Consensus on technical procedures for simulation-based training in anaesthesiology

A Delphi-based general needs assessment

Bessmann, Ebbe L.; Østergaard, Helle T.; Nielsen, Bjørn U.; Russell, Lene; Paltved, Charlotte; Østergaard, Doris; Konge, Lars; Nayahangan, Leizl Joy

Published in:
Acta Anaesthesiologica Scandinavica

DOI:
10.1111/aas.13344

Publication date:
2019

Document version
Peer reviewed version

Citation for published version (APA):
Bessmann, E. L., Østergaard, H. T., Nielsen, B. U., Russell, L., Paltved, C., Østergaard, D., Konge, L., & Nayahangan, L. J. (2019). Consensus on technical procedures for simulation-based training in anaesthesiology: A Delphi-based general needs assessment. *Acta Anaesthesiologica Scandinavica*, *63*(6), 720-729. https://doi.org/10.1111/aas.13344

DR EBBE LAHN BESSMANN (Orcid ID : 0000-0002-9734-3426)
DR LENE RUSSELL (Orcid ID : 0000-0001-7352-8728)

Article type : Clinical investigation

TITLE PAGE

Title: Consensus on technical procedures for simulation-based training in anaesthesiology: A Delphi-based general needs assessment

Authors: Ebbe L. Bessmann[1,2], Helle T. Østergaard[2,3], Bjørn U. Nielsen[4], Lene Russell[1,5,6], Charlotte Paltved[7], Doris Østergaard[1,2], Lars Konge[1,2], Leizl Joy Nayahangan[1]

Name and location of the institutions:

1) Copenhagen Academy for Medical Education and Simulation, The Capital Region of Denmark, Copenhagen and Herlev, Denmark
2) Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark
3) Department of Anaesthesia, Herlev Hospital, The Capital Region of Denmark, Denmark
4) TechSim – The Technical Simulation Centre of Southern Denmark, Odense University Hospital, Denmark
5) Department of Anaesthesia, Zealand University Hospital, Roskilde, Denmark
6) Department of Intensive Care 4131, Copenhagen University Hospital / Rigshospitalet, The Capital Region of Denmark, Denmark
7) MidtSim – Centre for Human Resources, Central Region of Denmark and Aarhus University, Aarhus, Denmark

Corresponding Author:
Ebbe Lahn Bessmann, MD, PhD Student
University of Copenhagen, Denmark

Copenhagen Academy for Medical Education and Simulation, The Capital Region of Denmark, Copenhagen, Denmark
Herlev Hospital, 25th floor, Herlev Ringvej 75, 2730 Herlev
Telephone: +45 51768676
E-mail: Ebbebessmann@gmail.com

Short title: Procedures for simulation-based training
Word count: 3140
Conflicts of interest: None

ABSTRACT

Background:

Anaesthesiologists are expected to master an increasing number of technical procedures. Simulation-based procedural training can supplement and, in some areas, replace the classical apprenticeship approach during patient care. However, simulation-based training is very resource-intensive and must be prioritised and optimised. Developing a curriculum for simulation-based procedural training should follow a systematic approach, e.g. the Six-Step Approach developed by Kern. The aim of this study was to conduct a national general needs assessment to identify and prioritise technical procedures for simulation-based training in anaesthesiology.

Methods:

A three-round Delphi process was completed with anaesthesiology key opinion leaders. In the first round, the participants suggested technical procedures relevant to simulation-based training. In the second round, a needs assessment formula was used to explore the procedures and produce a preliminary prioritised list. In the third round, participants evaluated the preliminary list by eliminating and re-prioritising the procedures.

Results:

All teaching departments in Denmark were represented with high response rates in all three rounds: 79%, 77%, and 75%, respectively. The Delphi process produced a prioritised list of 30 procedure-groups suitable for simulation-based training from the initial 138 suggestions. Top-5 on the final list was cardiopulmonary resuscitation, direct- and video laryngoscopy, defibrillation, emergency cricothyrotomy, and fibreoptic intubation. The needs assessment formula predicted the final prioritisation to a great extent.

Conclusion:

The Delphi process produced a prioritised list of 30 procedure groups that could serve as a guide in future curriculum development for the simulation-based training of technical procedures in anaesthesiology.

INTRODUCTION

Anaesthesiologists are expected to master an increasing number of technical procedures due to new techniques and technologically-advanced devices[1]. Performing challenging procedures can result in serious adverse events such as procedure-related complications, especially if the anaesthesiologist is inexperienced or not properly trained[2–4].

Currently, anaesthesiology trainees continue to learn procedures during patient care following the classical apprenticeship approach which has several weaknesses[5,6]. For procedural competence to develop bedside or in the operating room, the learner is dependent on expert instruction which might not be available. Insufficient exposure to the relevant procedures and competing concerns of patient safety and time limitations in the operating room may also impede experiential learning[6].

Simulation-based procedural training (SBPT) in anaesthesiology show promising results in effectiveness studies[7]. SBPT provides the trainees with the opportunity to learn at their own pace with the right degree of difficulty without fearing the consequences of failing. It can supplement and, in some areas, replace the classical apprenticeship approach and has therefore become an increasing part of education in anaesthesiology[5–7].

SBPT has many benefits but it is also costly. As the resources for education are limited in most health care systems, the focus of SBPT must be prioritised and optimised.

Developing an optimal curriculum for SBPT should follow a systematic approach, e.g. the six-step approach described by Kern[8]: 1. Problem identification and general needs assessment, 2. Targeted needs assessment, 3. Goals and objectives, 4. Educational strategies, 5. Implementation, and 6. Evaluation and feedback. Unfortunately, the first step is often neglected or performed in an unstructured fashion leading to SBPT programs based on local interests or available simulators[9].

