and its training is very structured, i.e. there is a formalized program describing the skills to be acquired and the times in the curriculum when the training takes place. This structure can be analyzed as a mark of maturity and mastery of the simulation. This dimension of mastery is reinforced by the frequent use of simulation in a multi-professional, in-situ setting and with largely mandatory participation. These elements are complex to master with higher stakes than a mono-professional, optional, in-center simulation; they indicate a high level of experience and mastery of the simulation. This is logically illustrated by the high rate of training in simulation of the AIC trainers.

The data on the use of simulation allows both the feasibility of a unified program to be assessed and the baseline to be drawn. The primary use is for training, with research, testing, and summative assessment following in that order. Training calls upon all simulation modalities (full-scale, procedural, simulated patient, hybrid, numeric, virtual reality and cadaver) with an almost ubiquitous use of full-scale simulation and procedural simulation. Full-scale simulation is used in multi-professional settings, which seems logical to meet the objectives of developing non-technical skills for a profession whose clinical practice is never isolated but in almost constant interaction with other care professions (nurse anesthetist, surgeon, midwife, operating room nurse, etc.). Full-scale simulation is mainly used from the second year of the curriculum. We can interpret this as the time needed to acquire the necessary technical skills so that the AIC residents can participate without too many technical obstacles in full-scale simulation with a cognitive availability to tackle the non-technical skills specific to full-scale simulation. At the same time, procedural simulation is primarily used at the beginning of the curriculum. The ideal pedagogical and ethical situation of having simulation training for care given systematically before its realization on patients, is for the moment not the most common. It seems necessary

to us, in view of the means available, to work on systematizing this practice of systematic training prior to care in order to raise the standards of quality of care and ethics in AIC resident training programs. This must certainly represent one of the challenges of setting up a unified simulation training program in AIC in France. This objective seems doable since simulation training is already largely mandatory in the centers and frequently an integral part of the curriculum's validation.

Among the uses made of the simulation, summative assessment is currently little used (13%) and comes in fourth position. However, the use of assessment scores is more widespread (42%). This means that scores are used in formative assessment to give feedback to residents based on tangible data. There is a growing trend toward the use of tools for summative assessment. This represents one of the first important steps toward the wider dissemination of summative assessment in simulation. The prior appropriation and mastery by trainers of the tools, concepts and organization of summative assessment through formative assessment is essential to the successful implementation of summative assessment in simulation. It is the same for AIC residents to get used to and to accept summative assessment through formative assessment in simulation. This is consistent with the idea of competency-based assessment models that are closer to the reality of the daily clinical practice.[8] Summative assessment with simulation can, among other things, meet this need.[42,43] It is first necessary to clearly define what is validated and what is not yet validated - and needs to be investigated - for summative assessment with simulation. This inventory is a prerequisite for the widespread development and integration in a unified simulation training program. Whether specifically for summative assessment or for simulation training more generally, resources are needed.

It is interesting to observe that the same resources (e.g. AIC trainers, human support resources, organizational resources, financial resources) are identified as being accelerators or hurdles to the development of simulation in AIC, depending on their presence or absence (**Article #1, Figure 5**). There are therefore centers for which their supervisory authorities have decided to grant financial and human resources to support the development of simulation in AIC. It would be interesting to know the motivations of these supervisory authorities in order to help the centers that lack allocated resources to obtain them. The development of a unified training program in simulation in AIC in France will also require the identification of the resources necessary for its implementation so that they can be mobilized and make the program concrete and effective throughout the country.

Finally, the results on the desirability of a unified AIC simulation training program in France are favorable since the Likert ratings (1 to 5) on usefulness (4.5+/-0.9), anticipated use (4.3+/-1.0) and willingness to participate in its development (4.3+/-1.1) are high. These results support the success of a future collaborative construction and adoption of a unified program, provided it is based on the data collected from the current practice of simulation training in AIC in France. Those results are consistent with a survey made in US.[44] The culture of a unified curriculum for simulation training in AIC in France should be possible to implement without too much difficulty for the entire AIC curriculum, given that there is already a regulation detailing the technical skills that can be taught through simulation for the first year of AIC residency.

This survey provides three levels of responses at three different levels: French, national and international. At the French level, it responds to the feasibility and the first step of the development of a unified simulation training program in AIC in France. At a national level, not specific to a country, it proves the feasibility of the development of a unified training program in simulation in AIC at the scale of a country. At an international level, this provides arguments for the feasibility of developing a unified international simulation training program in AIC, under certain conditions that we will address in article 3.

Based on the data and arguments presented in this section, we have seen the feasibility of a unified simulation training program in AIC. We have also found evidence of significant interest in summative assessment in simulation. If we are to integrate to the unified training program in simulation, the summative assessment with simulation component, it is necessary to have guidelines on summative assessment with simulation. If simulation training is homogenized by a unified program, and simulation is very close to the clinical practice for which we wish to assess competence, then the summative assessment is very likely to be an accurate reflection of competence. Thus, incorporating summative assessment into a unified AIC simulation training program makes sense. However, it is essential to better define the scope and validity of summative assessment in simulation. In order to prefigure possible guidelines on summative assessment in simulation, it is necessary to define as clearly as possible its contours, its use and its development. This is the subject of the following section.

# Part 2: Integration of summative assessment in simulation training programs

## Introduction to Article #2

Simulation has imposed itself in medical training because of its specific capacity to train clinical and behavioral/communication skills that are difficult or impossible to access otherwise, at least not without altering the quality of care or even the safety of patients and caregivers.[45] It is therefore mainly ethical and practical reasons that have participated in promoting the use of simulation-based training.[8] Ethics and the evolution of the patient-caregiver relationship have made it less and less acceptable and accepted that caregivers begin their professional training directly in a clinical care situation without any prior training, thus putting patients at risk of potential harmful errors. The current trend is therefore, as far as possible according to the available training resources, that simulation training takes place before the first patient care in a clinical situation.[46] There are many practical reasons for using simulation. The ability to reproduce situations on demand through simulation allows for multiple exposures in a controlled time frame, thus increasing the learning curve and mastering a skill.[47,48] It also allows exposure to a wider variety of situations as well as to rare or complex situations in a controlled environment.[49] This allows to create an experience for situations where it would be unlikely to have without the simulation (e.g. anaphylactic shock, malignant hyperthermia, damage control). Finally, it facilitates feedback and discussion through debriefing, which develops and normalizes the culture of debriefing beneficial in clinical situations.

The diffusion of the use of simulation is accompanied by a logical and natural trend towards the use of simulation in summative assessment for two reasons. The first is the respect of a pedagogical alignment between the training method and the summative assessment method. Preserving this coherence is logical and facilitates teaching and learning. The second reason is the desire to evaluate skills as close as possible to clinical reality. Since simulation is the closest

thing to a clinical situation, it is logical that it should be considered as a tool for assessing skills as close as possible to the conditions in which they will be used in real life.

Summative assessment with simulation represents important stakes for learners, trainers, program managers and institutions.[7,9,45,50,51] The consequences of selection, validation, and (re)certification that follow from a summative assessment impose a consequent level of proof, validity and robustness of the process; which should ideally have guidelines.

The objective of this research work is to map the current key principles on summative assessment with simulation so that it can serve as a basis for three work lead. The first lead is a valid and reliable use in summative assessment in simulation for what is already validated. The second lead is the identification of research and development area to be pursued in future work to progress in the validation of what can be done in summative assessment with simulation. The third lead is the development of guidelines on summative assessment with simulation. Establishing guidelines requires a baseline to build on, and this knowledge map will help to establish it. On the broader scale of this thesis, this step is necessary to determine if and how summative assessment can be integrated into a unified simulation training program in AIC.

# Article #2

## Summative assessment with simulation in healthcare: key principles for practice

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**Short title:** Summative assessment with simulation in healthcare

## Abstract

### Background

Healthcare curricula need summative assessments relevant to and representative of clinical situations to best select and train learners. Simulation provides multiple benefits with a growing literature base proving its utility for training in a formative context. Passing to the next step, "the use of simulation for summative assessment" requires a rigorous and evidence-based development because summative assessment is high stakes for graduates, trainers and programs. The first step of this process is to identify the baseline from which we can start.

### Methods

Using a nominal group technique, 34 experts defined themes to clarify the use of summative assessment during simulation, answering trainers' practical enquires to guide them in their education practice. Each theme was explored by a subgroup based on state-of-the-art literature reviews with a snowball sampling technique. Our goal was to identify the key principles and potential recommendations for future directions. Results were cross-checked among subgroups and reviewed by an independent expert committee.

### Results

Seven themes were selected: "What can be assessed in simulation?", "Assessment tools for summative assessment"," Consequences of summative assessment", "Scenarios for summative assessment", "Debriefing, video, and research for summative assessment", "Trainers for summative assessment", and "Implementation of summative assessment in simulation in healthcare". Together, they provide an overview of what is known and can be done with relative certainty, and what is unknown and probably needs further investigation. Based on this work, we highlighted for each of the seven themes, what emerges as validated, the remaining important problems and questions, and their consequences.

### Conclusion

Using simulation for summative assessment holds much promise, with increasing demand for this application. Due to the important stakes involved, it must be rigorously conducted and supervised. Guidelines for good practice should be formalized to help with conduct and

implementation. This state of the play can serve as a baseline for future investigation and the development of guidelines.

**Trial registration:** not applicable.

**Keywords:** Medical Education, Summative, Assessment, Simulation, Education, Competency-Based Education

**Word count:** 3492

## Introduction

There is an essential need for summative assessment in healthcare education. [1] High stakes are at play with summative assessment, both in certification for graduation and recertification in continuing medical education. [2–5] Knowing the consequences, deciding to validate assessments or not must be reliable and based on rigorous processes backed up by data. [6] Current summative assessment methods (written or oral exams) are imperfect and call for improvement to better benefit programs, learners, and finally patients. [7] Good summative assessment reflects clinical practice sufficiently to provide a meaningful assessment of competencies. [1,8] While some would say that oral exams are a form of verbal simulation, hands-on simulation may be seen as a solution to supplement current summative assessments and enhance their accuracy by bringing them closer to assessing needed competencies. [1,2]

Simulation is now well established in healthcare curriculum as part of a global strategy like in competency based medical education (CBME). [9–11] Rich in various modalities, simulation allows training for a large array of technical and non-technical skills in every discipline. Simulation adds value to the training pedagogical process particularly with feedback and formative assessment. [9] With the spread of simulation use, comes what could be seen as a logical next step: the use of simulation for summative assessment. There is a will to evolve with simulation from formative assessment to summative assessment in medical education.

Transition from formative to summative assessment with simulation in healthcare must be considered, evidence-based and rigorous. Program’s directors and educators are aware of that

and may find it challenging to evolve from formative to summative use for simulation. There are currently punctual experiences (e.g. OSCE [12,13]) but not established guidelines on how to do so. The needed evidence supporting the feasibility, the validity and defining the requirement for summative assessment with simulation in healthcare education are not yet well formally gathered. With that evidence, we can hope to build a rigorous and fair pathway toward summative assessment with simulation.

We proposed a state of the play and perspectives of some key elements and questions linked to the conditions, the tools and preparation for the use of simulation for summative assessment in healthcare. We think that could serve as a baseline for future investigation and the development of guidelines.

## Methods

Due to the nature of the research, Institutional Review Board involvement was not required.

### Context

The use of simulation for summative assessment was debated in May 2018 at the French Speaking Society for Simulation in Healthcare (SoFraSimS) meeting in Strasbourg, France. The main conclusions were to address the increases in interest in using summative assessment, its informal uses, and consideration for use in official programs in healthcare education; the group identified that these important areas had no current guidelines. To reduce gaps in knowledge, the SoFraSimS' board commissioned FL to lead a workgroup on these topics. His mission was to identify the key principles, or landscape of simulation used for summative assessments, the existing knowledge base, and potentially experts' recommendations.

### Data collection methods and processing

In order to begin answering the challenging question of "What do we need to know…", in September and October 2019, following the French *Haute Autorité de Santé* guidelines [14] we applied a modified nominal group technique approach (NGT) [15] to define the further questions to be explored (**Figure 1**). The modifications to NGT were that the interactions were not in-person, and asynchronous for some. This was due to the geographical dispersion of the participants over several countries and the context of the COVID19 pandemic. The first two stages of the NGT (generations of ideas and round robin) facilitated by the group coordinator (FL) took place simultaneously asynchronously online via email exchanges over a 6-weeks period. We asked group members, based on the literature provided, to reflect on the question asked and to formulate proposals for questions/themes to explore. These proposals were sent to the group coordinator who regularly synthesized them and sent back to the whole group the updated status of the questions/themes while preserving the anonymity of the contributors and asking them to check the accuracy of the synthesized elements. The third step of the NGT (clarification) was carried out during a 2-hours video conference session. All members were able to discuss the proposed ideas, group ideas by themes and make the necessary clarifications. As a result of this step, 24 preliminary questions were defined as a basis for the fourth step (**Supplemental Digital Content 1**). The fourth step of the NGT (the rating) consisted of four distinct asynchronous and anonymous online rounds that led us to a final set of themes with related sub-questions (**Supplemental Digital content 2**). All rating rounds followed similar validation rules. We kept items (either questions or themes) with more than 70% approval ratings by participants. For those items with 30-70% approval, we reformulated and resubmitted in the next round, and discarded items with less than 30% approval. We discussed discrepancies and achieved final ratings with complete agreement for all items. For each round we sent reminders to reach a minimum participation rate of 80% of the members. Then, we split the workgroup into subgroups, one for each of themes defined at the end of the rating step.

From November 2019 to October 2020, the subgroups had to identify the key principles, and potential recommendations for their subtopic based on a review of existing literature. Each subgroup contributed to the workgroup's common library on summative assessment with simulation in healthcare with their bibliographic research on their subtopic. Subgroups did state-of-the-art reviews [16] and expanded their reviews with a snowball sample technique based on the bibliography of the articles.

Researcher characteristics and reflexivity

The workgroup's researchers were recruited among volunteer simulation healthcare instructors in French speaking countries. There were 34 (12 women and 22 men) from 3 countries (Belgium, France, Switzerland). Twenty-three were physicians and 11 were nurses, while 12 total had academic positions. All were experienced trainers in simulation for more than 7 years and were involved or responsible for initial training or continuing education programs with simulation.

An external review committee reviewed the final version of the report. Its members were 4 senior experts in training and research in simulation from 3 countries (Belgium, Canada, France) with at least 15 years of experience in simulation. The final version was approved by the SoFarSimS' board.

Techniques to enhance trustworthiness

Subgroups' primary reports were reviewed and critiqued by other subgroups. After subgroup cross-reviewing, primary reports were compiled by FL and CB and submitted as one report to the external review committee. FL and CB responded directly to reviewers when possible and requested subgroups' assistance when needed. The final version of the report was approved by SoFraSimS' Board of Directors in January 2021.

Literature review strategy

For bibliographies, we searched electronic databases (MEDLINE), grey literature databases (including digital theses), simulation societies and centers' websites, generic web searches (e.g., Google Scholar), and reference lists from articles. We selected publications related to simulation in healthcare with keywords "summative assessment" and also specific keywords related to subtopics. The search was iterative to seek all available data until saturation was achieved.

## Results

The NGT results in seven themes with sub-questions (**Supplemental Digital content 2**). We split the workgroup into 7 subgroups, one for each of theme: (1) “What can be assessed in simulation?” (2) “Assessment tools for summative assessment,” (3) “Consequences of summative assessment using simulation,” (4) “Simulation scenarios for summative assessment,” (5) “Debriefing, video, research and summative assessment strategies,” (6) Trainers for summative assessment using simulation,” (7) “Implementation of summative assessment in simulation in healthcare”.

### What can be assessed in simulation?

This section aims to focus on the common denominator to summative assessment situation: the competency. Healthcare faculty and institutions must ensure that each graduate is practice ready. Readiness to practice imply to master some competencies, therefore that means to learn them in an adapted way. The competency approach involves explicit definitions of fundamental skills to acquire to be a "good professional." Professional competency could be defined as the ability of a professional to use judgment, knowledge, skills and attitudes associated with their profession to solve complex problems. [17–19] Competency is a complex “know how to act" based on the effective mobilization and combination of a variety of internal and external resources within an array of situations, is not directly observable. [17] It is the performance in the situation that can be observed. It must be taken into account that performance can vary according to human factors (stress, fatigue, etc.). During simulation sessions, competencies can be assessed through the observation of "key" actions with the help of analysis tools. [20] Simulation’s limitations must be taken into account in defining the skills that can be assessed with simulation. Not all simulation methods are equivalent for assessing specific competencies. [20]

Most healthcare competencies can be assessed with simulation, throughout the curriculum, if certain conditions are met. First, the competency being assessed summatively must have already been assessed formatively with simulation. Second, validated assessment tools must be available to perform this summative assessment. These tools must be reliable, objective, reproducible, acceptable, and practical. The current small number of validated tools is a limitation to the use of simulation for competency certification. Third, it is not necessary or

advisable to certify all competencies. The situations chosen must be frequent enough in the student's future professional practice (or potentially impactful for the patient) and cannot be assessed and validated in other circumstances (e.g. clinical internships). [2] Fourth, simulation can be used for certification throughout the curriculum. [21–23] Finally, limitations to the use of simulation throughout the curriculum may be logistical resources. **Table 1** summarizes the elements to be considered when implementing a summative assessment with simulation.

**Assessment tools for summative assessment**

One of the challenges of a competency assessment lies in the quality of the tools used. The tool, which allows the assessor to collect data, must also allow him to give meaning to his assessment, while securing that is really measuring what he aims to. A tool must be valid, capable of measuring the competency to be assessed with fidelity, reliable and providing reproducible data. [24] Having in mind that a competency is not measurable by its very nature, it is analyzed on the basis of learning expectations, the more "concrete" and observable form of a competency. [17] A tool must therefore be part of a global assessment approach, based on a search for evidence of his validity: the validation process. Several authors have described definitions of validity and the steps to achieve it. [24–26] Despite different approaches, objectives are similar: to ensure the tool's content validity, and to ensure that scoring items reflect the competency assessed and are adapted to learners and assessors. [27–29] A tool should have psychometric characteristics that allow users to be sure of its reproducibility, discriminatory nature, fidelity and external consistency.[30] One way to ensure that a tool has acceptable validity is to compare it to existing and validated tools that assess the same skills for same learners. Finally, considering the test's consequences is important to determine whether it best identifies competent students from others. [24,28]

An illustration of tool development used in summative assessment following the five-source framework of validity (unified validity) described by Downing, [24] following the work of Messick [31] for a technical task is presented in **Table 2**. Another one using three sources of validity for teamwork's non-technical skills is presented in **Table 3**. Like a diagnostic score, a relevant assessment tool must be specific. It is not good or bad, but valid and validated with a validation process. This validation process determines if the tool measures what it is intended

to and if this measurement is reproducible at different times (test-retest) or with 2 observers simultaneously. [24]

The language in which one assessment tool has been validated is the only language in which it can theoretically be used. Using a “translated” but not a “translated and validated” tool can lead to semantic biases that could affect the meaning of the content and its representation. For each assessment sequence, validity criteria are to use different tools, different assessment situations and to integrate them into a comprehensive program including all aspects of a competency. Once a tool is validated for a situation, it must be combined with other assessment situations, since there is no "ideal" tool. [32,33] The question arises about the different contexts in which an assessment tool may be used. The same tool can be used with different professions, or with learners at different levels of expertise or in different languages if it is validated for these different situations. [34,35] In a certification context, a tool must have demonstrated a high-level of validity to be used because of the high stake for the learners. [32] Finally, the use or creation of an assessment tool requires trainers to question its various aspects, from how it was created to its replicability and the meaning of the results.

Two types of assessment tools should be distinguished: tools that can be adapted to different situations and situation-specific assessment tools. [36] Thus, technical skills can have a dedicated assessment tool (e.g., intraosseous) [37] or an assessment grid can be generated from a list of pre-established and validated items (e.g., TAPAS scale). [38] Non-technical skills can be observed using scales that are not specific to a situation (e.g., ANTS, NOTECHS, etc.) [39,40] or specific to a situation (e.g., TEAM scale for cardiac arrest). [34,41] Assessment tools should be provided to participants and should be present in the scenario, at least as a reference. [42–45] In summative assessment of a procedure, structured assessment tools should probably be used using a structured objective assessment form for technical skills. [46] The use of a scale, as part of the evaluation of a technical action, seems essential. The scale must be validated beforehand. [37,46–48]

**Consequences of summative assessment**

Participants experienced commonly mild (e.g. appearing slightly upset, distracted, teary-eyed,

quiet, or resistant to participating in the debriefing) or moderate (e.g. crying, making loud and frustrated comments) psychological event in simulation. [49] Summative assessment has two notable impacts on learning strategies. First, it is essential to assess the competencies targeted, not the ability of the participant to adapt to the assessment tool. [6] Second, the pedagogy key concept -of "pedagogical alignment" must be respected. It means that assessment methods must be coherent with the pedagogical activities and objectives. For this to happen, participants must have formative simulation training focusing on the assessed competencies prior to the summative assessment. [50]

While it is classic to work on a voluntary basis in formative simulation, all students are required to take a summative assessment. This required participation in high stake assessment may have a psychological impact. This impact can be modulated by training and assessment conditions. First, the repetition of formative simulations reduces the psychological impact of summative assessment on trainees. [51] Second, the transparency on the objectives and methods of assessment limits the psychological impact. Finally, it is increased by abnormally high physiological or emotional stress such as fatigue, stressful events in the 36 hours preceding the assessment, history of Post-Traumatic Stress Disorder or psychological disorder that may be decompensated by the simulation, etc. [51–54]

It is necessary to optimize the implementation of the summative assessment in simulation to limit its pedagogical and psychological negative impacts. Ideally, during the summative assessment, it is proposed to take into account the formative assessment that has already been carried out. Similarly in continuing education, the professional context of the person assessed should be considered. In the event of failure, it will be necessary to ensure sympathetic feedback and to propose a new assessment if necessary. [19]

**Scenarios for summative assessment**

Some authors argue that there are differences between scenarios for summative and formative assessment. [51–54] The development of a summative assessment scenario begins with the choice of a theme, which is most often agreed upon by experts at the local level. [42] The themes are most often chosen in relation with the participant competences to be assessed, and included in the competency requirement for both initial [55] and continuing education. [23,56] A literature review even suggests the need to choose themes covering all the competences to be

assessed. [26] These choices of themes and objectives also depend on the simulation tools technically available: *"The themes were chosen if and only if the simulation tools were capable of reproducing "a realistic simulation" of the case."* [57]

The main quality criterion for summative assessment in simulation is that the selection of cases and their development are guided by the assessment objectives. [58] It is necessary to be clear about the assessment objectives in each scenario so that the right assessment tool can be chosen. Scenarios should meet four main principles: predictable, programmable, standardizable, and replicable. [59] Scenario writing should include a specific script, cues, timing, and events to practice and assess the targeted competencies. [60] The implementation of variable scenarios remains challenging. In fact, most authors develop a single scenario per topic and skill to be assessed. There is no recommendation for setting a predictable duration for a scenario. [61] The key elements structuring a summative assessment scenario are summarized in **Table 4**. For technical skills assessment, scenarios will be short and the assessment based on an analytical score. For non-technical skills, scenarios will be longer and the assessment based on analytical and holistic scores.