Our research group has developed a structured approach to conducting a general needs assessment[10]. We have performed national needs assessments in several specialities using the Delphi process and a needs assessment formula (NAF)[10]. To our knowledge, there is no such prioritised list for anaesthesiology.

The aim of this study was to conduct a national general needs assessment to identify and prioritise technical procedures for simulation-based training in anaesthesiology.

MATERIALS AND METHODS

Study design

The Delphi process is a well-established consensus-building method for achieving agreement on the content of a curriculum[11]. The method uses iterative rounds of surveys followed by individual and/or group feedback until a consensus is achieved. The Delphi process has many advantages including anonymity of the individual respondent which eliminates the potential bias of dominant participants getting excessive influence. Other benefits are the participation of large numbers of experts from various geographic locations, and the inexpensive setup with internet access being the only prerequisite to participate[11].

Between March and July 2017, an iterative three-round Delphi process was completed to establish consensus and produce a prioritised list of technical procedures for SBPT in anaesthesiology (Figure 1). In this study, all correspondences were sent to the participants individually through e-mail.

A steering committee of four members with experience in medical education and simulation (ELB, HTØ, LJN, and LK) supervised all processes including identification of participants, development of questionnaires, data collection, and data analysis.

Participants

The participants were key opinion leaders defined as physicians who had significant roles and involvement in the local, regional, and national planning and implementation of education and training of anaesthesiologists representing the four pillars of anaesthesiology in Denmark: anaesthesia, intensive care, pain and emergency medicine. A total of 106 participants were identified with some of the participants being members of more than one group (Table 1). The participants were all anaesthesiologists except for the eight anaesthesiology trainee board members. All participants were working clinically except a minority of the heads of department.

The Delphi process

In the first Delphi round, the participants were asked to elaborate on an open-ended question: "Which technical procedures do you believe a newly graduated specialist in anaesthesiology should be able to perform?"

The participants' responses were analysed and summarised by the steering committee. Second, the summarised answers were evaluated according to the following definition of technical procedures in anaesthesiology: "Clinical procedures using equipment involving direct contact with a patient". Knowledge-based responses and non-technical skills were removed from the list. Finally, closely related procedures that could be taught during the same simulation-based course were grouped together. These procedure groups were used in the next Delphi rounds.

In the second Delphi round, the participants review the procedures from the first round to produce a preliminary prioritised list of procedures suitable for SBPT. The Copenhagen Academy for Medical Education and Simulation (CAMES) needs assessment formula (NAF)[10] was utilised to prioritise the procedures according to four important factors:

1. Frequency of the procedure
2. Doctors (i.e. the number of potential trainees)
3. Impact on patients
4. Feasibility of SBPT

The CAMES NAF score estimates the need for SBPT for each procedure. Frequency, Doctors, and Impact were stated as multiple-choice items on a scale of 1-5 and answered by each participant through an online survey:

Frequency: The frequency of the procedures in your department; 1: Never or few times yearly, 2: Few times monthly, 3: Few times weekly, 4: Few times daily, 5: Many times daily.

Doctors: The number of doctors who should be able to perform the procedure in the department; 1: 0-20%, 2: 21-40%, 3: 41-60%, 4: 61-80%, 5: 81-100%.

Impact: The impact of training explored by agreement with the following statement: “This procedure is uncomfortable or risky to the patient if performed by a non-competent doctor”; 1: Strongly disagree, 2: Disagree, 3: Neither agree nor disagree, 4: Agree, 5: Strongly agree.

Feasibility: The feasibility of SBPT was assessed by the steering committee considering all types of simulation (part-task trainer / full-body simulator / healthy volunteer / animal model / cadaver / virtual reality / augmented reality etc.). Feasibility was calculated as the mean score of three equally weighed factors explored on a five-point Likert scale ranging from 1 to 5: Suitability for SBPT, equipment availability, and associated costs (Appendix A).

The CAMES NAF score for the individual procedures was the sum of the mean scores (1-5) of the four factors (frequency, physicians, impact, and feasibility) giving each factor 25% weight. The resulting total CAMES NAF score from 4 to 20 points determined the procedures’ ranking on the preliminary prioritised list.

In the third and final Delphi round, participants were invited to evaluate the preliminary list of procedures from the second round by answering an online survey consisting of two parts: First, procedures could be eliminated if the participant did not believe they should be part of a future simulation-based curriculum, and second, the remaining procedures could be re-prioritised.

Ethics

The collected data were anonymised. The Danish legislation exempts this type of study from ethical approval.

Statistical analysis

In the first Delphi round, technical procedures were analysed and grouped using summative content analysis. In the second Delphi round, descriptive analysis was performed by calculating the total mean scores of each question from the online survey and the feasibility analysis. The CAMES NAF score was used to produce a preliminary prioritised list of procedure groups. In the third Delphi round, frequency analysis was used to explore the number of occurrences. The principle of $2/3^{rd}$ qualified majority was employed, removing procedure groups if more than $1/3^{rd}$ of the participants had chosen to eliminate them. Finally, the mean scores of the remaining procedures were calculated to prioritise the final list.

The Spearman's rank correlation coefficient was calculated to compare the final prioritised list after the third round with the preliminary prioritised list after the second round.

All statistical analysis was performed using IBM SPSS Statistics version 24 (IBM Corp., Armonk, New York).

RESULTS

A total of 106 anaesthesiologists were invited for all three rounds of the study. All departments in Denmark involved in specialist training of future anaesthesiologists were represented.

Delphi round 1

The response rate was 79% (84/106) and 220 unique suggestions were identified. Eighty-two suggestions were removed from the list as they were not technical procedures according to the definition used, e.g. "analysis of arterial blood gas", "interpretation of advanced hemodynamic monitoring" and similar. The remaining 138 technical procedures were categorised into 51 procedure groups.

Delphi round 2

The response rate was 77% (82/106). The 51 procedure groups from the first round were ranked according to the CAMES NAF score. Central venous access ranked the highest as the procedure is performed very frequently and should be mastered by all specialists in anaesthesiology. Furthermore, it can have serious consequences if performed by an inexperienced, untrained physician and it is very feasible to practice in a simulation-based environment (realistic and relatively cheap phantoms are available). Lateral canthotomy gained the lowest score primarily based on the very infrequent performance of the procedure and because it is difficult to train using simulation. Table 2 presents the complete preliminary prioritised list including the CAMES NAF score.

Delphi round 3

The response rate was 75% (79/106). Twenty-one procedure groups were eliminated and the remaining 30 were re-prioritised into a final list of procedure groups that should be included in a simulation-based curriculum (Table 3).

There was a strong correlation between the ranking order of the preliminary list produced by the CAMES NAF after the second round and the final prioritised list after the third round with Spearman's rank correlation coefficient = 0.72, $p<0.001$ (Figure 2). From the second to the third round the most upgraded procedures included emergency cricothyrotomy (EC) from 21st place to 4th place, cardiopulmonary resuscitation (9th to 1st place), use of defibrillator (11th to 3rd place), and fibreoptic intubation (13th to 5th place), while the most downgraded procedures included central venous access (1st to 12th place), epidural anaesthesia (3rd to 14th place), spinal anaesthesia (4th to 16th place), and abdominal and truncal nerve blocks in a middle position (26th of 51 procedures) ending as the lowest ranked procedure on the 30th place (see Figure 2).

DISCUSSION

A prioritised list of 30 technical procedure groups suitable for SBPT was produced by an iterative three-round Delphi process among key opinion leaders in education in anaesthesiology. All departments involved in the specialist training programme in Denmark were represented, and the response rates were consistently high in all three rounds, which increased the generalisability and credibility of the study results.

The CAMES NAF prioritises procedures if they are frequent, performed by many physicians, potentially harmful to patients if performed by a non-competent physician, and easy to train with simulation. In the third round, the key opinion leaders were free to remove and rearrange the procedures from the second round if they did not agree with the prioritisation. A strong correlation was found between the ranking order after the second and third rounds, indicating that the key opinions leaders mostly agreed with the results based on CAMES NAF, which is consistent with previous studies[10].

The procedures mentioned in the final list (Table 3) will in the following be discussed using six headlines: Airway management, advanced life support procedures, point-of-care ultrasonography, peripheral nerve blocks, vascular access, and prehospital and intensive care.

1. Airway management

Airway management procedures dominated the top half of the final list. As airway management is a core competency for all anaesthesiologists, this was to some extent to be expected, but it also reflects that SBPT is a valued and preferred way of learning airway management.

The development in airway management has continually introduced new devices and techniques that anaesthesiologists must master[1]. For a new technology to improve patient safety, careful implementation and training of the new procedures are required, and SBPT could be considered for this purpose[12,13].

Some airway management procedures are performed infrequently and are not eligible for experiential learning in the operating room. The skills for these procedures must be acquired and maintained outside the operating room, as illustrated by EC which was highly prioritised in the final Delphi round and the only procedure that all participants voted to be included in the final list. The need for SBPT of airway management, especially EC, has previously been highlighted by studies such as the Fourth National Audit Project (NAP4)[3]: Only 36% of EC attempts were successful and poor education/training was a contributing factor to airway management failure in 49% of cases[3,4]. In a recent study exploring emergency surgical airway management, the success rate for the anaesthesiologist performing EC was 50% and airway management was evaluated as satisfactory in only 37% of the cases[14]. Much knowledge is now available on how to teach EC[15], and procedural skills can be improved considerably using only an instructional video and inexpensive low-fidelity simulation equipment[16]. Similarly, another key element of difficult airway management, fibreoptic intubation (FOI), can effectively be trained and assessed using simulation[17]. Overall, there is an increasing focus on improving patient safety in airway management[18] with a growing body of evidence supporting the benefits of SBPT[13].

2. Advanced life support procedures

Procedures related to advanced life support (ALS) were also prioritised which aligns with a recent study that demonstrated the need for SBPT in ALS-related procedures[19]. The ALS-courses held by the European Resuscitation Council (ERC) provide the opportunity to train most of the ALS-related procedures, but since participation is voluntary, not all anaesthesiologists have attended and few maintain their competencies with recertification courses. Training with high-fidelity manikins for ALS-procedures improves skills performance[20], and high-fidelity manikins are increasingly available at simulation centres. Systematic efforts have been put into developing a simulation-based mastery learning curriculum for ALS-procedures[21].

3. Point-of-care ultrasonography

The applications of Point-of-Care UltraSonography (PoCUS) is increasingly used in anaesthesiology[22]. While its use was considered controversial 5 to 10 years ago, it has now become the standard of care for vascular access and regional anesthesia[22,23]. The final list in this study included three areas of diagnostic PoCUS; Focused lung ultrasonography (FLUS)[24], focused cardiac ultrasonography (FoCUS)[25], and focused assessment with ultrasonography for trauma (FAST)[26]. Focused abdominal ultrasonography and focused intensive care ultrasonography were discarded after the second round, most likely because they are regarded as specialised procedures that only some anaesthesiologists should master. Clinical training and the necessary supervision is challenged by the fact that many anaesthesiologists use PoCUS infrequently and may not be formally trained[27]. Further training and assessment can be achieved during hands-on workshops and on advanced ultrasound simulators[27].