**Debriefing, video, and research for summative assessment**

Studies have shown that debriefings are essential in formative assessment. [62,63] No such study is available for summative assessment. Good practice requires debriefing in formative and summative simulations. [64,65] In that case, debriefing is frequently short feedback given at the end of the simulation session, in groups [58,66,67] or individually. [56] Debriefing can also be done later with a trainer and help of video, or written reports. [68] These debriefings allow for an assessment of clinical reasoning in summative assessment. [69] Some tools have been developed to help this assessment of clinical reasoning. [69]

Video can be used with four goals: preparing the session, improving the simulation, debriefing, and rating (**Table 5**). When conducting a summative assessment session, video can be used during the prebriefing to give participants standardized and reproducible information. [70] Video can increase the situation's realism during the simulation: ultrasound loop, laparoscopy, etc. Recorded sequences can be reviewed either for debriefing or rating purposes. Video helps a lot with the training (calibration and recalibration) of raters. [71] Video enables raters to rate the participants off-line, and to have external review if necessary. [22,47,72] Despite the

technical difficulties to be taken into account, [27,73] we may think that, in the future, automated scoring assistance video-based will helps assessment.

The constraints linked to video usage imply the participants' agreement, the compliance with local rules, and that the structure setting up the assessment with video organizes the person's rights protection and data safety, both at national and higher (e.g. European GDPR) levels.

**Table 5** lists the main uses of video during simulation sessions found in the literature.

Research in summative assessment can focus, as for formative assessment, on the optimization of simulation processes (programs, structures, human resources). Research can also explore summative assessment tools development and validation; the automation and assistance of assessment means ; and pedagogical and clinical consequences of summative assessment in simulation.

**Trainers for summative assessment**

Based on the OSCE experience, trainers for summative assessment probably need specific skills because of the high number of errors observed in summative assessment in simulation, despite the quest for objectivity (**Table 6**). [74] The difficulty to guarantee objectivity is probably why the use of self or peer assessment in the context of summative assessment is not well documented and the literature does not yet support it. [75–78]

Summative assessment requires the development of specific, reproducibly staged scenarios and the mastery of assessment tools to avoid assessment bias. [79–82] Fulfilling those requirement calls for specific abilities to fit with the different roles of trainer. These different roles of trainer would require specific initial and ongoing training tailored to their tasks. [79,81] In the future, notions about the roles and tasks of these trainers should be integrated into all training of trainers in simulation.

**Implementation of summative assessment in simulation in healthcare**

The use of simulation for summative assessment was already described by Harden in 1975 with OSCE (Objective and Structured Clinical Examination) tests for medical students. [83]

Summative use of simulation has been introduced in different ways depending on the professional field and the country. It appears more rapidly in undergraduate and graduate levels, and develops as certification in postgraduate in certain fields. Re-certification uses of simulation for summative assessment are more limited at present. It is often a mandatory participation, and not a formal competency assessment. Some countries are defining processes for maintaining certification in which simulation is likely to play a role (e.g. US [84], France [85]). Recommendations concerning the development of simulation for summative assessment for OSCE were issued by the AMEE (Association for Medical Education in Europe) in 2013. [12,86] Combined with other recommendations that address the organization of examinations on other immersive simulation modalities, in particular full-scale sessions using complex mannequins, [20,58] they give us a solid foundation for the implementation of simulation for summative assessment.

The overall process for ensuring a high-quality examination by simulation is therefore defined but particularly demanding. It mobilizes many material and human resources (administrative, trainers, standardized patients, and healthcare professionals) and takes a long development time (several months to years depending on the stakes). The steps to overcome during the implementation of simulation-based summative assessment range from the constitution of a coordination team, to the supervision of writers, raters and standardized patients, and the consideration of logistical and practical pitfalls.

The construction of the skills repository valid for the comprehensive curriculum (e.g. medical studies) and the associate blueprint are fundamental. This construction makes it possible to identify competences to be assessed with simulation, those to be assessed by other methods, and those requiring triangulation by several assessment methods. This identification then guides scenarios' writing and examination's development with good content validity. Scenarios and examinations will form a bank. The quality process of the examination, including psychometric analyses, is part of the development process from the beginning.

**Table 7** summarizes the different steps in the implementation of summative assessment in simulation.

*Recertification*

Recertification programs for various healthcare domains are currently being implemented or planned in many countries. (e.g. US [84], France [85]) This is a continuation of the movement to promote the maintenance of competence. Examples can be cited in France with the creation of an agency for Continuing Professional Development (CPD), or in the US with the Maintenance of Certification (MOC). The certification of health care facilities and even teams are also being studied. Simulation is regularly integrated into these processes (e.g. US [84], France [85]). Although there is a common basis between the certification and recertification processes, there are many differences (**Table 8**).

Currently, when simulation-based training is mandatory (e.g., "MOCA" in the US), it is most often a formative process. [22,56] Simulation-based summative assessment has a place in the recertification process, but there are many pitfalls to avoid. For this, it is easier in the short term to integrate formative sessions as the first step. The current consensus seems to be that there should be no pass/fail recertifying simulation without a global personalized professional support, in a quality process rather than in a binary aptitude/inaptitude approach.

## Discussion

In this discussion we propose to highlight for each of the seven identified themes, what emerges as validated, the remaining important problems and questions, and their consequences.

### What can be assessed in simulation?

Summative assessment with simulation is currently mainly used in initial training in mono-professional and individually via standardized patients or task trainers (OSCE). [12,13] Simulation-based assessment will also be used for practicing healthcare professionals (re-certification) as well as for groups of professionals who will be assessed throughout their career. [56] The difference between desired competencies and observed performance is important. [87] What a competency is, is defined in a rather precise and specific way. [6,17,19] Competencies are what we wish to evaluate during summative assessment to validate or revalidate a professional for his/her practice. Performance is what can be observed during an assessment.

[18,19] There are three unresolved problems. The first problem is that an assessment only gives access to a performance at a given moment (“Performance is a snapshot of a competency”), whereas one would like to assess a competence in a more general way. [87] The second problem is: How does the observed performance - especially in simulation - reveal the real competence - in real life? [88] In other words, is success or failure in a single simulation summative assessment a true reflection of real-life competence? [89] The third problem is that of assessing team performance/competence. [90–92] Until now, summative assessment in simulation came from the academic field and has been an individual assessment (e.g. OSCE). Future summative assessment with simulation may concern teams, driven by governing bodies, institutions, or insurances... [93,94] The competence of a team is not the sum of the competences of the individuals that compose it. How can we proceed to evaluate teams as a specific entity that is both composed of individuals and independent of them? To make progress in answering these three problems, it is probably necessary to consider the approximation between observed and assessed performance and competence as acceptable, but only by specifying the scope of validity. Research in these areas is needed to define this and answer these questions.

**Assessment tools for summative assessment**

Rigor and method in the development and selection of assessment tools are paramount to the quality of the summative assessment. [95] The literature demonstrates the need for assessment tools to be specific to their intended use, for their intrinsic characteristics to be described, and for them to be validated. [24–26] These precise characteristics must be respected to avoid two frequent problems. [1,6] The first problem is that of a poorly designed or poorly constructed assessment tool. This tool can only give bad assessments in the sense that it will be unable to correctly capture the performance and therefore to approach the skill to be assessed in a satisfactory way. The second problem is that of a poorly or incompletely evaluated or badly selected tool. If the tool is poorly evaluated, its quality is unknown. The scope of the assessment that is done with it is limited by the vagueness of the tool's quality. If the tool is poorly selected, it will not accurately "capture" the performance that is being assessed. Again, the summative assessment will be impaired. It is currently difficult to find tools that meet all the required quality and validation criteria. On the one hand, this requires complex and rigorous work; on the other hand, there is a large potential number of tools required. Thus, the overall volume of work involved in the rigorous production of assessment tools is substantial. However, the literature provides the characteristics of validity (content, response process, internal structure,

comparison with other variables, and consequences), and the process to follow to build quality and reliable assessment tools. [24–26] It therefore seems important to systematize the use of these guidelines for the selection, development and validation of assessment tools. Work in this area is necessary and collaboration in a network could be a solution for making faster progress in the constitution of a bank of valid and validated assessment tools.

**Consequences of summative assessment**

Establishing and maintaining psychological safety is mandatory in simulation. [96] Consideration of the psychological and physiological consequences of summative assessment is fundamental to control and limit its impacts. Summative assessment has consequences for both the trainees and the trainers. [97] These consequences are often ignored or underestimated. However, these consequences can have an impact on the conduct or results of the summative assessment. The consequences can be positive or negative. The "testing effect" can have a positive impact on long-term memory. [97] On the other hand, negative psychological (e.g. stress or PTSD) and physiological (e.g. sleep) consequences can occur or degrade a fragile state. [97,98] These negative consequences can lead to questioning the tools used and the assessment. The negative impact is then reflected on the summative assessment itself. These consequences must therefore be logically taken into account when designing and conducting the summative assessment. Strategies to mitigate their impact must be put in place.

**Scenarios for summative assessment**

The structure and use of summative scenarios are specific and require special development and skills. Summative assessment scenarios differ from formative assessment scenarios in the different pedagogical objectives that guide their construction. The formers are designed to assess a skill through the observation of a performance, while the latter are designed to learn and progress in the mastery of this same skill. While there may be a continuum between the two, they remain distinct. For summative assessment scenarios, they must be predictable, programmable, standardizable, and replicable [59] in order to ensure fairness among participants with respect to the assessment performed. This is even more crucial when standardized patients are involved (e.g. OSCE). [86,99] In this case a specific script with expectations and training is needed for the standardized patient. The problem is that there are a

large number of formative scenarios but few summative scenarios. The rigor and expertise required to develop them is time consuming and requires expert human resources. Ideally, we should aim at a homogenization of the scenarios, of the preparation of the human resources who will play them (trainers and standardized patients) and of their application. A solution to this problem would be the development of a methodology to guide the conversion of formative scenarios into summative ones in order to create a structuring model for summative scenarios while reinvesting the time and expertise already used for the construction of formative scenarios.

**Debriefing for summative assessment**

The place of debriefing in summative assessment is currently undefined and raises important questions that need to be explored. [62,100–103] Debriefing in a formative evaluation promotes knowledge retention and helps to anchor good behaviors and correct bad ones. [104–106] In general, taking an exam promotes memorization of the subject. [97,107] The absence of debriefing in formative assessment has been proven to be detrimental, so it is reasonable to assume that the same is true in summative assessment. [63] The ideal debriefing modalities in summative assessment with simulation are currently unknown. [62,100–103] The integration of debriefing into summative assessment raises a number of organizational, pedagogical, cognitive, and ethical issues that need to be clarified. From an organizational point of view, debriefing is time and human resource consuming. The importance of the organizational impact varies according to whether the feedback is automatized, standardized, personalized, collective or individual. From a pedagogical point of view, debriefing ensures pedagogical continuity and the continuation of learning. This notion is nuanced depending on whether the debriefing is integrated into the summative assessment or if it follows it, without being part of it (formative). If the debriefing is part of the summative assessment, it is no longer a teaching moment. This must be factored into the instructional strategy. How should the trainer prioritize debriefing points between those established in advance for the summative assessment and those that would emerge? From a cognitive point of view, the integration or not of debriefing in the summative assessment may modify the positions and behaviors of the trainer and the student. If the debriefing is integrated into the summative assessment, the student will be confronted with the cognitive dilemma of knowing whether to express his/her opinion or to try to provide the expected answer. The trainer is then in the uncertainty of what he/she is really assessing.

Finally, from an ethical point of view, the question of the impact on the summative assessment of a "good" or "bad" performance of the student during the debriefing of a good or bad performance during the simulation would be a source of difficulty in case of discordance. What to focus on between the observed performance and the reasoning? What weighting should be given to the two for the summative assessment? There is probably no single solution to the positioning of the debriefing in the summative assessment but rather adaptations (e.g. group or personalized debriefing) to conditions (e.g. success or failure in the summative assessment). These questions need to be explored to provide answers to the place of debriefing in summative assessment. A balance must be found that is ethically and pedagogically satisfactory, does not induce a cognitive dilemma, and is manageable from a practical standpoint.

**Trainers for summative assessment**

The skills and training of trainers required for the summative assessment in simulation are crucial and must be defined. [95,108] The summative assessment in simulation follows the training and formative assessment in simulation. This continuity is part of the pedagogical alignment. These different steps have common characteristics (e.g. rules in simulation, scenario flow) and specific ones (e.g. use of assessment tools, validation of competence). To ensure pedagogical continuity, the trainers who supervise these courses must be trained in all these characteristics. The summative assessment in simulation includes specific characteristics that are less often mobilized and that come in addition to what is done during the training. This represents new skills and a greater cognitive load for the trainers. It is necessary to bring solutions to these two issues: new skills and cognitive load. For the new skills of trainers, it is advisable to adapt or complete the training of trainers by integrating the knowledge and skills necessary for the proper conduct of summative assessment: good practices in assessment, assessment bias, calibration, mastery of assessment tools, etc. [109] To optimize the cognitive load caused by the missions and challenges of summative assessment, a division of missions between different roles of trainers could be a solution. We think that conducting summative assessment in simulation therefore requires three types of trainers with training adapted to their specific role. First, the trainer-designers responsible for designing the assessment situation, selecting the assessment tool(s), training the trainer-rater(s), and supervising the assessment session. Second, the trainer-operators responsible for running the simulation situation that supports the assessment. Third, the trainer-raters who carry out the assessment using the

assessment tool(s) selected by the trainer(s)-designer(s) for which they have been specifically trained. The important consequences and stakes of summative assessment in simulation require a high level of rigor and professionalism from the trainers, which means that we need to work on defining the skills and training necessary to be up to the task.

**Implementation of summative assessment in simulation in healthcare**

The implementation of summative assessment in simulation is delicate, requires rigor, respect of successive steps and must be evidence-based. While OSCEs are simulation, simulation is not limited to OSCEs. Summative assessment with OSCEs has been used and studied for many years. [12,13] This literature is therefore a valuable source for learning lessons about summative assessment applicable to simulation as a whole. [20,58,110] Knowledge from the practice of summative assessment with OSCEs needs to be supplemented so that simulation as a whole can perform summative assessment according to good evidence-based practices. Given the high stakes of summative assessment in simulation, it is necessary to rigorously and methodically adapt what is already validated during implementation; and to proceed with caution for what is not yet proven. As described above, many steps and prerequisites are necessary for an optimal implementation, including - but not limited to: identification of objectives; identification and validation of assessment tools; preparation of simulations, trainers and raters; planning of a global strategy from the integration of the assessment in the curriculum to the management of the consequences of the assessment. Summative assessment in simulation must be carried out within a strict framework for its own sake and that of the people involved. Poor implementation would be detrimental to all: participants, trainers and summative assessment. This risk is greater for recertification than for certification. [111] While initial training, which is familiar with certification, is able to accommodate summative assessment in simulation, as was the case for OSCEs, recertification of practicing professionals is not as obvious and may be context-dependent. [112] The consequences of failed recertification are potentially more impactful psychologically and for professional practice. Solutions that both fill gaps and preserve professionals and patients must be developed, tested, and validated. The implementation of simulation for summative assessment must be progressive, rigorous, and evidence-based to be accepted and successful.

*Limitations*

This work has certain limitations that must be emphasized to facilitate its appreciation and the bearing of the elements presented. First, this work covers only a limited number of questions related to summative assessment in simulation. The entire topic is probably not covered and questions of interest may not have been explored. Nevertheless, the nominal group methodology allowed this work to focus on those questions that were most relevant and challenging to the panel. Secondly, the literature review method (scoping literature reviews expanded with a snowball sample technique) does not guarantee exhaustiveness, and publications on the subject may have escaped the screening. However, it is likely that key articles on the questions explored have been identified. The potentially unidentified articles would therefore either not be important on the topic or would deal with questions not selected by the nominal group method. Third, this work was done by a Francophone group, and a Francophone-specific approach to simulation, although not described to our knowledge, cannot be ruled out. This risk is reduced by the fact that the work is based on international literature from different specialties in different countries and experts and reviewers were from different countries. Finally, this work raises questions and offers some tracks toward solutions.

## Conclusion

Summative assessment in simulation is a logical extension of formative assessment in simulation and the development of CBME. The widespread implementation of simulation-based formative programs and CBME is underway. Anticipating and getting a head start on thinking about the summative assessment in simulation that will follow is probably smart. Indeed, many moving parts, issues and important consequences are emerging. It is important to clearly identify them and their interactions, in order to develop reliable, accurate and reproducible concepts. All this requires a meticulous and rigorous preparation that is equal to the stakes: certifying or recertifying the skills of healthcare professionals. We modestly hope that this work can serve as a basis for reflection for future investigations and development of guidelines for summative assessment with simulation.

**List of abbreviations**

AIC: Anesthesia and Intensive Care

CBME: Competency-Based Medical Education

CPD: Continuing Professional Development

GDPR: General Data Protection Regulation

MOC: Maintenance Of Certification

MOCA: Maintenance Of Certification in Anesthesiology

NGT: Nominal Group Technique

OSCE: Objective Structured Clinical Examination

PTSD: Post Traumatic Stress Disease

## Declarations

### Ethics approval and consent to participate

Not applicable

### Consent for publication

Not applicable

### Availability of data and materials

All data generated or analyzed during this study are included in this published article.

### Competing interests

The authors declare that they have no competing interests.

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**Authors' contributions**

CB helped with study conception and design, data contribution, data analysis, data interpretation, writing, visualization, review and editing. FL helped with study conception and design, data contribution, data analysis, data interpretation, writing, review and editing. RDM, JWR and DB helped with study writing, and review and editing. JWR and DB helped with data interpretation, writing, and review and editing. LM, FL, EG, ALP, OB and ALS helped with data contribution, data analysis, data interpretation, and review. All authors read and approved the final manuscript.

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**Figure 1: Research process from debate on summative assessment with simulation, Nominal Group Technique to Results.**

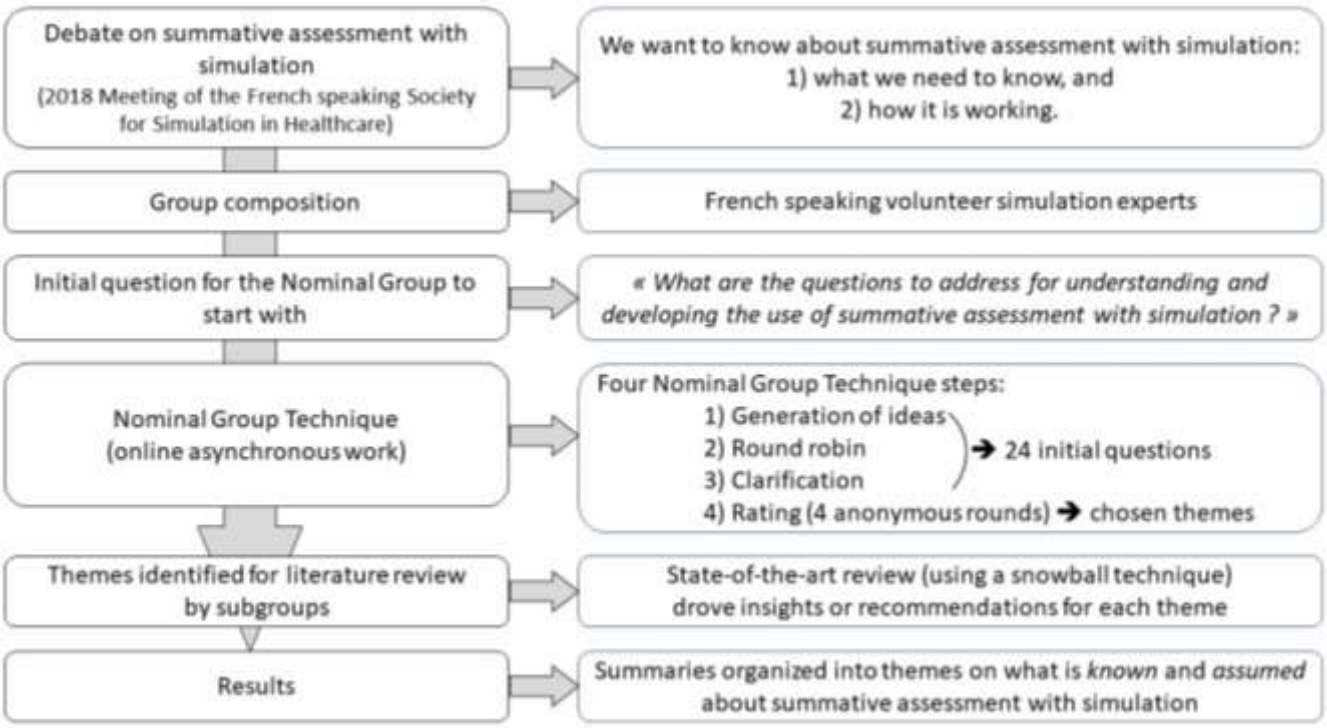

**Table 1: Considerations for implementing a summative assessment with simulation.**

| Considerations | Elements | Items | Example adapted to cardiopulmonary resuscitation (CPR) for an emergency physician |
|---|---|---|---|
| **Competency to be assessed** | **Clear definition of competency** | *Know how* to act in a professional situation | The practitioner is able to handle an in-hospital cardiac arrest (CA) |
| | | Identify *internal resources*: knowledge, skills, behavior, and reasoning | ACLS algorithm, airway management, leadership, management according to the type of CA (e.g. asystole, pulseless electrical activity, ventricular fibrillation) |
| | | Identify *external resources*: equipment, written or electronic resources), colleagues, and so on to mobilize | e.g. defibrillator, cognitive aids (a chart, a checklist, …), ECMO team, … |
| | **Number of competencies** | Consider the possibility of assessing one or more competencies simultaneously | In-hospital CA alone, or CA in adult patient and/or in specific conditions (e.g. child, pregnant, ...) |
| | **Measurements** | Consider measuring performance in representative and diverse situations | CA in a young polytrauma patient, in an elderly diabetic patient, in a pregnant woman or in a child out-of-hospital |
| **Assessment** | **Context Authenticity** | Complex problems | e.g., CA due to hyperkaliemia in a patient with renal failure |
| | | Adapt the complexity to the training level | Complexity may be tuned for an expert with patient's chronic use of beta-blockers. |
| | | Ensure context relevance to future or current professional practice | CA occurs in an ambulance or in an emergency room or in operating room or in intensive care unit |
| | | Interprofessional situations (vs uniprofessional) | Prefer a situation where the learner is not alone such as a member of an emergency team and not as a first responder in the street |
| | **Standardization** | Tasks and requirements known before by the participants | Send to the learner the assessment template prior to the assessment |
| | | Direct observation associated with a phase of student interaction (questioning) | The simulation is followed by a debriefing (feedback) |
| | | Rate with a checklist or a rubric | |

| | | | |
|---|---|---|---|
| | **Correction criteria** | Multiple sources and/or iteration (e.g., repeated performances of the same scenario) | e.g., time from the start of ventricular fibrillation to the first external electric shock and/or compliance with ACLS steps and/or quality of external cardiac massage (visual and/or via sensors). |
| | | Clear and specific objectives | Only items that have been previously decided are assessed (see above) |
| | | Adjusted to the assessed knowledge or to the simulation.<br>Integration of self-assessment | It is not possible to assess the use of the defibrillator if the situation is pulseless electrical activity. |
| | | Consider only important errors | 6 instead of 5 minutes between 2 doses of adrenaline (minor error) versus no recognition of a shockable rhythm (major error) |
| | | Strategies (cognitive and metacognitive) assessed during the interaction phase | Ask questions during feedback phase: "Can you remind me of the administration schedule for epinephrine in CA?" (cognition). "I have observed that you administered it every minute, but as you have just said and as I think it is every 3 to 5 minutes, could you explain why in the situation you administered it every minute?" (metacognition) |
| | | Prior consensus on rating and definition regarding expected level of development | Identify minor and major errors together (all instructors involved in the assessment of this competency). Define the number of acceptable minor and/or major errors to validate the acquisition or not of the competency at this level of development. |
| **Scenarios** | **Development** | Developing scenarios only after defining the skills and or competences to be assessed | e.g., if we want to evaluate the use of the defibrillator, we need to construct a scenario where the patient has VF or VT. |
| | | Ensuring the scenario reflects professional reality | e.g., use a hyperkalemia CA scenario after a burial extraction but not when releasing a tourniquet after a knee replacement for an emergency physician. |
| | | Incorporating the targeted skills into a scenario representing professional practice, rather than a task trainer, for example | Prefer to use a scenario with a clinical history of CA to assess CPR skills rather than performing CPR in a skill station. |
| | **Multiple skills** | Several stations with short scenarios (e.g., 5-6 minutes) each are preferable to long scenarios (e.g., >20 minutes) | Ensure that all steps can be assessed. E.g., the use of ECMO is reserved for refractory CA and cannot be considered if the scenario lasts for 5 minutes and begins with the recognition of the arrest. In this case, a scenario with a CA that has already been under management for 15 minutes should be used. |
| | | Critical situation | |
| | **Test prior to use** | Validity, reliability, reproducibility | The scenarios used should be pre-tested by the teaching team including using the assessment forms. |

| | | | |
|---|---|---|---|
| | **Simulators (High and low-Technology)** | Use and difficulty level validated | e.g., if intubation is expected during the scenario, the chosen manikin should allow it. |
| **Assessment test** | **standardization (Fairness)** | Facilitator's role and intervention specified in advance<br><br>Only one candidate per station | What can the facilitator do? E.g., can he/she guide on 4H-4T if the learner does not think about it? |
| | **Practical conditions** | Minimum number of scenarios (8 to 15) [113] | Scenarios in different circumstances (in and out-of-hospital), different causes (4H-4T), different ages (child to elderly adult). |
| | | Incentive to verbalize after action (Reasoning, what is done or not done) | To be recalled in the pre-briefing |
| | **Raters** | At least, two raters<br><br>Ideally, a rater should be involved in the formative assessment program | e.g., clinical supervisor, ACLS instructor, simulation instructor who has supervised the learner during the formative sessions, … |

**Table 2: Example of the tool development to assess a technical skill achievement in simulated situation, Oriot et al, based on Downing framework. [24,37]**

| Source of validity | Method | Judgment criteria | Results |
|---|---|---|---|
| **content** | 1. Description of the checklist development by 2 experts<br>2. Review by 2 outside experts<br>3. Definitive Checklist | Relevance of items<br>Adapted illustration of the skill<br>Conditions of skill achievement | Obtaining a list of 12 items (after initial proposal of 20 items) |
| **Response process** | Pilot study, search for error sources<br>Adapting items<br>Defining units of measurement | Interrater reproducibility<br>Item content (redundant, inaccurate)<br>Controlling the sources of measurement errors<br>Weighing items | Fusion/removal of redundant items<br>Minutes, degrees, centimeters justification |
| **Internal structure** | Internal coherence<br>Reproducibility<br>Discrimination of learners | Cronbach Alpha Coefficient,<br>interrater: Cohen Kappa, Intraclass Correlation Coefficient (ICC) | Cronbach result<br>Correlation between 2 raters |
| **Comparison with other variables** | Score vs success or failure of the procedure<br>Score vs theoretical assessment<br>Score vs previous experience/level of expertise | Correlation between procedure success or theoretical assessment and score with the tool | Time for success, score for success and rating |
| **Consequences** | Minimum passing score | Pass-fail score with procedure success | 14/20 |

**Table 3: Example of development of a simulated teamwork observation assessment tool [114]**

| Source of validity | Method | Judgment criteria | results |
|---|---|---|---|
| **content** | 1. Description of the *Clinical Teamwork Scale (CRM scale)* Development | Literature review<br>Scale already used in another field (aeronautics) | 15 items<br>5 categories<br>1 overall skill score |
| **Response process** | 1. Relevance of items<br>2. weighting items<br>3. Raters' training (moderate) | 1. Precise description of each item<br>2. Quantitative criteria<br>3. Qualitative criteria<br>4. CRM principles | 1. Ratings aid table<br>2. 0 to 10 or 0/1<br>Descriptive levels: Not Relevant / Unacceptable / Poor / Average / Good / Perfect |
| **Internal structure** | 1. Built-in Validity<br>2. Scale Usability<br>3. Reproducibility | 1. Distribution of scores from the preset level<br>2. Number of items filled in full<br>3. interrater concordance, correlation between overall score and categories (Kappa, Kendall, Pearsons, ICC)<br>4. Variance of each category | 1. Score tailored to each level<br>2. Easy-to-use scale (little loss of information)<br>3. correlation between raters<br>4. Variation in scores between scenarios sources of error |

**Table 4: Key elements structuring a summative assessment scenario.**

| Elements | Recommendations |
|---|---|
| **Duration** | 10 to 15 minutes<br>Short for technical skills<br>Longer for non-technical skills |
| **Objectives** | Accurate list of competencies and skills to be assessed |
| **Essential items** | Initial assessment<br>Diagnostic strategy<br>Situation management<br>Orientation strategy |
| **Script** | Computerized (programed if possible) |
| **Rating scale** | *Checklist, Global Rating Scale*<br>Scale (20 to 30 items)<br>Analytic score for technical skills<br>Analytic and holistic (e.g. ANTS) for non-technical skills |
| **Validation** | Pilot sessions (scenario testing and raters training)<br>1 or 2 cases per student during scenario testing |
| **Assessment** | Video rating<br>Cohen's Kappa test for differences between raters<br>Student t-test for ability to discriminate between students |

**Table 5: Using video in simulation for formative and summative assessment.**

| | Formative assessment | Summative assessment |
|---|---|---|
| **Prebriefing** | Participant information | |
| **Simulation** | Increased scenario realism (e.g. coelioscopy video)<br>Watching by observers | |
| **Immediate visualization after simulation** | Self-assessment | No self-assessment (in the literature) |
| | Debriefing by trainers (selected sequences) | |
| **Delayed visualization** | Learning teamwork or skills for a formative purpose | Deferred debriefing<br>Rater training (calibration and recalibration)<br>Administrative evidence |

**Table 6: Potential errors, effects and bias in summative assessment with simulation [115,116]**

| Type of error | Error description |
|---|---|
| **Error of homogenization** | Rater's tendency to rate neither too good or too bad, making discrimination more difficult. |
| **Halo effect** | Rater's tendency to see everything right or wrong in the same performance. |
| **Time effect** | Bias related to observations of early or late good or bad performance during session. |
| **Bias of "clemency"** | Willingness not to give bad grades. |
| **Repository error** | Judgment based on what the rater would have done and not on the assessment tool. |
| **Group effect** | Evaluation based on the team's performance rather than participant's performance. |

**Table 7: Setting up the summative assessment with simulation.**

| Items | Goals | Modalities |
|---|---|---|
| **Team** | Identify the training staff | Structure coordination<br>Size the team: skills, time available, stability (project over several months / years) |
| **Competencies repository** | Create the competencies repository to be assessed | Expert panels<br>Define number and type of examination needed<br>Must be known to students |
| **Curriculum** | integrate summative assessment in the curriculum | Pedagogical alignment: summative part drives formative part of the curriculum<br>No summative assessment without pre-simulation exposure<br>Intermediate summative assessment could be useful [117] |
| **Examination** | Define summative assessment modalities through simulation | Length and number of scenarios stations [118,119]<br>The higher is the fidelity of examination, the harder is it to set it up, the lower is the feasibility |
| **Scenarios** | Develop a bank of scenarios and rating grids [120] | Choose the editors for the scenarios<br>Write the scenarios<br>Scenarios' peer-review and test<br>Establish/choose assessment tools (Checklist or global scale)<br>Set the minimum passing score<br>The themes of the bank's scenarios cover the competencies of the repository |
| **Training raters** | Limit rating variations for a given performance | Choice of raters<br>Raters' Training Workshop |
| **Standardized Patients** | Develop a standardized patient pool | Recruitment, selection, training, standardization [121] |
| **D-Day** | How the examination take place | Logistics: dates, rooms, standardized patients, rights of personal portrayal, GDPR,…<br>Participants' path, breaks<br>Materials to supply, to be brought by students (e.g. stethoscope)<br>Examination-adapted briefings<br>Problems to anticipate: maintenance of standardization, failure or breakage of equipment, backup paper supports, dedicated staff for support to stressed participants, … |
| **immediately after examination** | Finalize the examination | Collect and check assessment grids for early detection of inconsistencies, rating oversights, missing data<br>Management of participants' complaints and plea |
| **Quality process** | Prepare future examination | Identify potential changes to do to some scenarios<br>Removal of inappropriate scenario: too long, misleading, source of rating inconsistency, …<br>Changes to standardized patients' training<br>Changes in raters' training |

**Table 8: Commonalities and discrepancies between certification and recertification.**

| Items | Commonalities | Discrepancies |
|---|---|---|
| **Modalities** | Multimodal process (course, simulation, etc.) [22,56,64]<br><br>Field follow-up opportunities [23] | Low percentage of existing recertification [22,56]<br>Level of acceptability and feasibility of recertification.<br><br>Level of recertification: pursuing individual certification or switching with team recertification |
| **Organization bodies** | Accredited centers (functional specification) [22,56]<br>Same rigor in setting up | Can institutions (universities, schools) in charge of certification, provide recertification? |
| **Objectives** | Targeted level of competency | Difficulties in the efficient selection of competencies to be assessed with recertification:<br>● Multiple constraints (time/means)<br>● Communication/teamwork, performance gaps, frequent adverse events?<br>Scenarios and assessment tools adapted for learning objectives [122] |
| **Consequences** | Possible failure of certification or recertification | The impact of a failure to recertification is major for a professional<br>Mandatory discretion of the recertification process<br>Opportunity for screening of professionals in difficulty (burn out...) [64,85] |
| **Funding** | Funding difficulties | Many options of financing in recertification (state, professional insurance, etc.) |

**Supplemental Digital Content #1: Initial set of 24 questions resulting from Nominal Group Technic.**

What are the criteria for a good assessment tool?

What assessment tools have been validated and are usable in summative assessment in simulation?

What can be assessed through simulation?

How can we define a competency?

What competencies can be assessed during a summative assessment in simulation?

How to implement summative assessment in simulation in initial training of health professionals?

How to implement summative assessment in simulation for surgeons (initial training/continuing education)?

How to implement summative assessment in simulation for continuing education/certification of healthcare professionals?

What are the specificities of summative assessment of healthcare professionals through simulation?

What are the interest and the place to give to self-assessment when using summative assessment in simulation?

What are the value and place of peer-to-peer assessment in the use of summative assessment in simulation?

What is the experience of those being assessed when using simulation for summative assessment?

Are the SOFRASIMS creation grids for mannequin scenarios usable for summative assessment?

Is the Good Practice Guidelines for Health Simulation usable for summative assessment?

Do trainers need specific training to do summative assessment?

Is there a debriefing during assessment evaluation?

If so, what is special about debriefing during summative assessment?

What simulation tools can/should be used for summative assessment?

How can procedural simulators be used for summative assessment through simulation?

How should full-scale simulators be used in summative assessment through simulation?

How do I use simulated patients in summative assessment with simulation?

How to use expert patients in summative assessment with simulation?

How can serious games be used in summative assessment with simulation?

What video tools can/should be used for summative assessment?

**Supplemental Digital Content #2: Final set of 7 themes with sub questions resulting from four Delphi rounds.**

1) What can be assess with simulation?
    - What is assessable with simulation / Not assessable by simulation?
    - How can we define a competency?
    - What competencies can be assessed in a simulation-based summative assessment?
2) Assessment tools?
    - What is a good assessment tool?
    - How do you create an assessment tool?
    - Is the assessment tool the same between a novice and an expert?
    - Is the assessment tool the same with different profession?
    - Team certification.
3) Consequences of summative assessment (emotion, psychological safety and ethical, legal consideration)
4) Is the existing scenario reference frame applicable to summative assessment? Are the SoFraSimS scenarios' template usable for summative assessment?
5) Are the existing healthcare simulation best practice guidelines applicable to summative assessment?
    - Debriefing:
        - is there a debriefing with summative assessment?
        - if yes: what are the specificities of the debriefing summative assessment?
    - Video tools:
        - What video tools can/should be used for summative assessment?
6) Is the trainer training standard applicable to summative assessment?
    - Who can do summative assessment in simulation?
        - self-assessment
        - peer-to-peer assessment
    - Do trainers need specific training?
7) How can we implement summative assessment in simulation?
    - In initial training of healthcare professionals?
    - In continuing education/recertification of healthcare professionals?
    - Example of a proposal for the implementation of simulation, particularly in the initial training and continue education curriculum in surgery (general or urological or pediatric)

# Discussion on Article 2

This article highlights important key principles on summative assessment in simulation through seven themes identified as important to the understanding and implementation of summative assessment in simulation. These themes can be broadly classified into three categories. The first category is one for which there is evidence in the literature that provides a clear understanding of the topic. Recommendations based on this evidence can be proposed. The second category is where there is evidence in the literature that provides guidance but needs to be supplemented. Recommendations with a limited level of evidence supplemented by expert opinion can be proposed and research should be undertaken. The third category is the one for which there is almost no data in the literature. Ideas and/or expert opinions can be proposed and research should be undertaken.

In the first category - recommendations based on this evidence can be proposed - we classify the topic "*What can be assessed in simulation?*" The answers to this question are well documented in the literature and provide practical applications for the use of summative assessment in simulation. We have identified three issues that can be further explored. The assessment provides access to a performance when it is a skill that one wishes to assess.[52–54] Does the evaluation done in simulation (however faithful to reality it may be) reflect the real competence in a clinical situation?[55,56] How can we manage the evaluation of teams that have their own operating dynamics that are partly independent of the individuals that make them up?[57–59] These three problems represent elaborate deepening of the theme, interesting to investigate, not being an obstacle to the summative evaluation in simulation.

We classify in the second category - recommendations with a limited level of proof completed with expert opinions can be proposed and research must be undertaken - the themes "*Assessment tools for summative assessment*", "*Scenarios for summative assessment*", and "*Implementation of summative assessment in simulation in healthcare*".

Validity and robustness characteristics for the construction and use of tools for summative assessment are well defined in the literature.[42,43,60] However, few tools meet these validation criteria in practice, and it is not clear that trainers are fully aware of the limitations that arise from using incompletely validated tools.[61] We believe that it would be useful for knowledge of the validation criteria for assessment tools to be widespread, both for use and for the design of

new tools. This will contribute to the appropriate use of more effective tools. It is therefore important that trainers and learners be familiar with assessment tools. Trainers to master them and make a reliable, reproducible and valid use of them. Learners to be aware of the assessment methods to which they are subjected. The rigorous construction of valid, reliable and reproducible assessment tools is time consuming. A mutualization of these efforts through a bank of evaluation tools would be an undeniable advance for the community of simulation trainers. This requires the identification of common competencies across the participating countries.

The design, writing and application of scenarios for summative assessment with simulation are very similar to those for simulation training and can be built upon. However, it is necessary that the scenarios to be used in a summative assessment with simulation be developed and applied with extreme rigor, on themes and clinical situations for which there are recognized management guidelines. These scenarios must be reproducible and reliable, logically incorporate the assessment tools used and be tested and validated beforehand with a view to the summative assessment. The particular case of the involvement of a standardized patient deserves to be mentioned because it is fundamental that the role sheet and the briefing of the standardized patient guarantee - in addition to careful recruitment - reproducibility and reliability in the interaction proposed to the participants. In order to save the trainers' time and to take advantage of the large number of existing scenarios for simulation training, it would be wise to develop a guide for the conversion of formative scenarios into summative ones. This guide would guarantee the necessary quality criteria for the scenarios in summative assessment in simulation.

Implementing summative assessment in healthcare simulation is a complex process as there are many elements, each with prerequisites and consequences. OSCEs have proven the feasibility of summative assessment with simulation for many years.[62,63] However, if OSCEs are simulation, simulation is not only OSCEs. Additional considerations (e.g. high-fidelity simulation scenarios, psychological consequences...) must be taken into account and need to be studied in depth. The case of recertification is particular since it concerns professionals already in practice who are revalidating the skills they already use on a daily basis.[52] The consequences (e.g. psychological, on the clinical practice, on the career) can potentially be more serious than for an initial certification. Because of the complexity of setting up a summative assessment with

simulation, we believe it would be useful to draw up a checklist to ensure that the various stages are respected and that the various elements essential to the success of the undertaking are used.

We classify in the third category - thoughts and/or expert opinions can be proposed, and research should be undertaken - the topics "*Consequences of summative assessment*", "*Debriefing for summative assessment*", and "*Trainers for summative assessment*".

Establishing and maintaining psychological safety is mandatory in simulation.[64] With regard to the consequences of summative assessment with simulation, we propose the following reflections and solutions to reduce its negative impacts. Because summative assessment with simulation is high-stakes, it can have strong psychological and pedagogical impacts that are potentially negative. We believe that it is important to identify these impacts in order to prevent and ideally mitigate them. These impacts may be related to the participants, the trainers or the interaction of the two. We hypothesize that taking these impacts into account and managing them in advance will be beneficial for the participants and for the conduct and outcome of the summative assessment. **Table 5** presents six tips for limiting these impacts. For the participants, a better experience will promote learning and adherence to the principle of summative assessment through simulation. For the raters and the summative assessment process itself, it will allow for a more accurate assessment by reducing the amount of stress not related to the skill but to the summative assessment process. Taking into account the negative impacts of the summative assessment is - from our point of view - part of the quality criteria for the due kindness that it represents for the participants and for the accuracy of the results that it provides. It is therefore an essential element to take into account.

Regarding the place of debriefing in the summative assessment with simulation, we propose the following reflections and three options to optimize the pedagogical benefit for the participants and the time spent for the trainers (**Appendix 3**). No clear guidelines on what and how to debrief after a summative assessment with simulation arise from the literature.[65] We propose a reflection on three possibilities: (i) no debriefing, (ii) with debriefing included in the summative assessment and (iii) with a formative debriefing following the summative assessment (2 options).

First, no debriefing included in summative assessment simulation sessions. There is no evidence in summative assessment but absence of debriefing in formative assessment is linked to worse

performance than with debriefing.[66] So, we can hypothesize that no debriefing in summative assessment is probably not good either. We would not recommend no debriefing in summative assessment with simulation.

**Table 5: Solutions to reduce the summative assessment impact in simulation.**

| Persons involved | Conditions | Solutions |
|---|---|---|
| **Participant-dependent** | Knowledge of "Simulation" tool | Experience in formative training ≥ 1 over the past 2 years |
| | Physiology | Sleep: no summative simulation done on post-call period<br>Sleep: Limited number of night shift in the last 7 days before summative simulation |
| | Psychological and emotions safeties | The importance of debriefing failure with the student (e.g. looking for a stressful event in relation to the assessment context)<br>If recent Burnout: green light received from the occupational medicine |
| **Raters and Participant-dependent** | Respect for the context-dependent nature of the assessed skills | The assessment case is in the current or future practice area of the participant |
| | Taking into account the perception of personal efficiency | Clear and transparent information on certification requirements |
| **Raters-dependent** | Psychological safety by prepared trainers | Ensure in advance that raters are able to establish and maintain psychological safety<br>Formative simulations programmed frequently |

Second, debriefing included in the summative assessment. The purpose may be to assess the participant's auto evaluation ability and capacity for self-criticism. Unfortunately, we think that bring more questions than solutions, such: "*At which point is it doable for the participant to sincerely reveal his/her thoughts knowing that will be assess?"; "Will the participant give his/her best effort to identify his/her cognitive frame, or to please the rater and give the "good" and awaited answer rather than his/her?"* Clearly, that puts the participant in a cognitive dilemma and the raters in the uncertainty of what they will really assess. We may also question

the ethics of including the debriefing in the assessment because it will need to have a clear answer to the questions: *"At which point a good analysis during the debriefing can compensate for a poor performance during simulation?" and "At which point a poor analysis during the debriefing may deteriorate the rating of a good performance during simulation?"* Including the debriefing in the summative assessment require answering many questions and issues before. We think it deserves further investigation and hard evidence before we can have a strong opinion on whether debriefing should be included in the summative assessment with simulation.

Finally, a formative debriefing following a summative assessment with simulation. In this situation, participants have the benefit of some feedback without the stress of being assessed for their cognitive frames. Trainers will fulfill their pedagogical duty without the discomfort and uncertainty previously described. This debriefing could be standardized feedback describing the actions awaited (first option). Participants will do the match and delta with their performance on their own. This could be done in groups. This may be generic feedback without personalized feedback. We can see it as a win-win, as the participants have some feedback and it is not too much time consuming for the trainers. A second option for this formative debriefing following a summative assessment may be a full classical debriefing giving personalized feedback. It is time consuming for the trainers but it is the follow-up of the teaching process and in case of failure, it will give useful and sympathetic feedback to the participant. It may be of great help for future improvement and success. We think those two last options can be complementary and standardized feedback could be given to successful participants (first option) and personalized feedback to failed participants (second option). Without solid evidence but based on the developed reasoning, we proposed modalities for the inclusion of debriefing in summative assessment with simulation.

Finally, for trainers preparing and supervising a summative assessment with simulation, it is clear that specific training must be provided.[61] We think that specific training must be adapted to the different roles. We propose to have three categories of trainers for the summative assessment with simulation: the trainer-raters, the trainer-operators and the trainer-designers (**Table 6**). This distribution of trainers' roles aims to limit the necessary training overload to the strict minimum, to gain in specificity for the trainers and to optimize the trainers' human resources. Thus, the trainer-raters can relatively simply and easily be trained on demand to use a specific tool and/or assessment once they have the generic training.[67] This provides organizational flexibility. The trainer-raters would exclusively focus on their rating activity

during the summative assessment with simulation.[67] This should provide the best of their skills to the benefit and the quality of the assessment. The trainer-operators are ideally those who provide the formative training. They are aware of the importance of replicability to ensure equity. The fact that they provide formative and summative training ensures coherence and pedagogical alignment, which is an important plus. The trainer-designers are the conductors in charge of the important work of preparing the simulation, the assessment and the training of the other trainers involved in the summative assessment with simulation beforehand. The trainer-designers can then dedicate themselves on the assessment-day to supervising and ensuring the smooth running of the session.