4. Peripheral nerve blocks

Peripheral nerve blocks of the lower extremity, abdomen, and truncus were included in the final list, whereas the upper extremity nerve blocks were surprisingly excluded. While upper extremity nerve blocks are important procedures for anaesthesiologists, the decision to remove them from the final list reflects that the key opinion leaders did not consider them as a priority for training in a simulation-based environment. Most peripheral nerve blocks are now guided by ultrasonography which has reduced the incidence of complications such as vascular puncture, and local anaesthetic systemic toxicity[28]. Several different teaching programs have been developed and implemented[29], and SBPT of ultrasound-guided peripheral nerve blocks significantly improves learners' knowledge and skills[30].

5. Vascular access

Vascular access is another core competency for anaesthesiologists. Arterial line insertion ranked 6th place in the second round but was surprisingly discarded in the third round. While arterial line insertion did not make it to the final list, peripheral venous access stayed in 10th place after both rounds. As the procedures for arterial and venous line insertion are technically similar, the decision to discard arterial line insertion may reflect the higher frequency and greater diversity in the techniques required to accomplish peripheral venous access using various devices for different patient groups (ex. small children) and for different anatomical sites with or without ultrasound guidance.

Central venous access ranked the highest after the second round but dropped down the list to the 12th place in the third round which might indicate that some of the participants found it feasible to continue practising this procedure on patients. However, placement of central venous catheters involves a high risk of iatrogenic complications, which can be significantly reduced by SBPT [32]. A SBPT program with deliberate practice for central venous catheter insertion demonstrated a significant increase in the technical skills of trainees[33]. The implementation of SBPT on central venous catheter insertion has furthermore been shown to be highly cost-effective as it significantly reduced catheter-related bloodstream infections[34]. Implementation of SBPT is costly and return on investment studies can provide a much-needed argument when discussing the costs with stakeholders. Unfortunately, there are still only a few studies exploring this topic[35].

6. Prehospital and intensive care

Some of the procedures on the list are primarily prehospital (spinal stabilisation in trauma, automatic external chest compression, external haemorrhage control, and midwifery) and procedures relating to intensive care (percutaneous dilatational tracheostomy and bronchoscopy). In Denmark, anaesthesiologists are also trained in intensive care medicine and prehospital medicine, which explains the presence of these procedures.

Discussion of the methods used

As the included key opinion leaders represent all departments involved in the specialist training programme in Denmark, the results constitute a strong national consensus reflecting our national needs and educational practices. Although there are differences in local healthcare delivery, competencies needed as an anaesthesiologist are alike across borders, and we believe the majority of study findings are generalisable to other healthcare systems.

The grouping of procedures is a limitation. As the initial 138 suggested procedures were not feasible to explore individually, the grouping of procedures was a practical necessity that could make the answers to the questions in the second round less precise. The participants were asked to focus on the most frequent procedure within the procedure groups, based on the belief that trainees would prioritise the common over the rare procedures.

The involvement of the steering committee by exploring feasibility for SBPT in the second round is another limitation. This decision was necessitated by the assumption that the participants do not have equivalent knowledge and experiences regarding simulation. However, feasibility weighs only 25% of the CAMES NAF. The participants remained the deciding power in the third round, where they were given the opportunity to eliminate and re-prioritise the procedures accordingly.

Some of the procedures on the final list may not yet be feasible to train with our current simulation modalities. However, we hope that the results will encourage simulation experts and simulation companies to develop SBPT equipment to address this need.

Finally, it is important to acknowledge that this study only covers the first step in Kern et al.'s six-step approach to curriculum development[8]. More steps are necessary to design a complete, simulation-based curriculum, i.e. a targeted needs assessment at the institutional level for the curriculum to comply with the local practices and traditions, followed by determination of goals/objectives, educational strategies, implementation, and evaluation and feedback[8]. Since the research question focusses on SBPT, all types of training *except* clinical training on patients could be considered when deciding on educational strategies, which might be considered a limitation.

CONCLUSIONS

The three-round Delphi process produced a prioritised list of 30 procedure groups suitable for simulation-based training. The list could be used to guide future curriculum development for the training of technical procedures in anaesthesiology.

ACKNOWLEDGEMENTS

The authors wish to thank Rikke Borre Jacobsen for her great help and advice in conducting the study.

FUNDING

Departmental funding only.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to disclose.