**Table 6: Training, missions and abilities of trainers involved in summative assessment in simulation.**

| | Trainer-designer | Trainer-operator | Trainer-rater |
|---|---|---|---|
| **Initial trainer training** | University diploma of simulation or degree in education / pedagogy associated with a trainer training in simulation | Trainer training in simulation | Trainer training in simulation and specific training to the assessment carried out. |
| **Continuous trainer training** | Conducting ≥ 6 sessions/year[68] | Conducting ≥ 6 sessions/year[68] | Conducting ≥ 6 sessions/year[68]<br>Regular recalibration suitable for the tools used. |
| **Missions** | Integrating assessment into the curriculum.<br>Design and validation of the assessment. | Lead the assessment situations. | Make the assessment. |
| **Generic abilities (integrated with trainer training)** | ● Master the types of errors in assessment.<br>● Have some knowledge of the assessed performance.<br>● Describe the tools available for summative assessment.<br>● Identify raters' behaviors.<br>● Explain the importance of raters' calibration.<br>● Recognize the importance of feedback/debriefing when appropriate.<br>● Consider the specifics of using the video (if applicable). | | |
| **Specific abilities for a given function (specific training)** | Design and validate the assessment situation.<br>Compare assessment tools.<br>Organizes the training of trainers-raters. | | Identify the performances assessed.<br>Master the assessment tools used.<br>Identify raters' behaviors.<br>Use an assessment tool accurately after calibration. |

We think that this distribution of roles has the advantage of limiting the cognitive load of the trainers and allowing them to work on a single task. Thus, preparation beforehand, practical organization on the assessment-day, management of the simulation and rating benefit from trainers who are dedicated to them. This allows a better concentration and probably better trainers' performances for the benefit of the summative assessment. These three distinct categories with specific roles also make it easier to define the expectations in terms of training trainers for summative assessment with simulation.

Based on the mapping of current key principles about summative assessment in simulation and the arguments presented in this section, we have seen the feasibility and conditions for integrating summative assessment into a unified simulation training program. We have also identified leads for improving understanding of elements deemed important for the use of simulation in summative assessment with simulation. The baseline described should reasonably serve as a starting point for proposing a first version of guidelines in the form of expert recommendations, which need to be confirmed by rigorously established evidence later. Again, positioning ourselves at the level of this thesis, we have proven the feasibility of a unified national simulation program in AIC. We have identified the conditions for integrating summative assessment into a simulation training program. These two tasks can be combined, yet they are still very resource intensive as we have discussed. Expanding the populations of AIC trainers and simulation training programs involved in a unified program would allow for the benefits described in part one, including reducing the effort of each country or region by pooling resources, facilitating adaptability and interoperability. To do this, it is necessary to identify regions with sufficiently similar AIC resident training repositories to share a unified repository of teachable competencies through simulation. This is the subject of part three.

# Part 3: A unified international repository of competencies in Anesthesia and Intensive Care

## Introduction to Article #3

In medicine, and therefore in AIC, knowledge and related skills are increasing over time and at a steadily increasing rate. This implies regular adaptations to the AIC training programs and reference materials to integrate this new knowledge and skills. These adaptations are time-consuming and require precious human resources that are complex to mobilize.[16] Over time, this task becomes increasingly cumbersome and recurs more frequently. To keep the repositories up to date, one solution could be to pool the necessary resources, thus sharing this task among a larger number of experts who are able to carry it out. This is already done in countries or regions such as the EU, US or Canada. [11,12,14] In order to be even more efficient, it would be necessary to move to a higher level, i.e. to carry out this task between several countries/regions. Europe and North America have a shared history of medical development over the last two centuries.[18] In addition, professional collaborations and exchanges take place daily in most medical disciplines. It is therefore reasonable to assume that there are relatively high degrees of similarity between AIC residency training standards. Having a shared international competency repository for AIC residents would have significant benefits. As indicating a shared international competency repository would facilitate the adaptation of programs to the latest science. A shared international competency repository would allow for a homogenization of practices facilitating the standardization of the quality of care to a higher level. This would facilitate professional mobility. A shared international competency repository could be disseminated in countries that do not have the capacity to produce competency repository and adapt them by themselves. Finally, a shared international competency repository would facilitate clinical, research and pedagogical collaborations among countries using it. This last dimension of pedagogical collaboration is in line with the subject of this thesis on the construction of a unified repository for training and assessment in AIC simulation. If it is

possible to develop a shared international competency repository for AIC residents, it can serve as a source for the development of a unified international AIC simulation training (and summative assessment) program.

The objective of this work is to map the similarities and differences between the EU, US, and Canadian AIC resident training curricula to identify a shared core of competencies that are sufficiently similar that training characteristics and expectations can be shared. At the scale of this thesis, this shared core of competencies identified would be transferable to a unified international AIC simulation training and summative assessment program.

# Article #3

## First steps towards international competency goals for residency training: A qualitative comparison of 3 regional standards in anesthesiology.

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**Short title:** International comparison of residency training competencies

## Abstract

### Background

Competency-based medical education (CBME) has revolutionized approaches to training by making expectations more concrete, visible, and relevant for trainees. Designing, applying, and updating CBME requirements challenges residency programs, which must address many aspects of training simultaneously. This challenge also exists for educational regulatory bodies in creating and adjusting national competencies to standardize training expectations. We propose that an international approach for mapping residency training requirements may provide a baseline for assessing commonalities and differences. This approach allows us to take our first steps towards creating international competency goals to enhance sharing of best practices in education and clinical work.

### Methods

We chose anesthesiology residency training as our example discipline. Using two rounds of content analysis, we qualitatively compared published anesthesiology residency competencies for the European Union (The European Training Requirement), United States (ACGME Milestones), and Canada (CanMEDS Competence By Design), focusing on similarities and differences in representation (round one) and emphasis (round two) to generate hypotheses on practical solutions regarding international educational standards.

### Results

We mapped the similarities and discrepancies between the three repositories. Round one revealed that 93% of competencies were common between the three repositories. Major differences between European Training Requirement, US Milestones, and Competence by Design competencies involved critical emergency medicine. Round two showed that over 30% of competencies were emphasized equally, with notable exceptions that European Training Requirement emphasized Anaesthesia Non-Technical Skills, Competence by Design highlighted more granular competencies within specific anesthesiology situations, and US Milestones emphasized professionalism and behavioral practices.

### Conclusions

This qualitative comparison has identified commonalities and differences in anesthesiology training which may facilitate sharing broader perspectives on diverse high-quality educational, clinical, and research practices to enhance innovative approaches. Determining these overlaps in residency training can prompt international educational societies responsible for creating competencies to collaborate to design future training programs. This approach may be

considered as a feasible method to build an international core of residency competency requirements for other disciplines.

**Trial registration:** not applicable.

**Keywords:** Internship and Residency, Curriculum, Clinical Competences, Education, Reference Standards, Anesthesia, Competency-Based Education

**Word count:** 3606

## Background

Competency-based medical education (CBME) has revolutionized approaches to training by making expectations more concrete, visible, and relevant for trainees. [1, 2] Yet overseeing a residency training program requires program directors, faculty and support staff, and institutions to nimbly adapt curricula to the ever-changing criteria for clinical excellence and competency-based medical education (CBME). [1, 3] The volume of medical knowledge approximately doubles in size every few months, [4] so CBME requirements may change frequently and demand regular updates to account for these advancements. [5] The work to updating residency requirements is often performed at a national level, to homogenize some aspects of training, but the burden on institutional education programs to translate these guidelines is heavy and investments by volunteer committees may be uneven. The result is incomplete or patchy national and international diffusion of evidence-based practices at the residency training level in any individual country. [6]

By matching the large-scale challenge of adapting curriculum through global processes, we can optimize resource management since all countries need to incorporate advancements on the same medical topics. But to do this, we need to have sufficiently common requirements for our training. This ambitious view mandates that we start with map of the current requirements for training. Outside of cardiac arrest resuscitation guidelines from the International Liaison Committee on Resuscitation (ILCOR), [7, 8] we have few examples of shared competency training goals that are created between countries. A few recent studies have compared international training structures, [9, 10] but none has considered individual competencies.

This study compared different regions' requirements to create a baseline map of existing anesthesia program requirements. This could be the starting point for creating a shared set of competencies for future internationally agreed-upon standards for anesthesia or other specialties' training programs. We hope to demonstrate that differences may be mapped in a way that allows for economies of effort and crowdsourcing to accelerate innovative educational design and reduce time wasted reinventing curricula. We used anesthesiology residency as a feasibility test for this conceptual approach.

## Methods

This study conforms to standards for reporting qualitative research (SRQR). [11] Due to the nature of the study, Institutional Review Board involvement was not required.

Context

During fellowship training of one researcher (CB), three researchers (CB, RE, and RDM) met and began discussions on the similarities and differences in our respective residency programs in EU (CB), Canada (RE), and US (RDM). We developed a collaborative research approach to compare published formal requirements quantitatively and qualitatively within those programs.

Sampling strategy

We first identified each region's current governance setting standards for anesthesiology residency education, which included: the European Board and Section of Anesthesiology working under the auspices of the European Union of Medical Specialists (UEMS); [12] the Accreditation Council for Graduate Medical Education (ACGME) for the United States; and the Royal College of Physicians and Surgeons of Canada. We reviewed available metrics for anesthesiology residency educational assessments published by these governing bodies, following White and Marsh's recommendations for choosing text to analyze. [13] Sources for consideration included the European Training Requirement (ETR) in Anesthesiology, [14] the ACGME Program Requirements and the ACGME Milestones for US,[15] and the Anesthesiology Competencies within Competence by Design (CBD) for Canada. [16] As the goal was to assess and compare published competencies, the ETR, the ACGME Milestones, and the Canadian Anesthesiology Competencies were chosen for comparison because they were most uniform in meeting our predefined criteria.

Repository descriptions

*The European Training Requirement (ETR)* [14]

ETR were produced by the European Committee on Education and Professional Development of the Section and Board of Anesthesiology. At the time of this writing, the ETR were intended as a shared repository for all countries in the EU training anesthesiology residents. The latest version was dated February 2018. The scope of ETR was to offer "a *comprehensive and robust overall training framework created by medical specialists and based on assembled EU-wide educational and training experience*." [14] Among the ETR objectives were facilitating professional mobility between European countries and promoting safe and quality care. ETR were not mandatory in EU countries, although the European Board and Section of Anesthesiology supported their adoption. [17] Nevertheless, repositories and certifications in EU's countries were based upon or generally approximate ETR, though there were still some

heterogeneity between European countries' programs. [18, 19] Objectives of the ETR were part of a global framework with four generic competencies: clinical expert, professional leader, academic scholar and inspired humanitarian. ETR consist of knowledge, clinical skills and specific attitudes. The clinical skills comprised 165 items distributed across 16 headlines (**Supplemental Digital Content 1**), which themselves belonged to two domains of (i) general competencies and (ii) specific core competencies. Mastery of skills followed four grades of recommendations: (A) observer level (has knowledge of, describes); (B) performs, manages, demonstrates under direct supervision; (C) performs, manages, demonstrates under distant supervision; and (D) performs, manages, demonstrates independently. Depending on complexity of the skills or items, residents were expected to achieve anywhere from B (e.g. "Management of nerve blocks in pain therapy" or "Management of organ donors in Intensive care and during organ retrieval"), C (e.g. "Performing anesthesiology for kidney transplantation" or "Double lumen tracheal intubation") or D grades (e.g. "Management of severe peri-partum hemorrhage" and "Management of difficult and delayed extubation after airway interventions"), with concessions given for rarer events.

*The United States ACGME Milestones* [15]

The ACGME Milestones, introduced in 2013 but applied to anesthesiology in 2015, attempted to expand upon the six Core Competencies defined by the ACGME and the American Board of Medical Specialties which were Professionalism, Patient Care, Medical Knowledge, Practice-Based Learning and Improvement, Interpersonal and Communication Skills, and Systems-based Practice (Headlines in **Supplemental Digital Content 2**). [20] The Milestones also intended to formalize the observations expected of residents within each of these six Core Competencies, driving residencies to teach and be assessed by how successfully their trainees met Milestones. Each specialty training programs' Milestones were developed by experts within their specialty and varied in number of Milestones per specialty. As of 2020, anesthesiology comprised 25 Milestones. Residents attained one of five levels of achievement within each Milestone with clear behavioral definitions and anchors. [15]

*The Canadian CBD Anesthesiology Competencies [Entrustable Professional Activities (EPAs)]* [16]

When this study was undertaken, two documents described the standards of achievement that are expected of Canadian anesthesiology residents when they were conferred fellowship in the Royal College of Physicians and Surgeons of Canada. [16, 21] The Entrustable Professional

Activity (EPA) guide summarized which EPAs residents were expected to achieve during their residency training (Headlines in **Supplemental Digital Content 3**). EPAs were clinical tasks which residents could perform with minimal or no supervision (i.e., the task can be entrusted to them to complete); these were considered the minimal standard of achievement expected at each stage of residency training. The Anesthesiology Competencies document provided a comprehensive description of the specialty of anesthesiology in Canada, and described what residents should aspire to achieve over their residency program. [21] The Anesthesiology Competencies were categorized in accordance with the CanMEDS competencies (i.e. Medical Expert, Communicator, Collaborator, Leader, Health Advocate, Scholar, Professional). EPAs were assessed with a 5-point scale of entrustability.

Qualitative approach and research paradigm

From April to December 2019, we (CB, RE, and RDM) applied content analysis methodology [13, 22] and considered each of the training requirement repositories as data sources individually situated within an important cultural context, a distinction highlighted by Ratner [23] and uniquely suited to qualitative comparison as it allowed interpreting these training competencies through a sociocultural lens (pragmatic paradigm). [24, 25] As our goal was to define similarities and differences between training expectations, we defined that each individually-numbered competency within any given repository would be considered the unit of data for comparison, which would be compared with all other competencies within the other two repositories.

Data collection methods, processing and analysis

The three researchers (CB, RE, and RDM) entered each of the ETR, US Milestones, and CBD EPAs into a Microsoft Excel spreadsheet (version 2019) to serve as each region's repository of competencies. Each competency item was reviewed by the investigator representing that region and compared with the other regions' competencies to determine congruence. English versions of published competencies were available and were used for comparisons; all authors were fluent in English. As cultural influences were critical for analysis, we together discussed interpretative nuances of our representative region's requirements and considered how anesthesiologists may have functioned in their scopes of practice in each of EU, US, and Canada. To avoid bias, each round consisted of separate and independent investigator review, followed by comparing and merging results, with discrepancies resolved through discussion and consensus, determining intersubjectivity. [26] For the first round of analysis, we identified

whether each competency item was represented in either of the other repositories. The ETR was chosen as the reference comparison here, given that it had the greatest number of competencies. The second round of analysis sought to determine the relative importance or emphasis of specific skill sets in each country's repository, using each repository as a reference for the other two to ensure full consideration of all competencies. Competency items were identified as having equal or different levels of importance, or "emphasis" between repositories based on how they were presented within the repository (i.e., competency items which were singled out and treated in-depth as unique competencies were interpreted as more emphasized than ones which were only briefly mentioned). For first round analysis, we sought to include rather than exclude, such that if a competency did not explicitly state an action, yet it could reasonably be included within the scope of the competency, common representation was considered between competencies. However, we applied stricter definitions whether domains were emphasized equally, and cultural context was considered more heavily. We used descriptive statistics to quantitatively present congruency and emphasis of competencies between the repositories.

Researcher characteristics and reflexivity

All three investigators were practicing anesthesiologists having completed training in their respective regions: CB in EU (France), RE in Canada, and RDM in the US. All had domain expertise in education, including educational fellowships and advanced degrees. All three had served on their residency program's clinical competency committees (either past or current). Two researchers were current or former residency or fellowship program directors (RE, RDM), and all actively taught anesthesiology residents at the time of data analysis.

Techniques to enhance trustworthiness

Rigor was maintained by investigator independence at each stage, coupled with demonstrating intersubjectivity through discussion. Consensus was achieved universally between researchers through these discussions, with minimal instances of disagreement. In addition, external expert reviewers were invited to critique our results prior to submission (see Acknowledgements), lending credibility to our process. Based on their feedback, minor changes and correction were performed.

## Results

Round 1: the broad view of shared competencies

Comparisons of ETR, US Milestones, and CBD EPAs competencies for anesthesiology resident training showed congruence of 93% (**Figure 1**). All CBD EPAs and US Milestones' competencies were present in the ETR. ETR competencies were represented in 98% of CBD EPAs and in 95% of US Milestones. CBD EPAs competencies were represented in 98% of US Milestones. US Milestones competencies were present in 96% of CBD EPAs. **Table 1** summarizes the main results for the matching between ETR, US Milestones, and CBD EPAs' competencies. Detailed results of the first round of comparisons of the three repositories' competencies are presented in **Appendix 1**.

*Differences between repositories*

Most of the difference between ETR, US Milestones, and CBD EPAs' competencies centered on critical emergency medicine (including pre-hospital and emergency medicine). This subject was completely absent from US Milestones (**Appendix 1**). CBD EPAs' competencies covered a similar field to the ETR for critical emergency medicine, except for "assisting in rescue work" and "declaration of death at the scene of emergency," which were present only in the ETR. Skills in ultrasound and *Perioperative patient positioning avoiding tissue damage* were common for CBD EPAs but were absent from US Milestones. (**Appendix 1**) Three competencies were common to ETR and US Milestones and absent from CBD EPAs were: (1) *Management of brain death syndrome and donor management including explanation*; (2) *Positioning of patients with specific pathological conditions*; and (3) *Responsibility to maintain personal emotional, physical, and mental health*.

Round 2: emphasis of certain competencies by ETR, Milestones, and CBD

Even if some competencies were cited in every repository, we did not determine all competencies had similar relative importance nor emphasis. **Table 2** depicts which competencies were interpreted to have an equal expression among the three repositories, and which were emphasized equally by two or mainly by only one repository. This differential emphasis was demonstrated by comparing unique competencies such as "Promoting safety and well-being of staff" (ETR, 1.6) and "Responsibility to maintain personal, emotional, physical and mental health" (Milestones, P5) with how well-being was represented in CBD, which was dispersed within Core EPA #24, TTP #2, TTP #3, and TTP #5. Based on this deeper analysis,

Venn diagrams (**Figure 2**) depict the respective emphasis from each perspective (Europe, US, and Canada). More than thirty percent of the competencies – whatever repository was taken as reference – had the same importance. ETR had only one (3%) competency that was specifically emphasized, Anaesthesia Non-Technical Skills (ANTS).[27] Both CBD EPAs and US Milestones had more unique competencies emphasized. CBD EPAs focused on specific anesthesiology situations highlighting more granular competencies (e.g., obstetric care, complex cases). Those competencies were included more generically for ETR and US Milestones, but without a high degree of detail. Professionalism and behavioral practices were emphasized by US Milestones (e.g., analysis of practice, education, communication).

## Discussion

This comparison provides a glimpse into common training goals shared among Europe, the US and Canada, using anesthesiology as the example discipline. We identified a high overlap rate of educational objectives (93%). The core competencies appear generally consistent as shown in **Table 2** (e.g., perioperative anesthetic plan, management, conduct, and monitoring; assessing, diagnosing and managing critically ill patients in acute care settings; airway management; and honesty, integrity, and ethical behavior, among others).

Differences on specific competencies emphasized are nuanced and likely have historical roots. For example, emergency medicine and prehospital medicine were initiated by anesthesiologists in some European countries, and anesthesiologists still play a large role in caring for prehospital patients despite emergency medicine internationally developing as a separate specialty. [28–30] Consideration is being given in the US for anesthesiologists to fill this gap via training in emergency medicine to care for critical patients. [31] A heavy societal focus on professionalism for US trainees likely has led to more defined behavioral guidelines regarding professional care, generating this unique emphasis in the US-based Milestones. [32] The large overlap identified in educational objectives with limited differences confirm that training in these regions appears very similar between regions and that anesthesiologists can work together, both at educational and professional levels. An important consideration for future work will be the differences in competencies required to practice in lower resourced or austere settings. The skills and knowledge required for clinicians practicing in wealthy, developed countries may not be the ones needed in poorer developing countries. Understanding these differences among residency

programs in developed nations highlighted in our study, and exploring the hypotheses stated above, should be topics for future investigation.

There are several reasons why this work has important potential. As countries strive to build better healthcare professionals through competency-based teaching and assessment, cross-cultural dialogue between international educational societies governing these competencies may enable effectively sharing best educational and clinical practices. For example, recently the Royal College of Anaesthetists in the UK adopted a curriculum update, entitled the 2021 Anaesthetics Curriculum, which included cultural values of diversity, inclusion, and respectful interactions between team members, [33] and the Milestones were updated to include assessment of point-of-care ultrasound. [34] These should serve as exemplars for future updates to all repositories in anesthesiology. If and when this expands to countries with different cultural norms or different levels of technology and resources, other adaptations may need to be made. As regions like the EU, US, and Canada revise their CBME curricula and assessment tools, reviewing other countries' successes and challenges in adopting changes will allow shared insights to be efficiently incorporated. [33] Thus, an educational global mindset may increase adaptation of new practices. In addition, best educational practices for adopting new techniques can offer faculty opportunities to refresh or gain new skills without reinventing educational approaches, saving expert time and organizational efforts.

Additionally, these administrative requirements burden program directors, providing a substantial source of their burnout. [35, 36] By focusing on similarities, the workload of national and regional competency assessment efforts could be reduced, freeing program directors and educators to mentor trainees more effectively and adapt requirements for teaching using a regional lens. Engaging in such collaboration may facilitate other large-scale partnerships, such as subspecialty educational groups, to advance the educational sciences of teaching and learning in residency.

Many countries are in the process of developing more healthcare provider training programs or improving existing ones. By highlighting overlaps in competencies between CBME residency programs around the world, an international consensus of disciplines' competencies may support creation of new training programs. Because best educational practices would be shared through international collaborations, this could facilitate training even in low-resource settings. Established training programs can also benefit from global innovations by identifying and closing their own educational gaps. Working towards a shared repository could be seen as

investing time and energy in reciprocal learning, though everyone will gain from such a repository in distinct ways.

Limitations

Our study has limitations that need highlighting. We focused on anesthesiology requirements in three wealthy, developed regions to illustrate our concept as the investigators are anesthesiologists. Generalizing to other specialties requires the existence of formally published competency repositories as a first step of many. Examining the process of creating competency repositories may serve as a preliminary step to unifying existing repositories, which could be aided by shared terminology and competency selection standards. We focused on a restricted area (EU, US, and Canada) as the investigators came from those areas (convenient sample). We would need to overcome difficulties to extend our analysis to other regions' repositories. First, not every area has an easily accessible recent English version (or other shared language version) of their competencies, introducing language translation and interpretation challenges. Second, integrating and comparing more than three competencies would have been technically arduous. Nevertheless, we offer a robust methodology in comparing CBME training applicable across disciplines in healthcare.

The qualitative characteristic of this study may have limited the objectivity of the comparisons. To reduce this, we have had extensive discussion on the analysis for each item among the three researchers and data are available for consultation (**Appendix 1**). We also had an external independent review of the results.

The US and Canada have wide national application of their competencies. In EU, despite intentions to harmonize anesthesiology training, [19] ETR adoption in its current form is less clear, [18] and active complementary national ones coexist (e.g., UK or Denmark). [37, 38] It is unclear how ETR have influenced the development of other EU national programs, as differences currently exist between length of training in EU countries, which may also lead to differential training, assessment, and regulation within the EU. [18] Gaps between these programs are not defined and only conjectural, as interpretation of competencies can vary by different program directors, specifically in EU where ETR application may differ from country to country. Furthermore, a final limitation remains that despite significant overlap in competencies, uniting accreditation practices between these three regions is likely to encounter barriers related to political and societal considerations.

Perspectives and Future Directions

We believe our work may have many potential benefits for moving towards creating educational standards, [3] sharing best clinical practices, and identifying areas for growth in all disciplines. We also think that a shared core of knowledge, skills, and attitudes, built on evidence-based practices, and delivered and assessed through best educational techniques, may have critical implications for patient safety.

With now-defined competencies of CBME anesthesiology training programs for EU, US, and Canada, we call upon educational leaders from international societies to further competency standards. Basic technical skills (e.g. epidural, central line placement) and common competencies from Table 2 "Competencies equally represented for ETR, Milestones, CBD" (e.g. regional anesthesia, airway management) should benefit from developing shared training programs which can become international standards. Future work should focus on determining the most effective teaching and assessment methodologies for achieving these competencies. While identifying the competencies for various countries has allowed refining the scope of practice for EU, US and Canada, analyzing assessment tools may help us gauge the relative importance of each competency in how countries define standards for an anesthesiologist. This will open the way to develop shared tools for competency assessment, solidifying shared requirements and standards. Future requirements' revisions should be coordinated between the regions, at least for the identified shared competencies. This could eventually facilitate implementation of new practice-based assessments for licensure and certification, enabling anesthesiologists to temporarily practice in other countries during disasters. International educational societies should strive to promote worldwide educational research efforts for sharing multiple perspectives and best practices for more effective training and safer patient care.

## Conclusions

With this qualitative comparison, we were able to made a map discerning a baseline of similar competencies between published anesthesiology residency training competencies among EU, US, and Canada. Our approach also highlighted unique regional differences which appeared to be based on importance and approach rather than on fundamental content. Together, these serve as learning opportunities to explore. With over 90% overlap, the AIC regional requirements we compared have enough in common to serve as a springboard to develop a shared core of

residency requirements in AIC. This conceptual approach is demonstrated to be feasible and may be applied to determine a baseline from which to build an international core of residency competencies required by other disciplines.

**List of abbreviations**

ACGME: Accreditation Council for Graduate Medical Education
CBD: Competence by Design
CBME: Competency-based medical education
EPA: Entrustable Professional Activity
ETR: European Training Requirement
EU: European Union
UEMS: European Union of Medical Specialists
US: United States

## Declarations

**Ethics approval and consent to participate**

Not applicable

**Consent for publication**

Not applicable

**Availability of data and materials**

All data generated or analyzed during this study are included in this published article [and its supplementary information files].

**Competing interests**

The authors declare that they have no competing interests.

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**Authors' contributions**

CB helped with study conception and design, data contribution, data analysis, data interpretation, writing, visualization, and review and editing. RE helped with data contribution, writing, and review and editing. JWR helped with writing, and review and editing. RDM helped with study design refinement, data contribution, data interpretation, writing, and review and editing. All authors read and approved the final manuscript.

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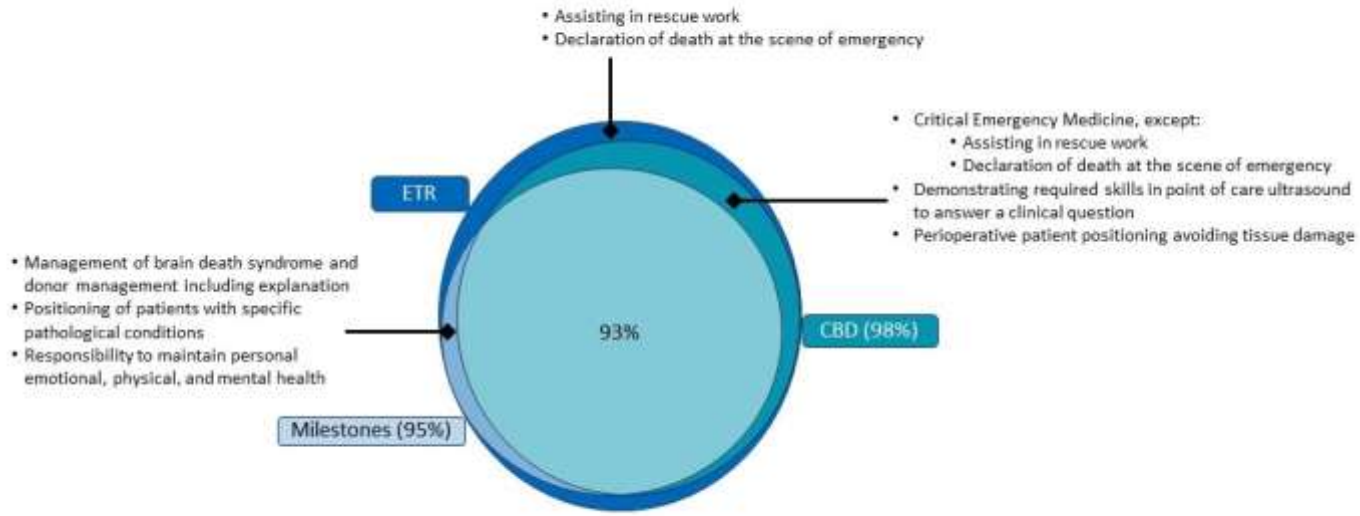



**Figure 1: Venn diagram of common competencies for anesthesiology residency training for EU, US and Canada.**

The EU's repository is the European Training Requirement (ETR), the US' repository is the ACGME Milestones (Milestones), and the Canada's repository is the Competence by Design (CBD). Incompletely matched competencies are described**.**

**Table 1: Comparison of competencies for anaesthesiology residency training for UE, US, and Canada.**

The UE's repository is the European Training Requirement (ETR), the US' repository is the ACGME Milestones (Milestones), and the Canada's repository is the Competence by Design (CBD). Incompletely matched competencies are described.

| ETR Domains' headlines (number of items) | Number of items matching (%) | | |
|---|---|---|---|
| | ETR with Milestones* | ETR with CBD* | ETR with Milestones with CBD** |
| Perioperative medicine, patient assessment and risk reduction (5) | 5 (100) | 5 (100) | 5 (100) |
| General anaesthesia and sedation (25) | 25 (100) | 24 (96) | 24 (96) |
| Airway management (4) | 4 (100) | 4 (100) | 4 (100) |
| Regional anaesthesia (8) | 8 (100) | 7 (88) | 7 (88) |
| Postoperative care and acute pain management (10) | 10 (100) | 10 (100) | 10 (100) |
| Intensive care medicine (40) | 40 (100) | 40 (100) | 40 (100) |
| Critical emergency medicine (CREM) (9) | 0 (0) | 7 (78) | 0 (0) |
| Anaesthesia Non-Technical Skills (ANTS) (5) | 5 (100) | 5 (100) | 5 (100) |
| Professionalism and ethics (8) | 8 (100) | 8 (100) | 8 (100) |
| Patient safety and health economics (4) | 4 (100) | 4 (100) | 4 (100) |
| Education, Self-directed Learning, Research (6) | 6 (100) | 6 (100) | 6 (100) |
| Obstetric anaesthesiology (12) | 12 (100) | 12 (100) | 12 (100) |
| Cardiothoracic anaesthesiology (9) | 9 (100) | 9 (100) | 9 (100) |
| Neuroanaesthesiology (6) | 6 (100) | 6 (100) | 6 (100) |
| Paediatric anaesthesiology (8) | 8 (100) | 8 (100) | 8 (100) |
| Multidisciplinary chronic pain management (6) | 6 (100) | 6 (100) | 6 (100) |
| **Total (165)** | **156 (95)** | **161 (98)** | **154 (93)** |

***Comparison of CBD and US' Milestones:**

- All but one (98%) CBD items were found in Milestones. The exception was C6: "*Demonstrating required skills in POCUS (point of care ultrasound) to answer a clinical question.*".
- All but one (96%) of Milestones items were found in CBD. The exception was P5: "*Responsibility to maintain personal emotional, physical, and mental health.*".

****Comparison of ETR, CBD and US' Milestones:** see Appendix 1

**Table 2: Common and emphasised anaesthesiology training competencies in EU, US and Canadian repositories.**

Table 2 summarizes competencies common to the three repositories (EU, US and Canada), to two repositories (EU and Canada; US and Canada; or EU and US), or rather specific to one repository (EU, US or Canada). The EU repository is the European Training Requirement (ETR), the US repository is the ACGME Milestones (Milestones), and the Canadian repository is the Competence by Design (CBD). Expressions are in percentage of their repository according to perspectives from (a) ETR, (b) Milestones, and (c) CBD.

| **Competencies equally represented for ETR, Milestones, CBD** |
|---|
| Perioperative medicine, patient assessment, management plan, preparation, and risk reduction (Can.TTD1, Can.F1, Can.C1, Can.TTP1, E.1.1, US.PC1) |
| Perioperative anesthetic plan, management, conduct, and monitoring (Can.TTD2, Can.F2, E.1.2, US.PC2) |
| Peri-procedural multimodal acute pain management, transfer of care, and postoperative orders (Can.TTD3, Can.C19, E.1.5, US.PC3, US.PC7) |
| Regional anesthesia (Can.C11, E.1.4, US.PC10) |
| Assessing, diagnosing and managing critically ill patients in acute care settings (Can.F9, Can.F10, Can.C21, E.1.6, US.PC6) |
| Airway management (Can.F4, Can.C4, E.1.3, US.PC8) – ***absence of extubation in US*** |
| Assessing, diagnosing and managing chronic pain (Can.C20, E.2.5, US.PC7) |
| Education, Self-directed Learning, Research (Can.TTP5, E.1.11, US.PBLI3) |
| Honesty, integrity, and ethical behavior (Can.C25, E.1.9, US.P2) |

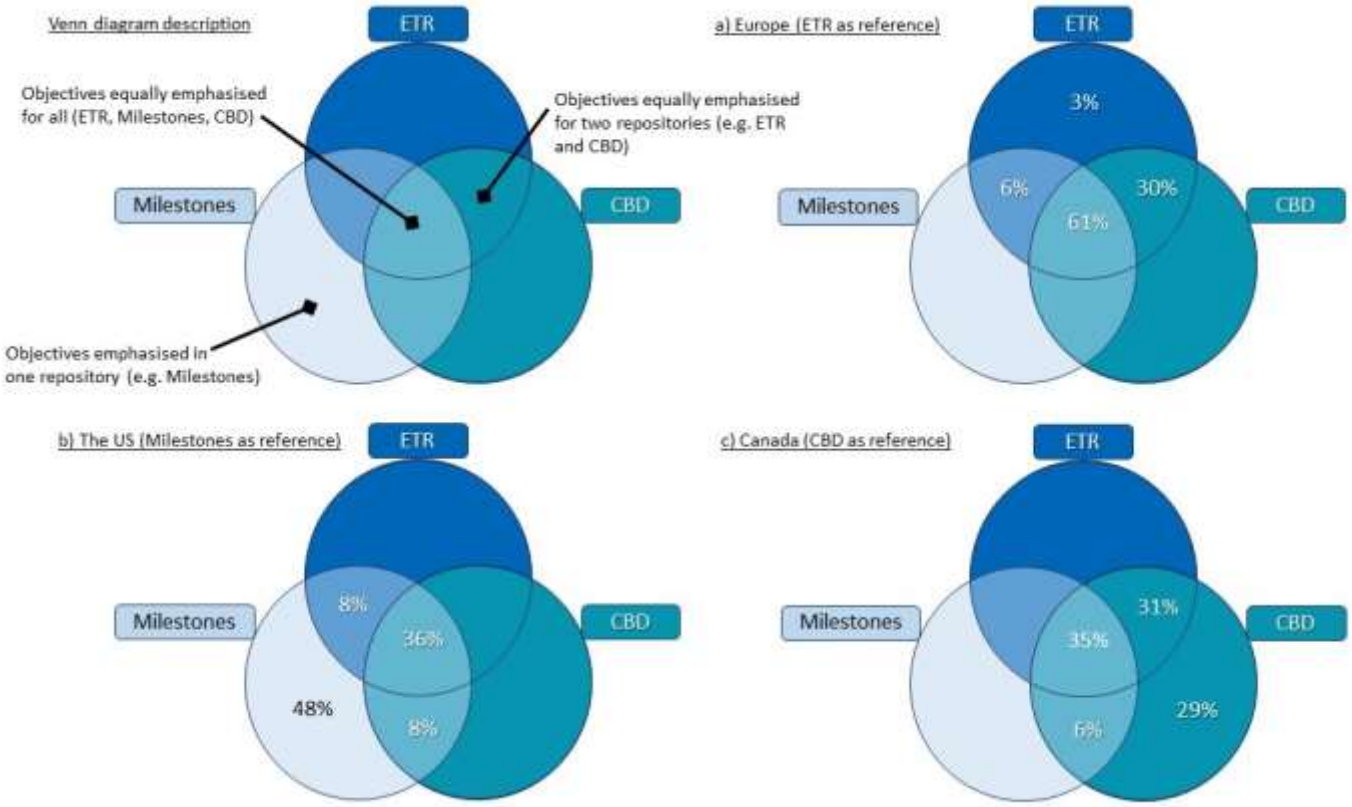
| **Competencies equally represented for CBD and ETR** | **Competencies equally represented for CBD and Milestones** | **Competencies equally represented for ETR and Milestones** |
|---|---|---|
| Obstetric anesthesia and care; including providing labor analgesia, anesthesia for caesarean, management of complications, management of high-risk parturient, and resuscitation of unstable parturient (Can.F12, Can.F13, Can.C7, Can.C8, Can.TTP4, E.2.1) | Anticipating, preventing, diagnosing and managing common or expected peri-anesthetic complications (Can.F6, Can.F8, US.PC4) | Responsibility to patients, families, and society (E.1.9, US.P1) |
| Pediatric anesthesia; including providing perioperative anesthetic management, management of common complications (Can.F14, Can.F15, Can.F16, Can.C10, E.2.4) | Communication with patients and families (Can.C23, US.ICS1) | Patient Safety and Quality Improvement (E.1.10, US.SBP2) |
| Providing anesthetic management for patients undergoing procedures outside the usual environment of the operating room (Can.C13, E.1.2) | | |
| Providing perioperative management for patients requiring shared airway procedures (Can.C14, E.1.2) | | |
| Providing perioperative anesthetic management for patients undergoing intracranial procedures (Can.C17, E.2.3) | | |
| Providing perioperative anesthetic management for patients undergoing thoracic surgery (CanC.18, E.2.2) | | |
| Resuscitation for unstable patients, outside of the operating room or PACU (Can.C22, E.1.7) | | |

| | | |
|---|---|---|
| Initiating and leading resuscitation for unstable patients in the perioperative period (Can.C5, E.1.6) | | |
| **Competencies emphasized in CBD** | **Competencies emphasized in ETR** | **Competencies emphasized in Milestones** |
| Managing and coordinating patient positioning during anesthesia care and preventing and recognizing related complications (Can.F5)<br>Assessing the indications for transfusion of blood products and managing side effects and complications (Can.F7)<br>Providing anesthetic management for patients with defined critical illness (Can.C3)<br>Assessing, investigating, optimizing and formulating anesthetic plans for more complex pediatric cases (Can.C9)<br>Diagnosing and providing management for patients with complications of regional anesthesia (Can.C12)<br>Providing care for patients who have experienced a patient safety incident (Can.C24)<br>Performing the non-airway basic procedures of anesthesiology (Can.F3)<br>Assessing pregnant patients and providing routine obstetric care or initial medical management for acute medical, surgical or obstetric conditions (Can.F11)<br>Providing anesthetic management for patients with defined critical illness (Can.C2)<br>Demonstrating required skills in POCUS (point of care ultrasound) to answer a clinical question. (Can.C6)<br>Providing perioperative management for patients requiring airway diagnostic and therapeutic procedures (Can.C15)<br>Providing perioperative anesthetic management for patients undergoing spinal procedures (Can.C16)<br>Managing all aspects of anesthesia care for a scheduled day list (Can.TTP2)<br>Providing anesthesia services for an on-call period (Can.TTP3) | Anaesthesia Non-Technical Skills (E.1.8) | Crisis management (US.PC5)<br>Technical skills: Use and Interpretation of Monitoring and Equipment (US.PC9)<br>Knowledge of biomedical, clinical, epidemiological, and social-behavioral sciences as outlined in the American Board of Anesthesiology Content Outline (US.MK1)<br>Coordination of patient care within the health care system (US.SBP1)<br>Team and leadership skills (US.ICS3)<br>Incorporation of quality improvement and patient safety initiatives into personal practice (US.PBLI1)<br>Analysis of practice to identify areas in need of improvement (US.PBLI2)<br>Education of patient, families, students, residents, and other health professionals (US.PBLI4)<br>Commitment to institution, department, and colleagues (US.P3)<br>Receiving and giving feedback (US.P4)<br>Responsibility to maintain personal emotional, physical, and mental health (US.P5)<br>Communication with other professionals (US.ICS2) |

*Can = Canada; EPA = Entrustable Professional Activity, TTD = Transition to Discipline EPA; F = Foundation EPA; C = Core EPA; TTP = Transition to Practice EPA*
*E = Europe*
*US = United-States; PC = Patient Care; MK = Medical Knowledge; SBP = Systems-based Practice; PBLI = Practiced-based Learning and Improvement; P = Professionalism; ICS = Interpersonal and Communications Skills*

**Figure 2: Venn diagrams of the competencies for anesthesiology residency training according to their relative emphasis in repositories for EU, US and Canada.**

The EU's repository is the European Training Requirement (ETR), the US' repository is the ACGME Milestones (Milestones), and the Canada's repository is the Competence by Design (CBD). Expressions are in percentage of their repository according to perspectives from (a) ETR, (b) Milestones, and (c) CBD.



**Appendix 1:** Detailed matching of competencies for anesthesiology residency training in EU [European Training Requirement (ETR)], US [ACGME Milestones (Milestones)], and Canada [Competence by Design (CBD)] using the descriptive items from the European Training Requirement as reference (16 headlines). Items for CBD are presented as Entrustable Professional Activities (EPA) distributed in four categories: Transition To Discipline (TTD) EPA, Foundation (F) EPA, Core (C) EPA, and Transition To practice (TTP) EPA. Items for Milestones are presented in six categories: Patient Care (PC), Medical Knowledge (MK), System-Based Practice (SBP), Practice-Based Learning and Improvement (PBLI), Professionalism (P), and Interpersonal and Communications Skills (ICS). Light grey color is used when the items are common to the three repositories. Medium grey color is used when the items are common to two of the repositories. Dark grey is used when the item is only in one repository. NA stands for Not Applicable when the item is not included in a repository.

| | ETR | Milestones | CBD |
|---|---|---|---|
| 1.1 Perioperative medicine, patient assessment and risk reduction | | | |
| Patient assessment based on history and physical examination, use of appropriate examinations and laboratory tests in patients of all age groups with and without reduced functional cardiorespiratory capacity undergoing major and minor surgical routine and emergency interventions | 1.1 | PC1, PC8 | TTD1, F1, F2, C1, C15, TTP1, TTP2, TTP3 |
| Evaluation of the scores, including risks and ASA physical status | 1.1 | PC1, PC8 | TTD1, F1, F2, C1, C15, TTP1, TTP2, TTP3 |
| Evaluation of the airway | 1.1 | PC1, PC8 | TTD1, F1, F2, F4, C1, C15, TTP1, TTP2, TTP3 |
| Interpretation, considering the value and limitation of preoperative tests and monitoring | 1.1 | PC1, PC9, PC10 | TTD1, F2, F7, C1, C6, C15, TTP1, TTP2, TTP3 |
| Interdisciplinary patient optimization and risk reduction, including preoperative anaemia correction, cardiopulmonary treatment | 1.1 | PC1, ICS2, ICS3 | F2, C1, C15, TTP1, TTP2, TTP3 |
| 1.2 General anaesthesia and sedation | | | |
| Providing safe inhalation and intravenous induction, maintenance of, and emergence from general anaesthesia, including the choice of drugs, airway management, ventilation technique and intraoperative adverse event management | 1.2 | PC2 | F2, C2, C15, TTP2, TTP3 |
| Defibrillation, cardioversion | 1.2 | PC4, PC5 | C5, C15 |
| Aseptic techniques for invasive procedures including peripheral and central (ultrasound guided) venous access, intraosseous access, arterial catheterization, arterial blood gas collection, urinary catheterization, chest drain insertion | 1.2 | PC9 | F3, C2, C5, C15, TTP2, TTP3 |
| Gastrointestinal tube insertion | 1.2 | PC2 | C2 |
| Blood salvage (US: perform independently vs administer product processed by licensed individual) | 1.2 | PC2 | F7, C2, C5, C15, TTP2, TTP3 |
| Blood transfusion | 1.2 | PC2 | F7, C2, C5, C15, TTP2, TTP3 |
| Preparation of the workplace according relevant checklists and environmental safety measures | 1.2 | PC2 | TTD2, F2, C2, C15, TTP2, TTP3 |
| Use of medical and technical equipment appropriately, including neuromuscular blockade monitoring, volume monitoring, echocardiography | 1.2 | PC2, PC9 | F2, C2, C5, TTP2, TTP3 |

| | | | |
|---|---|---|---|
| Trouble-shooting basic technical malfunctions of monitors and machines | 1.2 | PC2, PC9 | F2, F6, C2, TTP2, TTP3 |
| Use of relevant checklists and guidelines | 1.2 | PC2 | TTD2, F2, C2, C15, TTP2, TTP3 |
| Monitoring nerve function during brain and spine surgery | 1.2 | PC2, PC9 | C16, TTP2, TTP3 |
| Perioperative patient positioning avoiding tissue damage | 1.2 | NA | F5, C2, C16, TTP2, TTP3 |
| Maintenance of homeostasis of organ systems throughout different surgical procedures in patients with and without pre-existing diseases | 1.2 | PC2 | F2, C2, C5, C15, TTP2, TTP3 |
| Diagnosis and management of intraoperative critical incidents | 1.2 | PC2, PC4, PC5, PC8 | F6, F7, C2, C5, C15, TTP2, TTP3 |
| Performing anaesthesia for laser airway surgery and interventions with a shared airway | 1.2 | PC2, PC8 | C4, C14, TTP2, TTP3 |
| Performing anaesthesia for fast track surgery and enhanced recovery after surgery | 1.2 | PC2 | F2, C2, TTP2, TTP3 |
| Performing anaesthesia in ICU patients | 1.2 | PC2, PC6 | C2, C5, TTP2, TTP3 |
| Performing sedation for invasive procedures | 1.2 | PC2 | C13, C14, TTP2, TTP3 |
| Performing anaesthesia and sedation outside the OR, taking into account organization of the site, type of procedures and patients | 1.2 | PC2 | C13, TTP2, TTP3 |
| Management of patient transport to and from remote locations | 1.2 | PC6 | C13, TTP2, TTP3 |
| Application of principles of safety during X-ray, MRI | 1.2 | SBP2 | C2, C13, TTP2, TTP3 |
| Application of discharge criteria for ambulatory anaesthesia | 1.2 | PC3 | TTP2, TTP3 |
| Consideration of ethical and medico-legal aspects | 1.2 | P2, ICS1 | TTD1, F1, F2, F6, C2, C5, TTP2, TTP3 |
| Initial surgical intervention in burn trauma and traumatic injury of the upper airway | 1.2 | PC2, PC6, PC9 | C2, C5, TTP2, TTP3 |
| Management of brain death syndrome and donor management including explanation | 1.2 | PC2, PC6 | NA |
| **1.3 Airway management** | | | |
| Rapid sequence induction | 1.3 | PC2, PC8 | C2, C4, TTP2, TTP3 |
| Establishment and maintenance of an adequate airway in patients with anticipated and unanticipated difficult airway including patients with airway trauma and including the use of different devices and techniques according to existing algorithms | 1.3 | PC4, PC5, PC8 | C2, C4, C5, TTP2, TTP3 |
| Cricothyroidectomy (e.g. in medical simulation training) | 1.3 | PC4, PC5, PC8 | C4, C5 |
| Management of difficult and delayed extubation after airway interventions | 1.3 | PC4, PC8 | C2, C4, C5, TTP2, TTP3 |
| **1.4 Regional anaesthesia** | | | |
| Performing neuraxial blocks such as spinal (single shot), thoracic epidural and lumbar epidural (single shot and catheter technique) combined spinal-epidural, caudal block | 1.4 | PC10 | F3, C2, C11 |
| Performing peripheral nerve blocks of the upper extremity (single shot and catheter technique) such as interscalene, axillary blocks | 1.4 | PC10 | C11 |
| Performing peripheral nerve blocks of the lower extremity (single shot and catheter technique) such as femoral, obturator, sciatic blocks | 1.4 | PC10 | C11 |
| Performing nerve blocks of the torso such as paravertebral, intercostal blocks | 1.4 | PC10 | C11 |
| Providing safe regional anaesthesia, including choice of drugs, techniques, and monitoring | 1.4 | PC10 | C11 |
| Positioning of patients with specific pathological conditions | 1.4 | PC10 | NA |
| Management of nerve blocks in pain therapy | 1.4 | PC7, PC10 | C19 |
| Diagnosis and management of intraoperative critical incidents | 1.4 | PC4, PC5, PC10 | reC11, C12 |
| **1.5 Postoperative care and acute pain management** | | | |
| Providing handover of a patient in PACU (appropriate summary of relevant clinical features of the patient's care) | 1.5 | PC4 | TTD3, C2, TTP2, TTP3 |
| Providing postoperative standard monitoring, indicating and interpreting individualized testing (e.g. ischemia monitoring, X-ray) | 1.5 | PC4, PC9 | F8, C2, TTP2, TTP3 |