ORCID

E. L. Bessmann
https://orcid.org/0000-0002-9734-3426

REFERENCES

1. McNarry AF, Patel A. The evolution of airway management - new concepts and conflicts with traditional practice. Br J Anaesth 2017 ; 119: i154–66.
2. Cook TM, Counsell D, Wildsmith JAW. Major complications of central neuraxial block: Report on the Third National Audit Project of the Royal College of Anaesthetists. Br J Anaesth 2009 ; 102: 179–90.
3. Cook TM, Woodall N, Frerk C. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 1: Anaesthesia. Br J Anaesth 2011 ; 106: 617–31.
4. Cook TM, Woodall N, Harper J, Benger J. Major complications of airway management in the UK: Results of the Fourth National Audit Project of the Royal College of Anaesthetists and the Difficult Airway Society. Part 2: Intensive care and emergency departments. Br J Anaesth 2011 ; 106: 632–42.
5. Yunoki K, Sakai T. The role of simulation training in anesthesiology resident education. J Anesth 2018 ; 32: 425–33.
6. Green M, Tariq R, Green P. Improving Patient Safety through Simulation Training in Anesthesiology: Where Are We? Anesthesiol. Res. Pract.2016
7. Lorello GR, Cook DA, Johnson RL, Brydges R. Simulation-based training in anaesthesiology: a systematic review and meta-analysis. Br J Anaesth 2014 ; 112: 231–45.
8. Thomas PA, Kern DE, Hughes MT, Chen BY. Curriculum Development for Medical Education: A Six-Step Approach. 3nd ed. Baltimore: Johns Hopkins University Press, 2016.
9. Khamis NN, Satava RM, Alnassar SA, Kern DE. A stepwise model for simulation-based curriculum development for clinical skills, a modification of the six-step approach. Surg Endosc Other Interv Tech 2016 ; 30: 279–87.
10. Nayahangan LJ, Stefanidis D, Kern DE, Konge L. How to identify and prioritize procedures suitable for simulation-based training: Experiences from general needs assessments using a modified Delphi method and a needs assessment formula. Med Teach 2018 ; 40: 676–83.
11. Humphrey-Murto S, Varpio L, Wood TJ, Gonsalves C, Ufholz L-A, Foth T. The Use of the Delphi and Other Consensus Group Methods in Medical Education: A Review. Acad Med 2016 ; 91: S11.
12. Baker PA, Feinleib J, O'Sullivan EP. Is it time for airway management education to be mandatory? Br. J. Anaesth.2016 ; 117: i13–6.
13. Kennedy CC, Cannon EK, Warner DO, Cook DA. Advanced airway management simulation training in medical education: a systematic review and meta-analysis. Crit Care Med 2014 ; 42: 169–78.
14. Rosenstock C V., Nørskov AK, Wetterslev J, Lundstrøm LH. Emergency surgical airway management in Denmark: A cohort study of 452 461 patients registered in the Danish Anaesthesia

Database. Br J Anaesth 2016 ; 117: i75–82.

15. Kristensen MS, Teoh WH, Baker PA. Percutaneous emergency airway access: Prevention, preparation, technique and training. Br J Anaesth 2015 ; 114: 357–61.
16. Melchiors J, Todsen T, Nilsson P, Kohl AP, Bøttger M, Charabi B, Konge L, von Buchwald C. Self-directed simulation-based training of emergency cricothyroidotomy: a route to lifesaving skills. Eur Arch Oto-Rhino-Laryngology 2016 ; 273: 4623–8.
17. Nilsson PM, Russell L, Ringsted C, Hertz P, Konge L. Simulation-based training in flexible fibreoptic intubation. Eur J Anaesthesiol 2015 ; 32: 609–14.
18. Cook TM. Strategies for the prevention of airway complications - a narrative review. Anaesthesia 2018 ; 73: 93–111.
19. Lauridsen KG, Schmidt AS, Caap P, Aagaard R, Løfgren B. Clinical experience and skills of physicians in hospital cardiac arrest teams in Denmark: A nationwide study. Open Access Emerg Med 2017 ; 9: 37–41.
20. Cheng A, Lockey A, Bhanji F, Lin Y, Hunt EA, Lang E. The use of high-fidelity manikins for advanced life support training-A systematic review and meta-analysis. Resuscitation 2015 ; 93: 142–9.
21. Barsuk JH, Cohen ER, Wayne DB, Siddall VJ, McGaghie WC. Developing a Simulation-Based Mastery Learning Curriculum. Simul Healthc J Soc Simul Healthc 2016 ; 11: 52–9.
22. Ramsingh D, Fox JC, Wilson WC. Perioperative point-of-care ultrasonography: An emerging technology to be embraced by anesthesiologists. Anesth Analg 2015 ; 120: 990–2.
23. Lewis S, Price A, Walker K, McGrattan K, Smith A. Ultrasound guidance for upper and lower limb blocks (Review) SUMMARY OF FINDINGS FOR THE MAIN COMPARISON. Cochrane Database Syst Rev 2015 doi: 10.1002/14651858.CD006459.pub3.www.cochranelibrary.com
24. Volpicelli G, Elbarbary M, Blaivas M, Lichtenstein DA, Mathis G, Kirkpatrick AW, Melniker L, Gargani L, Noble VE, Via G, Dean A, Tsung JW, Soldati G, Copetti R, Bouhemad B, Reissig A, Agricola E, Rouby JJ, Arbelot C, Liteplo A, Sargsyan A, Silva F, Hoppmann R, Breitkreutz R, Seibel A, Neri L, Storti E, Petrovic T. International evidence-based recommendations for point-of-care lung ultrasound. Intensive Care Med 2012 ; 38: 577–91.
25. Via G, Hussain A, Wells M, Reardon R, ElBarbary M, Noble VE, Tsung JW, Neskovic AN, Price S, Oren-Grinberg A, Liteplo A, Cordioli R, Naqvi N, Rola P, Poelaert J, Gulič TG, Sloth E, Labovitz A, Kimura B, Breitkreutz R, Masani N, Bowra J, Talmor D, Guarracino F, Goudie A, Xiaoting W, Chawla R, Galderisi M, Blaivas M, Petrovic T, Storti E, Neri L, Melniker L, International Liaison Committee on Focused Cardiac UltraSound (ILC-FoCUS), International Conference on Focused Cardiac UltraSound (IC-FoCUS). International evidence-based recommendations for focused cardiac ultrasound. J. Am. Soc. Echocardiogr.2014 ; 27: 683.e1-683.e33.

26. Williams SR, Perera P, Gharahbaghian L. The FAST and E-FAST in 2013: Trauma Ultrasonography. Overview, practical techniques, controversies, and new frontiers. Crit Care Clin 2014 ; 30: 119–50.

27. Deshpande R, Montealegre-Gallegos M, Matyal R, Belani K, Chawla N. Training the anesthesiologist in point-of-care ultrasound. Int Anesthesiol Clin 2016 ; 54: 71–93.