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| Pain assessment in all patient groups | 1.5 | PC3, PC7 | F8, C2, C19, TTP2, TTP3 |
| Use of relevant checklists and guidelines | 1.5 | PC2, PC3, PC4, PBLI2 | TTD3, F9, C2, TTP2, TTP3 |
| Maintenance of homeostasis of organ systems after the impact of different surgical procedures and anaesthesia in patients with and without pre-existing diseases | 1.5 | PC4, PC9 | F8, F9, C2, TTP2, TTP3 |
| Diagnosis and management of postoperative critical incidents (beyond those listed in domain 1.1) and postoperative adverse events | 1.5 | PC3, PC4, PC5, PC8, PC10 | F5, F8, F9, C2, C5, C19, TTP2, TTP3 |
| Detection of, indication for, and interprofessional organization of re-operation | 1.5 | PC7 | F9, C2, C5, TTP2, TTP3 |
| Performing weaning from supportive therapy of vital functions | 1.5 | PC7 | F9, C2, TTP2, TTP3 |
| Application of discharge criteria and transfer criteria to ICU | 1.5 | PC7 | F9, C2, C5, TTP2, TTP3 |
| Application of multimodal and pre-emptive analgesia concepts | 1.5 | PC4, PC7 | F8, C2, TTP2, TTP3 |
| **1.6 Intensive care medicine** | | | |
| Performing patient assessment and physical examination including repetitive testing e.g. of peristaltic sounds, respiratory sounds, capillary refill, temperature gradient) | 1.6 | PC1, PC6 | F9, F10, C21, TTP3 |
| Identification of signs of instability of the cervical spine | 1.6 | PC1, PC5, PC6 | F9, C5, C21, TTP3 |
| Performing sedation, general anaesthesia, multimodal analgesia | 1.6 | PC2, PC6 | TTP3 |
| Performing neuraxial and peripheral nerve blocks for analgesia | 1.6 | PC3, PC6, PC10 | C19, TTP3, |
| Performing airway management including intubation under emergency situations | 1.6 | PC5, PC6, PC8 | C21, TTP3 |
| Performing aseptic insertion of venous, central venous, arterial, intra-osseus cannulation, pleural drainage | 1.6 | PC6 | F3, C21, TTP3 |
| Gastrointestinal tube insertion, urinary catheterization | 1.6 | PC6 | C21, TTP3 |
| Disease assessment and disease management | 1.6 | PC6, PC8, PC9 | F10, C5, C21 |
| Applying EBM-based therapeutic interventions, care bundles, guidelines protocols, and organ support in single or multiple organ failure (MODS) | 1.6 | PC6, PBLI3 | F10, C21, TTP3 |
| Patient transportation inter- and intra-hospital | 1.6 | PC6 | C21, TTP3 |
| Applying damage control and systematic priority-based approach in severe trauma patients | 1.6 | PC6 | C5, C21, TTP3 |
| Applying transfer criteria to specialized centres e.g. the critically ill child | 1.6 | PC6 | C21, TTP3 |
| Applying neuroprotection in head trauma and spinal cord trauma patients | 1.6 | PC6 | C5, C21, TTP3 |
| Performing general anaesthesia for repeated surgical interventions in burn trauma patients | 1.6 | PC2 | C2, TTP3 |
| Applying triage and prioritization of patients | 1.6 | PC6 | C5, TTP3 |
| Applying scoring systems (e.g. sedation depth, pain severity, APACHE, SAPS, TISS) | 1.6 | PC6 | C21, TTP3 |
| Performing basic ultrasound techniques for ultrasound-guided central venous line placement; recognition of severely abnormal ventricular function; measurement of inferior vena cava diameter; recognition of large pericardial, pleural, or abdominal effusion; recognition of urinary retention | 1.6 | PC6, PC9 | C5, C6, C21, TTP3 |
| Indicating, interpretation, considering the value and limitation of tests and monitoring | 1.6 | PC1, PC6, PC9, PC10 | F10, C5, C6, C21, TTP3 |
| Differential diagnosis, liaising with interdisciplinary specialists to interpret complex data | 1.6 | PC6, ICS2, ICS3 | F10, C5, C21 |
| Indicating physio- and ergotherapy | 1.6 | PC6, SBP1 | C21 |
| Consideration of ethical and medico-legal aspects | 1.6 | PC6 | F10, C21 |
| Performing regular visit rounds, ensuring continuity of care | 1.6 | PC6 | F10, C21 |
| Applying discharge criteria | 1.6 | PC6 | F10, C21 |
| Applying criteria for management change from curative to palliative care | 1.6 | PC6 | C21 |
| Providing handover of a patient to the ward (appropriate summary of relevant clinical features of the patient's care) | 1.6 | PC6 | F10, C21 |
| Accurate record keeping | 1.6 | PC6, P1 | F10, C21 |
| Performing brain stem testing | 1.6 | PC6, PC9 | C21 |
| Management of organ donors in Intensive care and during organ retrieval | 1.6 | PC6 | C21 |

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| Performing anaesthesia for kidney transplantation | 1.6 | PC2 | C2 |
| Performing immediate postoperative care of a kidney transplant patient | 1.6 | PC4, PC6 | C21 |
| has been exposed to the skills required to discuss with relatives about end of life issues, brain death and organ donation | 1.6 | PC6 | C21, C23 |
| *Effectively communicate with patients, treat patients with respect of basic ethical principles such as autonomy, privacy, dignity, confidentiality, including discussing end of life decisions* | 1.6 | PC1, PC6, SBP1, PBLI4, P1, P2, ICS1 | F10, C21, C23 |
| *Establishing effective interaction with patients, including patients with impaired capacity of discernment and consent and their relatives* | 1.6 | PC1, PC6, SBP1, PBLI4, P1, P2, ICS1 | F10, C21, C23 |
| *Effectively communicate with patients with language barriers* | 1.6 | PC1, PC6, SBP1, PBLI4, P1, P2, ICS1 | F10, C21, C23 |
| *Effectively communicate with other health care providers* | 1.6 | PC1, PC5, PC6, SBP1, PBLI1, PBLI4, P1, P2, P3, P4, ICS1, ICS2, ICS3 | F10, C21, C23 |
| *Team work together with other health care professionals to ensure smooth patient care and safety* | 1.6 | PC1, PC5, PC6, SBP1, PBLI1, PBLI4, P1, P2, P3, P4, ICS1, ICS2, ICS3 | F10, C5, C21 |
| *Vigilance and situational awareness* | 1.6 | PC5, PC6, SBP1, SBP2, PBLI1, P1, ICS2 | F10, C5, C21 |
| *Respecting legal constraints* | 1.6 | PC6, SBP1, P1, P2, ICS1 | F10, C21 |
| *Promoting safety and well-being of staff* | 1.6 | PC6, SBP1, SBP2, PBLI1, P1, P3, P5 | C21 |
| *Promoting infection control measures* | 1.6 | PC6, SBP2, PBLI1 | C21 |
| **1.7 Critical emergency medicine (CREM)** | | | |
| Applying skills from domains 1.1 to 1.5 in pre-hospital critical emergency scenarios | 1.7 | NA | F9, C22, TTP3 |
| Management of life-threatening medical and surgical emergency conditions | 1.7 | NA | F9, C5, C21, C22, TTP3 |
| Applying resuscitation algorithms and trauma guidelines | 1.7 | NA | F9, C5, C21, C22, TTP3 |
| Assisting in rescue work | 1.7 | NA | NA |
| Performing emergency medicine in the interdisciplinary team of an emergency room | 1.7 | NA | C5, C21, C22, TTP3 |
| Performing intra-hospital resuscitation in the interdisciplinary cardiac arrest team | 1.7 | NA | C5, C21, C22, TTP3 |
| Performing echocardiography for fast differential diagnosis (FAST approach) | 1.7 | NA | F9, C5, C6, C21, C22, TTP3 |
| Supporting the complex organization of health care in cases of mass accidents and disasters | 1.7 | NA | TTP3 |
| Declaration of death at the scene of emergency | 1.7 | NA | NA |
| **1.8 Anaesthesia Non-Technical Skills (ANTS)** | | | |
| Task management | 1.8 | PC1, PC5, PC6, SBP1, SBP2, PBLI1, P1, P3, ICS2 | F6, C2, C5, TTP1, TTP2, TTP3 |

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| Team working | 1.8 | PC5, PC6, SBP1, SBP2, PBLI1, PBLI4, P1, P3, ICS2, ICS3 | C2, C5, TTP1, TTP2, TTP3 |
| Situation Awareness | 1.8 | PC5, PC6, SBP1, SBP2, PBLI1, P1, P3, ICS2 | F6, C2, C5, TTP1, TTP3 |
| Decision making | 1.8 | PC5, PC6, SBP1, SBP2, PBLI1, PBLI4, P1, P3, ICS2 | C2, C5, TTP1, TTP2, TTP3 |
| Leadership | 1.8 | PC5, PC6, SBP1, SBP2, PBLI1, P1, P3, ICS2, ICS3 | C2, C5, TTP1, TTP2, TTP3 |
| **1.9 Professionalism and ethics** | | | |
| Applying principles of medical ethics to problem solving | 1.9 | PC1, PC2, PC6, SBP1, P1, P2, P3, ICS1 | C2, C5, C23, C25, TTP2, TTP3 |
| Attaining attributes in the 4 roles of a specialist in anaesthesiology: medical expert, leader; scholar; professional | 1.9 | PC5, PC6, SBP1, PBLI4, P1, P2, P3, ICS2, ICS3 | F11, C2, C5, TTP2, TTP3 |
| Applying the principles of evidence-based medicine to clinical practice | 1.9 | PC6, MK1, PBLI3 | C2, C5, TTP2, TTP3 |
| Use of information technology in order to optimize clinical care, conducting literature searches | 1.9 | PC6, MK1, PBLI3 | TTP2, TTP3 |
| Basic appraising journal articles including the interpretation of study design, statistics, results, and conclusions | 1.9 | PC6, MK1, PBLI3 | TTP2, TTP3 |
| Awareness and management according to medico-legal obligations related to medical practice | 1.9 | PC1, PC2, PC4, PC6, P1, P2 | C24, TTP2, TTP3 |
| Commitment to the main ethical principles and professional values, such as altruism, fidelity, social justice, honour, integrity, and accountability | 1.9 | PC1, PC2, PC6, SBP1, PBLI1, P1, P2, P3, ICS1, ICS2, ICS3 | F11, C5, C24, C25, TTP2, TTP3 |
| Commitment to the rights of patients to autonomy, confidentiality, informed consent, comprehension of the risks of medical techniques (patient-centeredness) irrespectively of race, culture, gender, sexual orientation, and socio-economic status | 1.9 | PC1, PC2, PC6, SBP1, P1, P2, P3, ICS1, ICS2 | F11, C5, C24, TTP2, TTP3 |
| **1.10 Patient safety and health economics** | | | |
| Application of standards of quality of care and patient safety in daily practice including anaesthesia in remote locations | 1.10 | PC2, SBP2, PBLI1, PBLI2, ICS1 | F6, C2, C5, TTP2, TTP3 |
| Use of checklists and guidelines | 1.10 | PC2, PC5, SBP2, PBLI1, ICS1 | C2, C5, TTP2, TTP3 |
| Providing data for both local and national data systems | 1.10 | SBP2 | C2, C5, TTP2, TTP3 |
| Considering cost-effectiveness | 1.10 | SBP2, P1 | C2, TTP2, TTP3 |
| **1.11 Education, Self-directed Learning, Research** | | | |

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| Conducting and appraising literature searches | 1.11 | MK1, PBLI3 | TTP5 |
| Appraising journal articles including the application of statistics | 1.11 | MK1, PBLI3 | TTP5 |
| *Applying the principles of evidence-based medicine to clinical practice (identic to 1.9)* | 1.11 | MK1, PBLI3 | C2, TTP2, TTP3, TTP5 |
| Carrying out oral presentations and professional communication | 1.11 | SBP2, PBLI4, ICS2, ISC3 | TTP5 |
| Presenting quality assurance exercises or projects | 1.11 | SBP2, PBLI1, PBLI2, ICS1 | F6, TTP5 |
| Developing facilitation skills, such as tutoring in small-group learning and conducting small group meetings | 1.11 | SBP2, ICS1, ICS2, ICS3 | TTP2, TTP3, TTP5 |
| **2.1 Obstetric anaesthesiology** | | | |
| Applying skills from domains 1.1 to 1.4 in parturients including | 2.1 | PC1, PC2, PC4, PC5, PC8 | F11, F13, C7, TTP4 |
| Positioning of parturients | 2.1 | PC2 | C7, TTP4 |
| Performing anaesthesia for delivery | 2.1 | PC2 | F12, C7, TTP4 |
| Performing spinal anaesthesia (single shot), combined spinal-epidural anaesthesia and lumbar epidural anaesthesia (single shot and catheter technique) for caesarean section | 2.1 | PC10 | F13, C7, TTP4 |
| Management of pain in pregnancy and labour | 2.1 | PC3 | F12, C7, TTP4 |
| Performing lumbar epidural catheter placement for labour analgesia | 2.1 | PC10 | F12, C7, TTP4 |
| Management of severe peri-partum haemorrhage | 2.1 | PC5 | C7, C8, TTP4 |
| Initial management of high-risk parturients and application of transfer criteria to higher level hospitals | 2.1 | PC5 | C7, TTP4 |
| Performing anaesthesia in pregnant and breastfeeding women | 2.1 | PC2 | C2, TTP4 |
| Performing anaesthesia and analgesia in assisted reproductive technologies and intrauterine surgery | 2.1 | PC2 | C7 |
| Applying skills from domains 1.7 to 1.9 in parturients | 2.1 | PC1, PC2, PC6 | F10, C8, TTP4 |
| Basic and advanced life support, including resuscitation of the newborn (+ Accurate record keeping) | 2.1 | PC5, P1 | F10, F12, F13, C8, TTP4 |
| **2.2 Cardiothoracic anaesthesiology** | | | |
| Specific respiratory evaluation with regards to planned surgery (assessment of operability) | 2.2 | PC1, PC8 | C18 |
| Performance of lung separation techniques (double lumen intubation, fiberoptic control and tube positioning) | 2.2 | PC2, PC8 | C18 |
| Patient positioning, particularly in the lateral decubitus position | 2.2 | PC2 | C18 |
| Using chest tube drainage systems and suction | 2.2 | PC2 | C18 |
| Basic skills in the management of anaesthesia and perioperative care for cardiac operations performed on-pump and off-pump | 2.2 | PC2 | C3 |
| Use of advanced haemodynamic monitoring | 2.2 | PC2, PC9 | C3, C6, C15 |
| Use of TEE for evaluation of size and function of left and right ventricle, all valves (stenosis, insufficiency, severity), diagnosis of pericardial fluid or tamponade, dilation or dissection of the aorta | 2.2 | PC9 | C3, C6, C15 |
| **2.3 Neuroanaesthesiology** | | | |
| Specific evaluation with regards to planned surgery (assessment of operability) | 2.3 | PC1 | C17 |
| Patient positioning, particularly in the sitting position | 2.3 | PC2 | C17 |
| Management of specific complications including air embolism, intracranial hypertension | 2.3 | PC2, PC4, PC5 | C17 |
| Basic skills in the management of anaesthesia and perioperative care for intracranial operations, including induced hypotension, induced hypothermia | 2.3 | PC2 | C17 |
| Apply principles of neuroprotection | 2.3 | PC2, PC6 | C17 |
| Use and interpretation of advanced neuromonitoring (e.g. evoked potentials, cerebral oxygenation, blood flow, metabolism) | 2.3 | PC2, PC9 | C17 |
| **2.4 Paediatric anaesthesiology** | | | |
| Applying skills from domains 1.1 to 1.4 in paediatric patients > 1 year of age | 2.4 | PC1, PC2 | F14, F16, C9 |

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| Performing vascular access in young children < 1 year | 2.4 | PC2 | F14, C10 |
| Performing airway management in young children < 1 year | 2.4 | PC8 | C10 |
| Performing general anaesthesia in young children < 1 year | 2.4 | PC2 | C10 |
| Performing peripheral and neuraxial regional blocks including caudal anaesthesia in young children < 1 year | 2.4 | PC10 | C10 |
| Performing postoperative care, pain management, general intensive care in young children < 1 year | 2.4 | PC3, PC4 | F15, C10 |
| Performing cardiorespiratory resuscitation in children and neonates | 2.4 | PC5 | C10 |
| Recognizing patients that should be transferred to a higher competence facility and safely transfer them | 2.4 | PC4, PC6 | C10 |

2.5 Multidisciplinary chronic pain management

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| Evaluation of patients with chronic pain: history, physical examination and requesting and interpretation of additional tests considering the bio-psycho-social model | 2.5 | PC1, PC3, PC7 | C20 |
| Applying pain scales and validated questionnaires | 2.5 | PC3, PC7 | C20 |
| Explaining treatment options and clinical goals | 2.5 | PC1, PC3, PC7 | C20 |
| Initial multimodal treatment of patients with chronic cancer and non-cancer pain | 2.5 | PC3, PC7 | C20 |
| Diagnosis and management of adverse effects of pain therapy | 2.5 | PC3, PC7 | C20 |
| Accurate record keeping (logbook), including treatments and procedures. Documentation of pain evolution | 2.5 | PC7, P1 | C20 |

# Discussion on Article 3

This article comparing the competency repositories for AIC residency between the EU, US and Canada has highlighted in detail the similarities and differences between these repositories. This had not been described before. These results are interesting because they open up promising perspectives, both for the similarities and differences and also for the feasibility of the method used.

First, the very high similarity rate of 93% confirms a high degree of overlap in the expected competencies of AIC residents. This reinforces the hypothesis - which remains to be confirmed - that within these regions the ACI profession is practiced in a similar manner. This high rate of similarity prefigures the feasibility of interactions around the hard core of identified shared competencies. These interactions can be of three types: construction of a common repository of competencies; cross-inspiration between repositories to improve the repositories and fill in any gaps identified; and collaboration in the development of new competencies based on the existing. It is reasonable to expect to use this shared competency repository in "rich" countries, but its practical application in developing countries is more uncertain and may need to be adapted. This adaptation could be the subject of future international collaborative work.

Second, the differences identified are limited and of two types. The first type is that of differences in the themes addressed, which are present in one or more reference systems and absent in another. There are very few of these, as the very high rate of similarity shows. These differences may be explained by the history of regional development of the specialty (e.g. emergency medicine in EU, organ donor management) and would deserve to be explored in more detail specifically. The second type of difference is the relative importance given to competencies in the different repositories. Competencies are present in all three repositories studied, but they are more developed in some than in others. We can interpret this as a more pronounced interest in these competencies in this repository and its region. Thus - without prejudging a lack of interest in the other repositories for the subject - the ETR is the one which insists most specifically on non-technical skills (ANTS).[69] Non-technical skills are also present in the US and Canadian repositories but in a more diffuse way in other items. Since the ANTS were developed by a Scottish team, this may explain the emphasis placed on them in the ETR. Similarly, the US Milestones places particular emphasis on the relational and behavioral dimensions - again, these elements are present in the other repositories but the place given to

them is less marked. We assume that there is a strong cultural component to the positioning of these items. For Canada, specific competencies of AIC subspecialties (e.g. gynecology-obstetrics, pediatrics, neurosurgery) are detailed. We interpret this as a logical continuation of the development of the CBME approach for which Canada was a forerunner and remains a driving force for innovation.[17] Finally, these (two types of) differences make it possible to identify potential gaps in competencies in the repositories and thus offer the opportunity to fill them. This can be done through the interactions described above: by inspiration or collaboration.

Third, the feasibility of the method employed is of interest beyond AIC. In addition to replicating this work in AIC by integrating more widely other repositories from other regions to broaden the scope of the expected benefits collaboration; we can consider applying this approach to other disciplines. Many healthcare disciplines have similar criteria to the IAC: existence of competency repositories in English, international meeting and publications that contribute to the cross-dissemination of knowledge and practices, regular and significant evolution of knowledge to be integrated into the competency repositories, etc. To simplify this strategy of globalizing competency repositories around a shared core of competencies, it would be necessary to establish a checklist of feasibility conditions. This represents a path with a high potential of benefits for a large public.

With this article, we have demonstrated that there is a shared core of competencies in AIC between the EU, the US and Canada. This is in line with the focus of this thesis to broaden the base of countries and programs that could be involved in a unified AIC simulation training and assessment program.

# Discussion

With the goal of building a unified, national simulation-based training and assessment strategy in AIC, we have collected data through the three studies that make up this thesis. These data allow us to better understand and appreciate how to develop a unified simulation training and summative assessment program for AIC, as well as the feasibility of this strategy. We will discuss the main results, their implications, their contribution to the field of health education, along with limitations and perspectives.

## Main results

The first study highlighted the feasibility of a unified simulation program in AIC at a national level (France). The ubiquitous use of simulation, the high homogeneity of the modalities used (**Article #1** **Figure 5**) as well as the themes taught (**Article 1** **Table 4**) are concrete elements identified that will serve as a basis for a unified simulation program in AIC in France. Based on this inventory, it is now possible to set precise objectives and to determine the best way to reach them. We believe that building a unified program from the existing one reinforces the chance of adoption, since this program will come from users' practice. The mapping done is therefore an asset for successful future implementation, in addition to the expressed desire for a unified program and the expressed willingness to be involved in its creation (**Article 1** **Table 2**). It is also important to highlight the large number of centers for which participation in simulation is mandatory (97%) and is part of validating their curriculum (48%), as well as the discrete - but already existing - use of simulation in summative assessment (16%). (**Article 1,** **Figure 3** **and 5**) These data underscore the community's readiness to move towards the widespread use of summative assessment with simulation.