28. Lewis SR, Price A, Walker KJ, Mcgrattan K, Smith AF. Ultrasound guidance for upper and lower limb blocks. Cochrane Database Syst Rev 2015

29. Kessler J, Wegener JT, Hollmann MW, Stevens MF. Teaching concepts in ultrasound-guided regional Anesthesia. Curr Opin Anaesthesiol 2016 ; 29: 608–13.

30. Chen XX, Trivedi V, Alsaflan AHA, Todd SC, Tricco AC, McCartney CJL, Boet S. Ultrasound-Guided Regional Anesthesia Simulation Training: A Systematic Review. Reg Anesth Pain Med 2017 ; 42: 741–50.

31. Bream PR. Update on Insertion and Complications of Central Venous Catheters for Hemodialysis. Semin Intervent Radiol 2016 ; 33: 31–8.

32. Barsuk JH, McGaghie WC, Cohen ER, O'Leary KJ, Wayne DB. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. Crit Care Med 2009 ; 37: 2697–701.

33. Corvetto MA, Pedemonte JC, Varas D, Fuentes C, Altermatt FR. Simulation-based training program with deliberate practice for ultrasound-guided jugular central venous catheter placement. Acta Anaesthesiol Scand 2017 ; 61: 1184–91.

34. Cohen ER, Feinglass J, Barsuk JH, Barnard C, O'Donnell A, McGaghie WC, Wayne DB. Cost Savings From Reduced Catheter-Related Bloodstream Infection After Simulation-Based Education for Residents in a Medical Intensive Care Unit. Simul Healthc J Soc Simul Healthc 2010 ; 5: 98–102.

35. Zendejas B, Wang AT, Brydges R, Hamstra SJ, Cook DA. Cost: The missing outcome in simulation-based medical education research: A systematic review. Surg (United States) 2013 ; 153: 160–76.

LEGENDS

Figure 1. A general overview of the three-round Delphi process

Figure 2. The correlation between the ranking order of the final 30 procedures after the second and third Delphi rounds. The x-axis shows the ranking after the second round (out of 51 procedures), while the y-axis shows the ranking after the third round (30 procedures)

Table 1. Key opinion leaders in education in anaesthesiology in Denmark

Table 2. Preliminary prioritisation according to the CAMES NAF score after the second Delphi round

Table 3. The final prioritised list of 30 procedure groups for simulation-based training in anaesthesiology

TABLE 1 Key opinion leaders in education in anaesthesiology in Denmark	
Function	**n**
Heads of department at departments of anaesthesiology and intensive care	33
Consultants responsible for clinical education at departments of anaesthesiology and intensive care	33
Course directors of the national education program of specialist training in anaesthesiology	24
Members of the board of the Danish Society for Anaesthesiology and Intensive Care Medicine	15
Members of the committee on education for the Danish Society for Anaesthesiology and Intensive Care Medicine	11
Members of the board of the Society of Young Anaesthesiologists in Denmark	8
Regional postgraduate assistant professors	4

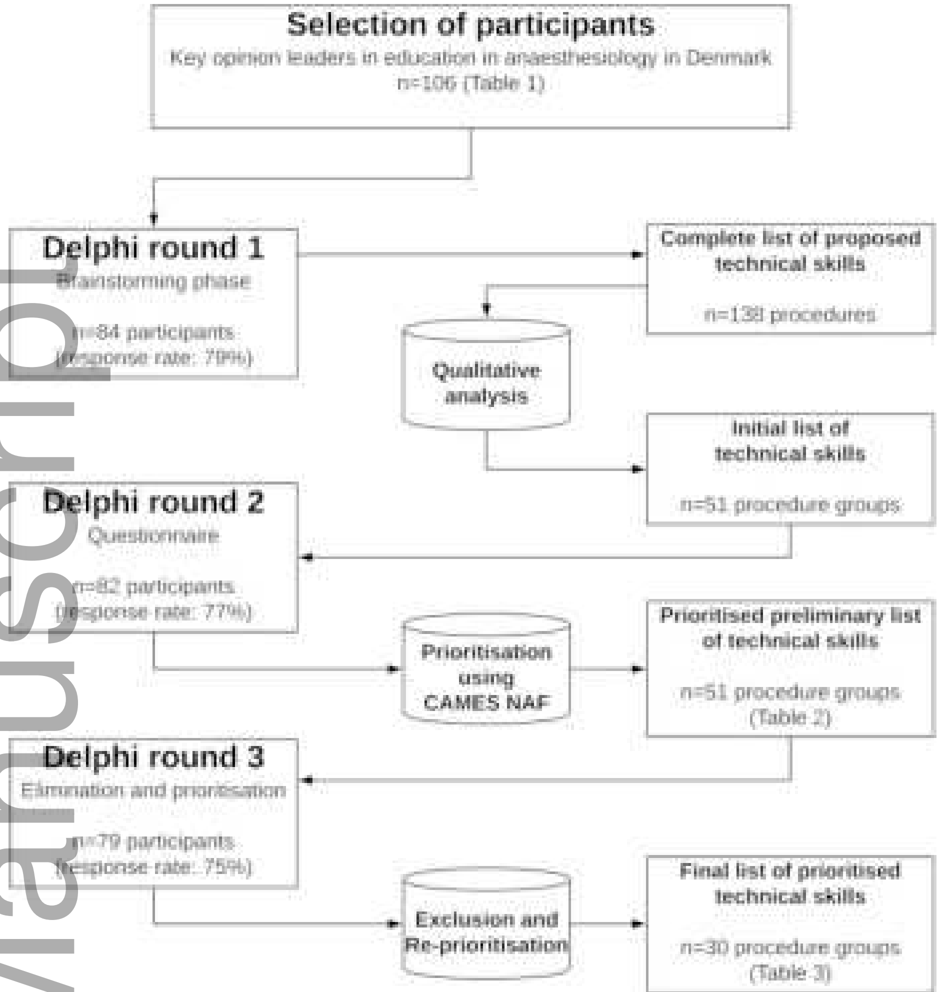
TABLE 2 Preliminary prioritisation according to the CAMES NAF score after the second Delphi round