The second study allowed us to establish an initial orientation map on summative assessment with simulation healthcare. We were able to identify seven key themes that address many issues related to the design, preparation and implementation of a summative assessment approach with simulation. Of these themes, one is well documented in the literature ("What can be assessed in simulation?") and three are described and partially evaluated, but require further study to

deepen our understanding ("Assessment tools for summative assessment", "Scenarios for summative assessment", and "Implementation of summative assessment in simulation in healthcare"). For the other three themes ("Consequences of summative assessment", "Debriefing for summative assessment", and "Trainers for summative assessment) the data currently available in the literature are far more limited. For these themes, studies need to be conducted to gather concrete and accurate data. However, based on what is known about training and formative assessment with simulation, and what is known about summative assessment in general, some initial experts' opinions can likely direct us while evidence is gathered to establish consistent guidelines. Working to fill the knowledge gaps identified within the themes described is an important research area for the future. In this sense, we have proposed leads in the discussion following article #2 for managing the consequences, the place of debriefing, and the specific roles of trainers in summative assessment with simulation. With the appropriate precautions, building on existing and ongoing data, it seems feasible to deliberately integrate summative simulation more extensively into healthcare curricula. By being aware of the limitations and by controlling the risks where possible, the benefits of summative assessment with simulation can be applied simultaneously while gathering the evidence needed for guidelines. This conclusion is consistent with the observations reported in the first study on the use and desirability of summative assessment with simulation.

The third study, comparing the competency repositories for AIC residencies in the EU, US and Canada, characterized the high level of similarity (93%) and the limited differences. The differences we found are essentially based in the relative importance given to the same competencies between the different repositories (**Article #3 Figure 1 and Table 2**). While these results do not revolutionize the development of competency repositories in AIC, they do confirm on the basis of concrete, factual data what could be assumed based on observing day-to-day practices, collaboration and publications in AIC: there are significant similarities between the competency repositories of AIC residencies in the EU, US and Canada. The results on similarities are also a mapping of the core competencies shared between the three regions concerned (the EU, US and Canada) on the basis of which it would theoretically be possible to build a shared repository of competencies in AIC. If desired, this shared repository could be complemented by region-specific repositories for competencies whose emphasis is unique to each region. The results on differences are an interesting source for exploration. If relevant, these differences can be informed by drawing inspiration from other repositories or by integrating them into the shared repository. The benefits of a potential international shared

repository of AIC competencies are numerous but would not be immediately realized. In view of the important work of coordinating, reconciling existing repositories and the diplomacy required between the various governing bodies concerned, a great deal of goodwill and energy would be needed to turn what appears to be factually and theoretically possible into a concrete reality. However, the implications that would result from a shared international repository of competences in AIC deserve to be considered carefully.

# Implications

There are four main implications of the results of these three studies. Some of these implications are related to each other and their achievements depend in part on the strategic orientations of the governing bodies in charge of training and assessing AIC residents.

The first implication of the first study's results is the feasibility of a unified AIC simulation program on a country-wide scale (France). The identified simulation activity profiles, very homogeneous in nature and supported by the national training program, should allow a simple coordination to formalize a unified simulation program in AIC (France). It is now up to the governing bodies in charge of training residents in AIC to initiate concrete development.

The second implication is related to the first and integrates the results of the first two studies. In the second study, mapping the key principles on conducting summative assessment with simulation provides sufficient data to make it reasonable to consider its use in healthcare curricula. The first study shows that summative assessment with simulation is already used in France and that its generalization is expected. These two elements taken together imply that it is conceivable to integrate summative assessment with simulation into a unified AIC training program in France. Again, it is up to the governing bodies in charge of training and assessing AIC residents to integrate into a unified simulation program. Integrating summative assessment from the design of a unified program will likely simplify the implementation to follow.

The third implication stems from the third study's results: it is theoretically feasible to work towards a shared AIC competency repository between the EU, US and Canada. According to these results, such a shared program would cover a large majority of objectives within the current repositories. It is important to emphasize the theoretical aspect of this implication because mobilizing key governing bodies and actors necessary to concretize such a project is uncertain and requires numerous complex conditions to be met. Strong political and strategic will is necessary to make such a project succeed.

The fourth implication comes from integrating the results of these three studies in this thesis. If it is possible to:

1) have a unified AIC simulation training program based on an AIC competency repository, as demonstrated for France in the first study;
2) integrate summative assessment into such an AIC simulation training program to make it a unified AIC training and summative assessment program;
3) develop a shared international AIC competency repository across the EU, US and Canada, as demonstrated in the third study; then it is reasonable to think that it is possible to develop a unified AIC simulation training program across the EU, US and Canada based on a shared competency repository.

It is also conceivable on the long term to finally integrate summative assessment with simulation to build a unified training and summative assessment with simulation program in AIC throughout the EU, the US and Canada. Strong political and strategic will as well as human and financial resources would be necessary to make such a project succeed. However, the various studies conducted provide good evidence of feasibility of such an initiative.

# Transferability

It is interesting to note that some of the conclusions drawn can be extended more widely to the fields of healthcare education and simulation. Thus, what is observed and described for AIC should logically be reproducible for other healthcare disciplines. The first study confirmed what has been done, in part, in Canada[17] and validates the feasibility of the method, and the scientific approach used to assess the feasibility, and maps the initial state of the art for developing a national unified, single-discipline simulation program.

The second study, on general principles of using summative assessment in healthcare simulation, is already yielding results that are broadly applicable to the field of simulation-based healthcare education. Generic elements can be identified as applicable to simulation-based education in fields other than healthcare (e.g. validity of summative assessment tools, consequences of summative assessment, debriefing in summative assessment, trainers in summative assessment and implementation of summative assessment).

The third study validates feasibility of the method and the scientific approach used to assess the similarities (and differences) between competency repositories within a discipline across different regions. To be feasible, this requires prerequisites, such as existing structured competency repositories ideally written in the same language, and surface commonalities in scope of practice. These prerequisites should be defined for a better transferability of the method to other disciplines.

Finally, other healthcare disciplines could take this logical approach of assembling the different studies' conclusions to build a unified, international simulation training program based on shared competencies within a healthcare discipline and integrates summative assessment. This approach is more hypothetical at this stage and requires validating the prerequisites needed to uniformly apply the above methods to other disciplines.

# Limitations

This thesis has certain limitations that deserve to be highlighted.

First, a more in-depth exploration of the pedagogical methods and simulation materials available with the survey on simulation in AIC in France would have allowed for more precisely knowing the practice of simulation beyond the themes and modalities. The choice not to go into more detail on these themes (pedagogical methods and simulation materials) was deliberate at this stage. Completing the online questionnaire was already time-consuming (68 questions in 5 sections) for AIC resident program directors whose time available for participation was limited. Lengthening the questionnaire risked losing participants and would have been detrimental to the study. These data were not central to characterizing simulation activity and the feasibility of a unified AIC simulation program. Nevertheless, it will be useful to fill this knowledge gap to facilitate developing and implementing a unified AIC simulation training program in France.

Second, more data on simulation-based summative assessment would have allowed for evidence-based recommendations to be made directly. Despite a careful review of the literature, we had to make do with data from the literature that did not provide certain answers to the main questions posed for most of the seven themes identified by the NGT. However, we have developed some reflections based on the available data and our knowledge of the topics. Simulation-based summative assessment is already in use, and needs to be guided given its high-stakes nature. Recommendations based on expert opinion would be a useful intermediate step until the literature is enriched with the necessary evidence. This work can serve as a basis for considering such expert recommendations on summative assessment in healthcare simulation.

Third, we have used the ETR as a pedagogical repository of competencies for AIC resident training for the EU while some European countries have their own pedagogical repositories. Jonker et al reported that, among the EU's countries, assessment and certification processes vary between knowledge based, knowledge and skills based, or competency based.[70] Assuming there is alignment between repositories and assessment, it would be necessary to know the similarities and differences between the different European countries' repositories and the ETR in order to confirm how representative the ETR is in relation to the reality of each European

country. It is also not always clear whether the national repositories in the EU are adapted from the ETR or developed de novo. However, the ETR are the official European reference on the basis of which AIC doctors trained in one of the EU countries are allowed to practice freely throughout the EU. The availability and clarity of the recently updated ETR lead us to give them priority for this work.

Finally, the concrete application of the different pedagogical references used (ETR, US Milstones and CanMEDS)[11,12,14] in the daily practice of training AIC residents is not reported in the literature and we have not measured it. A useful next step to strengthen the relevance of a shared set of educational objectives for AIC residencies will be to assess the application of the current repositories.

# Perspectives

We identify two main areas of focus based on the work we have done: summative assessment with simulation and the development of a unified simulation program in AIC. The first area could feed the second one later on.

Supporting the development of summative assessment in simulation (first area) requires filling in the gaps in knowledge identified, determining the means necessary for the design and implementation in good conditions, and network work. Filling the knowledge gaps requires further study and data collection when using simulation in summative assessment. The knowledge gaps we identify as relevant to explore are the following. Regarding what can be assessed through summative simulation, the correlation between summative assessment performance and real-life performance, the correlation between performance and competence, and team assessment. Regarding summative assessment tools, a step forward for the community would be to have a clear specification to guide the development of a summative assessment tool in simulation. Given the potentially large number of tools to be developed, a collaborative networked effort to build an international repository of summative assessment tools in simulation would seem to be a high value-added project. Concerning the consequences of summative assessment with simulation, it is necessary to explore the different positive and negative effects expected and not expected. This is important in order to ideally control, limit or at least take into account these different effects on the organization of summative assessment with simulation. Concerning the scenarios for the summative assessment with simulation, to propose a precise and reproducible framework helping to guarantee the validity of the summative assessment would be useful. Especially if this framework makes it possible to evolve the formative scenarios to evaluative purposes. Concerning the place of debriefing in summative assessment, the benefits and disadvantages of incorporating debriefing in the assessment or not, the type of debriefing (complete or simple one-way feedback) must be the subject of rigorous studies. Those studies should integrate pedagogical, psychological and organizational aspects to determine a more precise picture of the balance of benefits/disadvantages on which trainers will be able to base their choice. Regarding simulation trainers involved in summative assessment, expert recommendations should help determine the skills and training they need to best fulfill their mission. Regarding the implementation of summative assessment with simulation, the recertification of professionals who have already

graduated has characteristics that are specific and need to be addressed separately. The context and topic of recertification must be related to the professional's practice to be feasible and useful.[71] Knowledge of summative assessment with simulation for recertification needs to be increased.

From a practical point of view, the design, the preparation and the realization of summative assessment with simulation have and will certainly need material and human resources. Among these resources, some are generic and constant for all types of summative assessment (e.g. design time, trainers, raters ...) and others are specific (e.g. simulators, standardized patients ...). It is essential that these resources be identified and listed. Otherwise, the quality and even the sustainability of the planned summative assessment with simulation cannot be maintained.
These resources can be saved and optimized thanks to community networking approaches, whether to gather evidence to fill knowledge gaps or to build banks of scenarios, assessment tools, etc., at the level of specialties, a country or more widely. This same approach should be considered for the development of a unified AIC simulation training program. This will optimize resources, make savings and improve adherence to the program.

We consider the perspective of building a unified simulation program in AIC (second area) through a Delphi method approach. On the basis of the state-of-play of the use of simulation in AIC in France (**article #1**), we were able to identify the key stakeholders, the themes and the modalities of simulation. This preliminary step will now allow us to precisely define the research question, to determine the scope of the literature review, to develop the initial questionnaire for the participants, to prepare the necessary information on the research question for the participants and to select the participants (**Methods section and Table 2**). The goal of this project is to develop a pedagogical repository for AIC simulation training consisting of a broad range of technical skills, entrustable professional activities, and crisis situations. We have created three categories to specifically explore technical and procedural aspects:

- Based-Simulation Competencies and Skills (BaSiCS) - essential management or technical skills encountered in common practice.
- Entrustable Professional Activities (EPA) - of skill sets that may be performed by a resident autonomously without direct supervision.
- Crisis and Exceptional Situations in Simulation (CrESiS) - management of critical and rare events, each of which require escalated care, performance of technical and patient management skills, and application of crisis resource management principles.

Based on data from the literature, BaSiCS,[72] EPA[73] and CrEsiS[74] are proposed (**Appendix 4**) as a basis for the Delphi method. The lists of items can be enriched and modified during the Delphi process. The questionnaire submitted to the participants will determine for each item (1) whether it should be included in the curriculum, (2) how often it is expected to be used in professional practice, (3) what is the estimated level of difficulty, (4) in what year a resident should be able to perform this skill with indirect supervision, and (5) whether this skill should be taught/evaluated in a clinical or simulation setting. The intended end result is a searchable database of the five characteristics to guide the use of simulation in teaching skills according to the objectives of the trainers (e.g., *Which skills to teach in the second year? Which skills are most common in professional clinical practice? What are the most frequent skills in professional clinical practice to teach in the second year?*) This approach can be considered on a French scale, where we have already gathered data showing feasibility, desirability and the needed professional community; or on a larger international scale. The development of a unified AIC simulation program on an international scale between the EU, US and Canada could also be reasonably envisaged since we have highlighted the existence of a very high proportion of similarities between the pedagogical reference systems of these regions.

# Conclusion

This thesis work involves the first steps in developing a large-scale unified training and summative assessment strategy with simulation in AIC. In three steps, we have demonstrated the feasibility of this strategy. First, we have demonstrated homogeneity of simulation practices in AIC in France, i.e. in a space using a same repository of competencies. Second, we have gathered data and offered thoughts on summative assessment in healthcare simulation that argue that, although further evidence is needed through studies, it is already possible to integrate some summative assessment into the design of health training programs. Third, we have demonstrated the feasibility of a shared competencies' repository on a large scale between the EU, US and Canada based on a high degree of similarity that exists between their current repositories. It is possible to build a unified simulation program when a single competency-based curriculum is used (**Article #1**). It is possible to integrate summative assessment with simulation into a simulation training program (**Article #2**). It is possible to have a shared competency repository on a large scale in AIC - between the EU, US and Canada (**Article #3**). It is therefore feasible to build a unified simulation program integrating summative assessment on a large scale (between the EU, US and Canada) based on a shared competencies' repository.

This thesis did not explore the pedagogical methods and the resources needed to develop and implement a unified simulation program. We have also not measured the actual application of the competencies' repositories in general, and more specifically that of the ETR for European countries with a national competencies' repository. These data are interesting to know and useful for the future, but we judged them to be not central to the conduct of the thesis and at this stage of the overall strategy. Further work would be necessary to collect them for future analysis.

This thesis lays the groundwork for two important areas of future research: knowledge development in summative assessment in healthcare and the development of a unified simulation training program in AIC. Knowledge development in summative assessment in healthcare is an extremely broad topic, requiring community-based networking to conduct multiple studies to establish the needed evidence. The development (Delphi method) of a unified simulation training program in AIC based on a shared competencies' repository is currently being developed in France, as the needed conditions for this have been met. The same

development on a large scale is feasible but requires institutional and governing bodies' support before it can be initiated. On the basis of the data gathered through this thesis, we believe that we have modestly taken a step forward towards a better understanding of the place that simulation can have in training and summative assessment in AIC. We are now in a position to move concretely towards developing a unified simulation program in AIC.

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# Appendix

**List of Appendix**

**Appendix #1:** Fourteen different type of review adapted from Grant and Booth 2009 and presented in Booth 2016, Table 2.5.[24] In grey are underlined literature review, scoping review and systematic search and review.

**Appendix #2:** Stages for Consensus Group methods; Appendix to Humphrey-Murto S, Varpio L, Gonsalves C, Wood TJ: Using consensus group methods such as Delphi and Nominal Group in medical education research. Medical Teacher 2017; 39:14–9[32]

**Appendix #3:** Speculative author preliminary assessment of risks and benefits of debriefing depending of the context: formative or summative.

**Appendix #4:** Three categories created to specifically explore technical skills, entrustable professional activities, and crisis situations aspects.

1. Based-Simulation Competencies and Skills (BaSiCS) - essential management or technical skills encountered in common practice.
2. Entrustable Professional Activities (EPA) - of skill sets that may be performed by a resident autonomously without direct supervision.
3. Crisis and Exceptional Situations in Simulation (CrESiS) - management of critical and rare events, each of which require escalated care, performance of technical and patient management skills, and application of crisis resource management principles

**Appendix #1 (from Grant and Booth 2009[23])**

| Type of Review | Description | Search | Appraisal | Synthesis | Analysis |
|---|---|---|---|---|---|
| Critical review | Aims to demonstrate extensive research and critical evaluation of quality. Goes beyond mere description to include degree of analysis and conceptual innovation. Typically results in hypothesis or model. | Seeks to identify most significant items in field | No. Evaluates by contribution. | Narrative, conceptual chronological. | Significant component: seeks to identify conceptual contribution to embody existing or derive new theory. |
| Integrative review | Utilises broadest type of research review methods to include both experimental and non-experimental research in order to understand more fully a phenomenon of concern. Integrative reviews combine data from theoretical and empirical literature. | Exhaustive search to identify maximum number of eligible primary sources, using two or more strategies. Purposive sampling may be combined with exhaustive search if appropriate. | Reports coded according to quality but not necessarily excluded. | Tabular (matrices, graphs, charts, or networks) usually according to a framework. | Creativity, critical analysis of data and data displays key to comparison and identification of important patterns and themes. |
| Literature review | Examines recent or current literature. Can cover wide range of subjects at various levels of completeness and exhaustivity. May include research findings. | Possibly exhaustive. | Possibly. | Narrative. | Chronological, conceptual, thematic, etc. |
| Mapping review/ systematic map. | Maps out and categorises existing literature from which to commission further reviews and/or primary research by identifying gaps in research literature. | As Time allows. | No. | Graphical. Tabular | Characterises quantity and quality of literature, perhaps by study design and other key features. May identify need for primary/secondary research. |
| Meta-analysis | Statistically combines results of quantitative studies to provide precise effect of results. | Exhaustive. May use funnel plot to assess completeness. | May determine inclusion/exclusion and/or sensitivity analyses. | Graphical. Tabular. Narrative. | Numerical analysis. |
| Mixed studies review/ mixed methods review | Combines methods that include review component (usually systematic). Specifically combines review approaches such as quantitative with qualitative research or outcome with process studies. | Sensitive search or separate quantitative and qualitative strategies. | Generic appraisal instrument or separate appraisal processes with corresponding checklists. | Narrative. Tabular. Graphical (to integrate quantitative and qualitative studies). | May look for correlations between characteristics or use gap analysis to identify aspects absent in one literature but missing in other. |

| Type of Review | Description | Search | Appraisal | Synthesis | Analysis |
|---|---|---|---|---|---|
| Overview | Surveys literature and describe its characteristics. | Depends on how systematic methods are. | Depends on how systematic methods are. | Depends on how systematic methods are.<br>Narrative.<br>Tabular. | Chronological, conceptual, thematic, etc. |
| Qualitative systematic review/ qualitative evidence synthesis | Integrates or compares findings from qualitative studies. Looks for 'themes' or 'constructs' in or across individual studies. | Selective or purposive. | Typically to mediate messages not for inclusion/ exclusion. | Qualitative, narrative synthesis. | Thematic may include conceptual models. |
| Rapid review | Assesses what is already known about policy or practice issue. | As time allows, uses systematic review methods to search existing research. | As time allows, uses systematic review methods to critically appraise existing research. | Narrative. Tabular. | Quantities of literature and overall quality/direction of effect of literature. |
| Realist synthesis | Synthesises large and diverse selection of literature to inform policy revision, design effective interventions and identify potentially effective and innovative interventions. | Mainly iterative and purposive. | Privileges relevance over rigour. | Narrative, causal chains and graphical. | Key output is programme theory/ies of target intervention, specifying how and why programme/ service is thought to cause intended outcomes (theory building), and then testing assumptions against further evidence, to strengthen and refine it (theory testing). |
| Scoping review | Identifies nature and extent of research evidence (including ongoing research). | As time allows. May include research in progress. | No. | Narrative. Tabular. | Quantity and quality of literature, perhaps by study design and other features. Attempt to specify viable review. |
| State-of-the-art review | Addresses current matters. May offer new perspectives on issue or point out area for further research. | Exhaustive coverage of current literature. | No. | Narrative. Tabular. | Current state of knowledge, priorities for future investigation research limitations. |
| Systematic search and review | Combines strengths of critical review with exhaustive search process. Addresses broad questions to produce "best evidence synthesis". | Exhaustive. | Possibly. | Narrative. Tabular. | What is known, recommendations for practice. |
| Umbrella review | Summarises results from systematic reviews on a topic. | Exhaustive search for reviews only. | Possibly using a review specific appraisal tool (for example, AMSTAR). | Graphical and tabular. | What is known and research gaps for primary research or further reviews. |

**Appendix #2 (from Humphrey-Murto S 2017[32])**

**Stages for Consensus Group methods**

| Stages in Consensus Group Methods | | |
|---|---|---|
| **Delphi** | **Nominal Group** | **RAND/UCLA** |
| Identify a research problem | same | same |
| Complete a literature search | +/- | Complete a literature search |
| Develop a questionnaire of statements for participants | Formulation of the nominal question | Generation of indicators, criteria to be rated |
| Prepare background information for participants | same | same |
| Select participants (4-thousands) | Usually 5-12 | Usually 9 |
| Round 1 mail or email questionnaire | Face to face meeting where nominal question is presented | Round 1 mail or email questionnaire |
| Collect individual and group feedback by research team; new items may be added | Round robin feedback from individual group members to record each idea in turn; idea generation | Collect individual and group feedback by research team; no new items |
| | Group discussion of each idea in turn for clarification at the face-to-face meeting | Next, a face-to-face meeting for group discussion for clarification |
| Round 2 mail or email questionnaire with individual and group feedback for anonymous re-ranking | Round 2; individual voting on ideas | Round 2; individual voting on ideas at the face-to-face meeting |
| Continue iterative process of feedback by mail or email and re-ranking until complete | Continue iterative process of feedback and re-ranking until complete | Continue iterative process of feedback and re-ranking until complete |

**Appendix #3: Speculative author preliminary assessment of risks and benefits of debriefing depending of the context: formative or summative.**

| Situation | Learners | | Trainers | |
|---|---|---|---|---|
| | **Benefit** | **Risk** | **Benefit** | **Risk** |
| Formative simulation<br>+ formative debriefing | Adapted cognitive activation<br>Analyzing and learning post action<br>Interactive feedback | Low stress<br>Limited psychological impact | Analyzing and teaching post action<br>Interactive feedback | Time consuming<br>Aligning feedback on performance when the simulation performance and debriefing performance are discordant can be difficult |
| Summative simulation<br>+ no debriefing | | Mild stress<br>Negative learning<br>High risk of uncontrolled psychological impact | Time saving<br>Compatible with mass assessment | Learners' thought processes remain unknown |
| Summative simulation<br>+ summative debriefing | Opportunity to demonstrate self-evaluation ability and capacity for reflective practice<br>Get feedback | Severe stress<br>Possible miss of learning opportunity if learner withhold "true" thought processes | Assess self-evaluation ability and capacity for reflective practice<br>Satisfy the desire to improve performance with feedback | Time consuming<br>Learners don't reveal their thoughts<br>Learners tend to give the "good" awaited answer rather than express their thinking<br>Aligning a performance rating when the simulation performance and debriefing performance are discordant can be difficult<br>Cognitive conflict between debriefing and rating tasks |
| Summative simulation<br>+ formative debriefing (simple standardized feedback) | Get basic feedback | Low stress<br>Don't get tailored feedback<br>May miss specific feedback points | Time saving<br>Give standardized feedback<br>OK if simulation performance is good<br>Compatible with mass assessment | Give no specific feedback<br>Not sufficient if simulation performance is poor (failure) |
| Summative simulation<br>+ formative debriefing (complete interactive debriefing) | Follow-up of the learning process<br>Receive useful and sympathetic feedback | Mild stress | Maintain pedagogical contract<br>Follow-up of the teaching process<br>Allow useful and sympathetic feedback<br>Necessary if simulation performance is poor (failure) | Time consuming<br>Not compatible with mass assessment |

**Appendix #4**

1. **Based-Simulation Competencies and Skills (BaSiCS) - essential management or technical skills encountered in common practice.**

| | Sub-categories | BaSiCS items | BaSiCS items description |
|---|---|---|---|
| 1 | Vascular access | Management of peripheral venous access | Preparation, placement, use, maintenance and removal of a peripheral venous access |
| 2 | Vascular access | Management of peripheral venous access (ultrasound guided) | Preparation, placement, use, maintenance and removal of a peripheral venous access ultrasound guided |
| 3 | Vascular access | Management of PICC line/midline catheter | Preparation, placement, use, maintenance and removal of Picline / Midline |
| 4 | Vascular access | Management of central venous access (ultrasound guided) | Preparation, placement, use, maintenance and removal of central venous access under ultrasound guidance |
| 5 | Vascular access | Management of Swan-Ganz pulmonary arterial catheter | Preparation, placement, use, calibration, maintenance and removal of a Swan-Ganz pulmonary arterial catheter |
| 6 | Vascular access | Management of arterial catheter | Preparation, placement, use, calibration, maintenance and removal of an arterial catheterization |
| 7 | Vascular access | Management of arterial catheter (ultrasound guided) | Preparation, placement, use, calibration, maintenance and removal of an arterial catheterization ultrasound guided |
| 8 | Vascular access | Management of intraosseous access | Preparation, placement, use, maintenance and removal of an intraosseous access |
| 9 | Loco-regional anesthesia | Spinal anesthesia | Preparation, placement, use, maintenance and removal of hypo, normo and hyperbaric spinal anesthesia in single or continuous injection |
| 10 | Loco-regional anesthesia | Epidural anesthesia | Preparation, placement, use, maintenance and removal of lumbar, thoracic and cervical epidurals |
| 11 | Loco-regional anesthesia | Combined spinal epidural anesthesia | Preparation, placement, use, maintenance and removal of combined peri-spinal anesthesia |
| 12 | Loco-regional anesthesia | Epidural blood patch | Preparation, realization and monitoring of a blood patch |
| 13 | Loco-regional anesthesia | Ultrasound guidance of neuraxial anesthesia | Preparation and use of ultrasound apparatus for the identification and / or guidance of spinal anesthesia |
| 14 | Loco-regional anesthesia | Upper limb peripheral blocks | Preparation, realization and monitoring of isolated or combined upper limb blocks |
| 15 | Loco-regional anesthesia | Lower limb peripheral blocks | Preparation, realization and monitoring of isolated or combined lower limb blocks |
| 16 | Loco-regional anesthesia | Ultrasound guidance for peripheral nerve blocks | Preparation and use of ultrasound apparatus for the identification and / or guidance for peripheral nerve blocks |

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| 17 | Loco-regional anesthesia | Head, face and neck blocks | Preparation, realization and monitoring of isolated or combined head, face and neck blocks (surgical context) |
| 18 | Loco-regional anesthesia | Wall blocks (chest and abdomen) | Preparation, realization and monitoring of isolated or combined wall blocks (thorax and abdomen) |
| 19 | Loco-regional anesthesia | Caudal anesthesia | Preparation, realization and monitoring of caudal anesthesia |
| 20 | Ultrasounds | e-Fast ultrasound assessment | Preparation, realization and interpretation of an e-FAST ultrasound |
| 21 | Ultrasounds | Lung ultrasound to detect pneumothorax/pleural effusion | Preparation, realization and interpretation of a lung ultrasound |
| 22 | Ultrasounds | Gastric ultrasound | Preparation, realization and interpretation of a gastric ultrasound |
| 23 | Ultrasounds | Transcranial Doppler | Preparation, realization and interpretation of a Transcranial Doppler |
| 24 | Ultrasounds | Transthoracic echocardiography | Preparation, realization and interpretation of transthoracic echocardiography |
| 25 | Ultrasounds | Transesophageal echocardiography | Preparation, placement, interpretation and removal of a transesophageal echocardiography |
| 26 | Ultrasounds | Esophageal Doppler | Preparation, placement, interpretation and removal of an esophageal Doppler |
| 27 | Ventilation | Ventilation with face mask | Preparation, setting up and management of facial mask ventilation in conscious or unconscious patients |
| 28 | Ventilation | Non-Invasive Ventilation | Preparation, establishment and management of non-invasive ventilation in a conscious patient (including respirator settings) |
| 29 | Ventilation | Mechanical / Invasive Ventilation | Preparation, placement, management and weaning of invasive ventilation, including transport ventilators (including respirator settings) |
| 30 | Airway Control | Tracheal intubation | Preparation, realization, positioning control and removal of oro or nasotracheal intubation |
| 31 | Airway Control | Supraglottic device | Preparation, realization and control of the positioning of a supra-glottic device |
| 32 | Airway Control | Difficult intubation | Preparation, implementation and control of the positioning of a difficult oro or nasotracheal intubation using the techniques and devices recommended in difficult intubation algorithms |
| 33 | Airway Control | Fiberoptic intubation | Preparation, realization and control of the positioning of an oro or nasotracheal intubation by means of a fiberscope |
| 34 | Airway Control | Fiberoptic bronchial lavage | Preparation, realization and control of the efficiency of fiberoptic bronchial lavage |
| 35 | Airway Control | Use of lung isolation techniques (e.g., bronchial blockers, double-lumen endotracheal tubes) | Preparation, implementation and control of the positioning of selective right or left orotracheal intubation or bronchial blocker |
| 36 | Airway Control | Intubation using airway exchange catheter (e.g., reintubation) | Preparation, realization and control of airway exchange catheters |

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| 37 | Airway Control | Transtracheal oxygenation | Preparation, realization and control of the efficiency of transtracheal oxygenation |
| 38 | Airway Control | Cricothyroidotomy | Preparation, realization and control of the positioning of a cricothyroidotomy |
| 39 | Transfusion | Administration of Blood Products | Preparation, placement and monitoring of RBC, plasma and / or platelet transfusion |
| 40 | Transfusion | Use of rapid transfusion device | Preparation, setting up and management of a fast transfusion |
| 41 | Transfusion | Use of blood salvage techniques/intraoperative cell salvage machines (e.g., "cellsaver") | Preparation, setting up and management of a cellsaver |
| 42 | Drain | Needle/catheter decompression of the pleural space | Preparation and realization of a pleural decompression of a pneumothorax with a catheter |
| 43 | Drain | Chest tube insertion | Preparation, placement, use, management, maintenance and removal of a chest tube |
| 44 | Drain | Drainage of cerebrospinal fluid and measurement of intracranial pressure | Use, management, maintenance and removal of cerebrospinal fluid drainage and / or intra-cranial pressure measurement |
| 45 | Cardiopulmonary resuscitation | External chest compressions | Organization, performance and evaluation of the quality of external chest compression |
| 46 | Cardiopulmonary resuscitation | Use of defibrillators | Indication, preparation, installation and use of automatic, semi-automatic and manual defibrillators |
| 47 | Cardiopulmonary resuscitation | Use of external pacemakers | Indication, preparation, installation and use of external electrosystolic training |
| 48 | Cardiopulmonary resuscitation | ACLS certification | |
| 49 | Put in condition | Establishment of non-invasive and semi-invasive monitoring and collection of vitals | Preparation for, set-up for, use of, and removal of ECG, ST segment analysis, SpO2, NIBP, EEG or processed EEG monitoring, temperature, assessment of neuromuscular blockade, other noninvasive monitors (e.g., pain monitoring devices) |
| 50 | Put in condition | Placement of immobilization | Millitary AntiShock Trousers, cervical collar, splints |
| 51 | Put in condition | Proper patient positioning | Preparation, implementation and monitoring of protective positioning for the patient under general anesthesia or with otherwise limited mobility (e.g., prolonged sedation or neurologic change) |
| 52 | Put in condition | Management and regulation of the patient's temperature | Preparation, implementation, management and monitoring of systems to regulate the patient's temperature |
| 53 | Put in condition | Management of urinary catheters | Preparation, placement, use, maintenance and removal of urinary catheters |
| 54 | Put in condition | Management of gastric tubes (placed orally or nasally) | Preparation, placement, use, maintenance and removal of oro- or naso-gastric tubes |
| 55 | Put in condition | Interpretation of evoked potentials | Interpretation of evoked potentials during a neurosurgical procedure with adaptation/modification of the anesthetic |

**2. Entrustable Professional Activities (EPA) - of skill sets that may be performed by a resident autonomously without direct supervision.**

| | Sub-categories | EPA items | EPA items description |
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| 1 | Anesthesia Management | Epidural, spinal, and combined spinal-epidural anesthesia | Performing informed consent and deciding upon an indicated anesthetic. Performing the anesthetic and providing aftercare regarding epidural and/or spinal analgesia/anesthesia. |
| 2 | Anesthesia Management | Management of massive blood loss | Prevention, recognition, diagnosing and treatment of massive blood loss in adult and pediatric patients, in different circumstances. |
| 3 | Anesthesia Management | Management of the difficult airway | Recognition of the (possible) difficult airway, preparation of backup anesthetic techniques, and perioperative and acute anesthetic care for the patient involved. |
| 4 | Anesthesia Management | Peripheral nerve block | Performing informed consent and deciding upon an indicated anesthetic. Performing the anesthetic and providing aftercare regarding aspects of the most commonly used peripheral nerve blockades for anaesthesia of the torso, upper and lower extremities. |
| 5 | Anesthesia Management | Sedation for medical interventions and examinations | Providing light, intermediate, and deep sedation according to current guidelines during medical interventions and examinations in adult and pediatric patients. Acting as a supervisor or consulting specialist during sedation provided by other healthcare providers. |
| 6 | Anesthesia Management | Preoperative assessment | Preoperative screening and designing a tailored anesthetic management plan at a preoperative outpatient clinic and in the hospital wards. |
| 7 | Pain Management | Management of acute pain | Prevention, recognition, treatment and aftercare for various forms of acute pain. |
| 8 | Pain Management | Management of chronic pain | Prevention, recognition, treatment and aftercare for various forms of benign chronic pain. |
| 9 | Pain Management | Management of oncological pain and palliative care | Prevention, recognition, treatment and aftercare for various forms of pain with oncologic cause. Palliative care according to current medical and legal guidelines. |
| 10 | Pain Management | Peripartum pain management | Performing informed consent and deciding upon an indicated anesthetic. Performing the anesthetic and providing aftercare regarding aspects of pain relief during labor. |
| 11 | Perioperative anesthetic care | Perioperative anesthetic care for ASA I-II patients undergoing low to medium risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA I-II patients undergoing low to medium risk surgery. |

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| 12 | Perioperative anesthetic care | Perioperative anesthetic care for ASA III patients undergoing low to medium risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA III patients undergoing low to medium risk surgery. |
| 13 | Perioperative anesthetic care | Perioperative anesthetic care for ASA IV patients undergoing low to medium risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA IV patients undergoing low to medium risk surgery. |
| 14 | Perioperative anesthetic care | Perioperative anesthetic care for ASA I-II patients undergoing high risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA I-II patients undergoing high risk surgery. |
| 15 | Perioperative anesthetic care | Perioperative anesthetic care for ASA III patients undergoing high risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA III patients undergoing high risk surgery. |
| 16 | Perioperative anesthetic care | Perioperative anesthetic care for ASA IV-V patients undergoing high risk surgery | Preoperative, perioperative, and postoperative anesthetic care for ASA IV-V patients undergoing high risk surgery. |
| 17 | Perioperative anesthetic care | Perioperative anesthetic care for infants up to the age of one year | Preoperative, perioperative, and postoperative anesthetic care for the pediatric patient up to 1 year of age undergoing surgery. |
| 18 | Perioperative anesthetic care | Perioperative anesthetic care for children between one and four years old | Preoperative, perioperative, and postoperative anesthetic care for the pediatric patient between 1- and 4-years old undergoing surgery. |
| 19 | Perioperative anesthetic care | Perioperative anesthetic care for children over four years of age | Preoperative, perioperative, and postoperative anesthetic care for the pediatric patient older than 4 years old undergoing surgery. |
| 20 | Perioperative anesthetic care | Perioperative anesthetic care for ambulatory surgery | Preoperative, perioperative, and postoperative anesthetic care for patients undergoing surgery in an ambulatory surgical setting. |
| 21 | Perioperative anesthetic care | Perioperative anesthetic care for laparoscopic surgery in day care | Preoperative, perioperative, and postoperative anesthetic care for patients undergoing laparoscopic surgery in daycare. |
| 22 | Perioperative anesthetic care | Perioperative anesthetic care for peripheral vascular surgery | Preoperative, perioperative, and postoperative anesthetic care for patients undergoing peripheral vascular surgery. |
| 23 | Perioperative anesthetic care | Perioperative anesthetic care for non-vascular abdominal surgery | Preoperative, perioperative, and postoperative anesthetic care for patients undergoing abdominal surgery, with the exception of vascular surgery. |
| 24 | Perioperative anesthetic care | Perioperative anesthetic care for abdominal vascular surgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing abdominal vascular surgery. |
| 25 | Perioperative anesthetic care | Perioperative anesthetic care for vascular surgery of the carotid artery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing carotid arterial vascular surgery. |
| 26 | Perioperative anesthetic care | Perioperative anesthetic care for complex orthopedic surgery | Preoperative, perioperative, and postoperative anesthetic care for patients undergoing complex orthopedic surgery. |
| 27 | Perioperative anesthetic care | Perioperative anesthetic care for cesarean delivery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing a cesarean delivery. |

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| 28 | Perioperative anesthetic care | Perioperative anesthetic care for coronary artery bypass grafting and valve surgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing coronary artery bypass grafting and non-complex cardiac valvular surgery. |
| 29 | Perioperative anesthetic care | Perioperative anesthetic care for cardiothoracic surgery on the thoracic vessels | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing cardiothoracic surgery on the thoracic vessels. |
| 30 | Perioperative anesthetic care | Perioperative anesthetic care for pulmonary surgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing pulmonary surgery. |
| 31 | Perioperative anesthetic care | Perioperative care for heart and/or lung transplantation | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing heart and/or lung transplantation. |
| 32 | Perioperative anesthetic care | Perioperative anesthetic care for laryngotracheobronchoscopy in adults and children | Preoperative, perioperative, and postoperative anesthetic care for adult and pediatric patients undergoing laryngotracheobronchoscopy. |
| 33 | Perioperative anesthetic care | Perioperative anesthetic care for situations of a shared airway with the surgical team | Preoperative, perioperative, and postoperative anesthetic care for adult and pediatric patients undergoing an intervention with a shared airway with the surgical team. |
| 34 | Perioperative anesthetic care | Perioperative anesthetic care for head and neck surgery, excluding neurosurgery and vascular surgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing major head and neck surgery, with the exception of neurosurgery and vascular surgery. |
| 35 | Perioperative anesthetic care | Perioperative anesthetic care for urgent neurosurgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing traumatic and non-traumatic urgent neurosurgery. |
| 36 | Perioperative anesthetic care | Perioperative anesthetic care for elective neurosurgery | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing elective neurosurgery. |
| 37 | Perioperative anesthetic care | Perioperative anesthetic care for vascular neurosurgical procedures | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing vascular neurosurgical procedures. |
| 38 | Perioperative anesthetic care | Perioperative anesthetic care for awake neurosurgical procedures | Preoperative, perioperative, and postoperative anesthetic care for the patient undergoing awake neurosurgical procedures. |
| 39 | Communication | Interviewing the patient | Interviewing the patient or his/her representatives regarding (among others) anticipated complications, do-not-resuscitate policies, goal-directed care, and anticipated bad news or patient preferences for receiving bad news. |
| 40 | Communication | Breaking bad news, apologizing (having difficult conversations) | Having discussions with the patient or his/her representatives regarding breaking bad news, apologizing, having difficult conversations. |
| 41 | Communication | Science and evidence-based medicine | Constructing an answer, according to Evidence Based Medicine guidelines, for a clinical issue. Communicating this knowledge to colleagues, other healthcare providers and the general public. |

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| 42 | Postoperative Care | Postoperative care during the recovery period | Postoperative care in the recovery unit, determining the indicated postoperative treatment, recognition and treatment of complications, identifying and arranging the appropriate discharge ward, for patient of all ages. |
| 43 | Postoperative Care | Post-acute and long-term intensive care | Post-acute and long-term daily care of the adult patient admitted to the intensive care ward. Including diagnostics and treatment of intercurrent problems and communication with relevant healthcare providers and family of the patient. |
| 44 | Postoperative Care | Postoperative intensive care after cardiac surgery in the post-anaesthesia care unit (PACU) | Informing the patient and determining the indicated postoperative treatment. Executing the indicated treatment, recognition and treatment of complications. Identifying and arranging the appropriate discharge ward of adult patients on post-anesthesia care unit (PACU) after cardiac surgery. |
| 45 | Resuscitation & Intensive Care | Cardiopulmonary resuscitation of the adult patient | Team membership and leadership in cardiopulmonary resuscitation of the adult patient, inside and outside the hospital. |
| 46 | Resuscitation & Intensive Care | Cardiopulmonary resuscitation of the pediatric patient | Team membership and leadership in cardiopulmonary resuscitation of the pediatric patient, inside and outside the hospital. |
| 47 | Resuscitation & Intensive Care | Resuscitation and admission of the adult patient in need of intensive care | Resuscitation and determination of the indicated treatment of the adult patient in need of intensive care. Transportation of the patient according to current guidelines. Executing the indicated treatment, and providing aftercare regarding the admission of the patient to the intensive care ward. |
| 48 | Resuscitation & Intensive Care | Resuscitation and treatment of sepsis in the intensive care unit | Recognition, resuscitation and treatment of sepsis according to the current guidelines in the adult patient in need of intensive care or already admitted to the intensive care ward. |
| 49 | Resuscitation & Intensive Care | Resuscitation of the acutely ill pediatric patient | Primary survey, resuscitation and stabilization of the acute ill pediatric patient in life-threatening condition. Transportation of the pediatric patient conform current guidelines. |
| 50 | Resuscitation & Intensive Care | Resuscitation of the adult multiple trauma patient | Resuscitation of the adult trauma patient. Active participation in the trauma team. Assessment and management of hemodynamic parameters. Transportation of the patient conforming to current guidelines. Pain management in trauma patients. |
| 51 | Resuscitation & Intensive Care | Resuscitation of the pediatric multiple trauma patient | Resuscitation of the pediatric trauma patient. Active participation in the trauma team. Assessment and management of hemodynamic parameters. Transportation of the patient conforming to current guidelines. Pain management in trauma patients. |
| 52 | Resuscitation & Intensive Care | Management and resuscitation of burn victim | Resuscitation and perioperative care for the burn patient. Assessment and treatment to stabilize hemodynamics. Management of the patient which conforms to current guidelines. |
| 53 | Resuscitation & Intensive Care | Management of severe peripartum hemorrhage | Prevention, recognition, diagnosing and treatment of severe peripartum hemorrhage. |

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| 54 | Resuscitation & Intensive Care | Care around organ donation | Resuscitation, preoperative, perioperative, and postoperative anesthetic care for the patient undergoing organ donation. |
| 55 | Resuscitation & Intensive Care | Ventilation on the intensive care unit | Starting, maintaining and optimizing, and ending invasive and non-invasive ventilation of the adult patient admitted to the intensive care ward. |
| 56 | Resuscitation & Intensive Care | Performing emergency medicine in an interdisciplinary team | Performing emergency medicine in an interdisciplinary team including cases of mass accidents and disasters. |
| 57 | Resuscitation & Intensive Care | Management of patient whom should be transferred to a higher acuity medical facility | Recognition, preparation and organization of the transfer of the patient whom should be transferred to a higher acuity medical facility. |
| 58 | Resuscitation & Intensive Care | Management of patient transportation inter- and intra-hospital | Preparation, prevention of the related risks and realization of transportation inter- and intra-hospital. |

**3. Crisis and Exceptional Situations in Simulation (CrESiS) - management of critical and rare events, each of which require escalated care, performance of technical and patient management skills, and application of crisis resource management principles**

| | CrESiS Subcategories | CrESiS items |
|---|---|---|
| 1 | Cardiac Events | Cardiac arrest - adult patient |
| 2 | Cardiac Events | Cardiac arrest - pediatric patient |
| 3 | Cardiac Events | Perioperative management of ST segment changes (including MI) |
| 4 | Cardiac Events | Cardiac Arrhythmias (Supraventricular and non-lethal ventricular arrhythmias, sinus bradycardia) |
| 5 | Cardiac Events | Cardiac tamponade |
| 6 | Cardiac Events | Hypotension (ranging from moderate to severe--requiring more than one intervention to correct) |
| 7 | Shock States | Hemorrhagic shock |
| 8 | Shock States | Cardiogenic shock |
| 9 | Shock States | Septic shock |
| 10 | Shock States | Anaphylactic shock |
| 11 | Shock States | Management of a trauma patient |
| 12 | Respiratory Events | Hypoxemia |
| 13 | Respiratory Events | Massive aspiration event |
| 14 | Respiratory Events | Post-extubation respiratory distress |

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| 15 | Respiratory Events | Unplanned extubation |
| 16 | Respiratory Events | Pneumothorax |
| 17 | Respiratory Events | Acute pulmonary edema |
| 18 | Respiratory Events | Embolism (venous thromboembolism, air or carbon dioxide, fat and amniotic fluid) |
| 19 | Respiratory Events | Bronchospasm |
| 20 | Respiratory Events | Laryngospasm |
| 21 | Environmental Events | OR evacuation (due to fire or environmental cause) |
| 22 | Environmental Events | Management of inadvertent erroneous medication administration event (neuromuscular blockade, pressor, hypnotic, opioid, etc.) |
| 23 | Environmental Events | Supply failure (oxygen or power) |
| 24 | Environmental Events | Transfusion reaction |
| 25 | Environmental Events | Conflict management (with patients or with staff) |
| 26 | Obstetric/Perinatal Events | Newborn resuscitation |
| 27 | Obstetric/Perinatal Events | Pre-eclampsia and eclampsia |
| 28 | Obstetric/Perinatal Events | Obstetric hemorrhage |
| 29 | Obstetric/Perinatal Events | Emergency cesarean delivery |
| 30 | Obstetric/Perinatal Events | Cardiac arrest in a pregnant woman |
| 31 | Anesthesia-related Events | Total spinal anesthesia |
| 32 | Anesthesia-related Events | Difficult tracheal intubation |
| 33 | Anesthesia-related Events | Malignant hyperthermia |
| 34 | Anesthesia-related Events | Local anesthetic systemic toxicity |

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