	Procedure group	Frequency	Physicians	Impact	Feasibility	CAMES NAF score
1	Central venous access	4.44	4.99	4.66	4.33	18.42
2	Direct laryngoscopy and video laryngoscopy	4.68	4.99	4.73	4.00	18.40
3	Epidural anaesthesia	4.20	4.80	4.73	4.33	18.06
4	Spinal anaesthesia	4.27	4.84	4.59	4.33	18.03
5	Spinal stabilisation in trauma	3.00	4.68	4.39	5.00	17.07
6	Arterial line insertion	4.50	4.95	4.23	3.33	17.01
7	Optimal face mask ventilation	4.36	4.98	4.31	3.33	16.98
8	Supraglottic airway devices	4.32	4.94	4.37	3.33	16.96
9	Cardiopulmonary resuscitation	2.85	5.00	4.75	4.33	16.93
10	Peripheral venous access	4.40	4.85	3.95	3.67	16.87
11	Use of defibrillator	2.85	4.93	4.61	4.33	16.72
12	Nasogastric tube insertion	4.24	4.88	3.93	3.67	16.72
13	Fibreoptic intubation	2.57	4.67	4.76	4.33	16.33
14	Upper extremity nerve blocks	4.27	4.11	4.47	3.33	16.18
15	Urinary catheterisation	3.94	4.39	4.08	3.67	16.08
16	Lower extremity nerve blocks	4.15	3.98	4.37	3.33	15.83
17	Sheet insertion	2.53	4.26	4.50	4.33	15.62
18	Automatic external chest compression system	2.40	4.28	4.46	4.33	15.47
19	Neonatal airway management	2.58	3.89	4.78	4.00	15.25
20	Pleural drainage	2.04	4.00	4.54	4.67	15.25
21	Emergency cricothyrotomy	1.01	4.76	4.61	4.33	14.71
22	Percutaneous dilatational tracheostomy	2.59	3.39	4.73	3.67	14.38
23	Focused cardiac ultrasonography	3.52	3.76	3.36	3.33	13.97
24	Double-lumen endotracheal tube insertion	2.60	3.00	4.65	3.67	13.92
25	FAST ultrasonography	3.26	3.89	3.24	3.33	13.72
26	Abdominal and truncal nerve blocks	3.39	3.74	4.16	2.33	13.62
27	Percutaneous transtracheal jet-oxygenation	1.41	3.58	4.54	4.00	13.53
28	Focused lung ultrasonography	3.13	3.67	3.32	3.33	13.45
29	Umbilical catheter insertion	1.62	3.27	4.22	4.33	13.44
30	Alternative types of ventilation	2.71	4.19	4.42	2.00	13.32
31	Intravenous regional anaesthesia	2.36	3.72	4.12	3.00	13.20
32	Transoesophageal echocardiography	3.15	2.36	4.00	3.67	13.18
33	Bronchoscopy	2.18	2.64	4.35	4.00	13.17
34	Midwifery	1.07	3.11	4.48	4.33	12.99

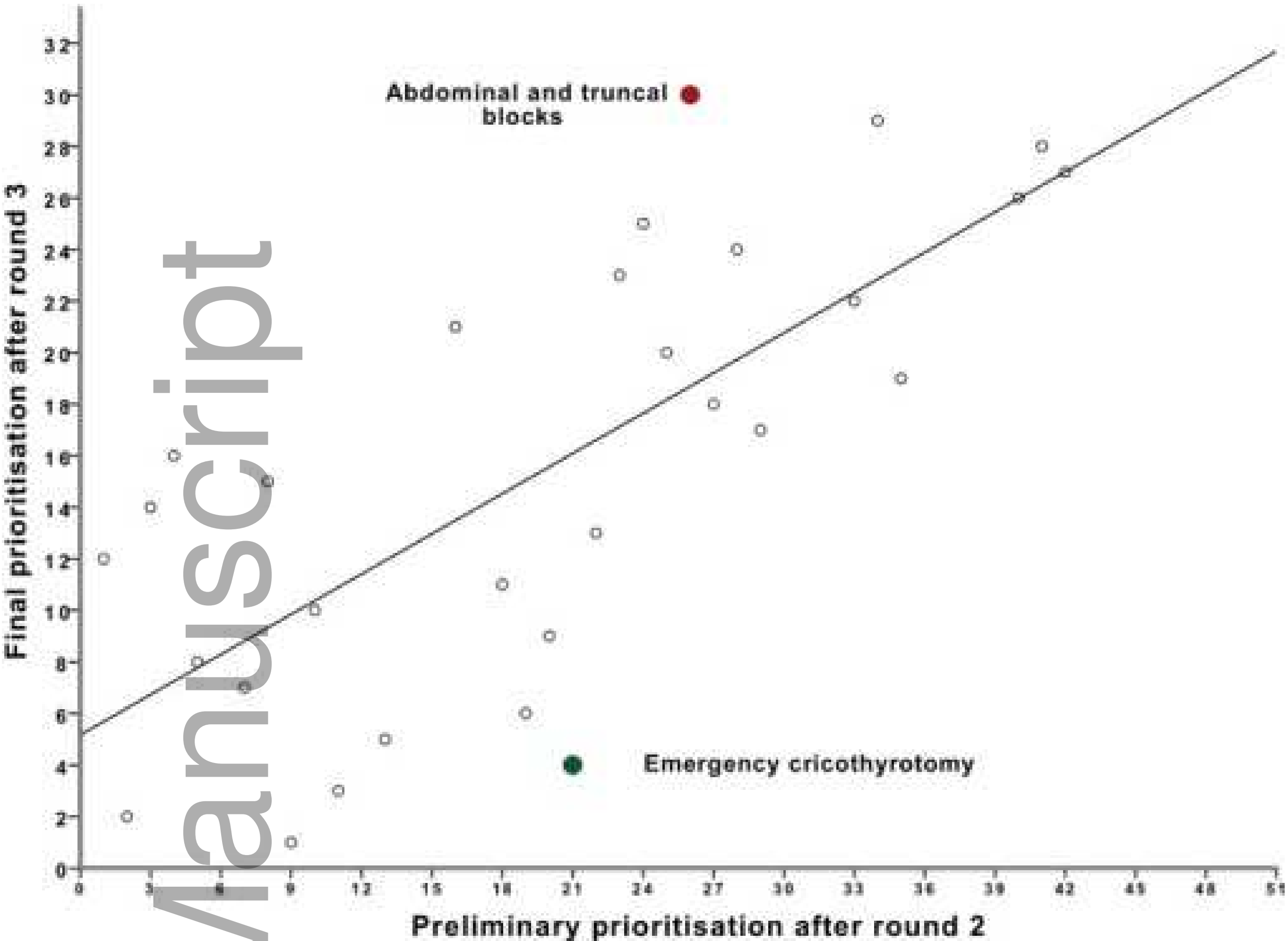
35	External haemorrhage control	1.56	4.54	4.47	2.33	12.90
36	Permanent venous catheter insertion	3.09	2.29	4.46	3.00	12.84
37	Terminal nerve blocks	2.83	3.13	4.09	2.67	12.72
38	Pulmonary artery catheter	2.50	3.28	4.55	2.33	12.66
39	Focused abdominal ultrasonography	2.38	2.95	3.32	3.67	12.32
40	Retrograde intubation	1.22	2.42	4.29	4.33	12.26
41	Pericardiocentesis	1.19	2.89	4.59	3.33	12.00
42	Finger thoracostomy	1.24	3.15	4.59	3.00	11.98
43	Sacral nerve block	2.29	2.14	4.52	3.00	11.95
44	Resuscitative endovascular balloon occlusion of the aorta (REBOA)	1.20	2.00	4.64	3.67	11.51
45	Long line catheter insertion	2.82	3.21	3.80	1.67	11.50
46	Ascitic drain insertion	1.89	2.19	3.93	3.33	11.34
47	Focused intensive care ultrasonography	2.54	2.35	3.38	2.67	10.94
48	Joint repositioning	1.68	3.43	4.08	1.67	10.86
49	Clamshell thoracotomy	1.00	2.18	4.36	3.00	10.54
50	Emergency escharotomy	1.05	2.59	4.04	1.67	9.35
51	Lateral canthotomy	1.00	2.60	3.67	1.67	8.94

TABLE 3 The final prioritised list of 30 procedure groups for simulation-based training in anaesthesiology		
	Procedure group	**Description**
1	Cardiopulmonary resuscitation	Chest compressions and face mask ventilation for adults, children and neonates
2	Direct laryngoscopy and video laryngoscopy	Direct laryngoscopy with Macintosh blade, video laryngoscopy with Macintosh and hyperangulated blade, use of various endotracheal tubes (e.g. spiral and RAE), tube exchanger, and bougie. For adults and children
3	Use of defibrillator	Defibrillation – manual and with AED, sync. cardioversion, transcutaneous pacing
4	Emergency cricothyrotomy	Narrow-bore cannula, wide-bore cannula-over-trochar, wide-bore cannula w. Seldinger, surgical technique such as Rapid 4-Step. For adults
5	Fibreoptic intubation	Fibreoptic intubation (awake/asleep, nasal/oral), fibreoptic guided tracheal intubation through 2nd gen. supraglottic airway device, video laryngoscopy for awake intubation, local anaesthetic for upper airway for awake intubation. For adults
6	Neonatal airway management	Optimal face mask ventilation incl. oropharyngeal airway, nasopharyngeal airway, and optimal positioning. Mask-CPAP, supraglottic airway, direct- and video laryngoscopy
7	Optimal face mask ventilation	Optimal face mask ventilation with 1-2 persons using 2-3 hands, oropharyngeal airway, nasopharyngeal airway, and optimal positioning. Mask-CPAP, and application of mask for non-invasive ventilation. For adults and children
8	Spinal stabilisation in trauma	Use of spineboard, vacuum board, traumat ransfer board, and manual in-line cervical spine immobilisation
9	Pleural drainage	Surgical chest tube, ultrasonography-guided pig-tail chest tube, ultrasonography-guided thoracentesis, chest tube with Heimlich-valve for pneumothorax, needle decompression of pneumothorax, SAM chest seal or similar for open thoracic trauma
10	Peripheral venous access	IV line +/- ultrasonography using different types for all age groups, large IV lines with flow-switch for neck and groin (e.g. SECALON), IV line using transillumination (e.g. Astodia) for children, venous puncture, and intraosseous vascular access
11	Automatic external chest compression system	Automatic external chest compression system (e.g. LUCAS / Autopulse)
12	Central venous access	Central venous access +/- ultrasonography in the internal and external jugular vein, subclavian vein, femoral vein; ultrasonography-guided hemodialysis catheter in internal jugular vein, subclavian vein, and femoral vein
13	Percutaneous dilatational tracheostomy	Percutaneous dilatational tracheostomy +/- prior tracheal ultrasonography, change of tracheostomy and tracheal cannula (cuffed and uncuffed)
14	Epidural anaesthesia	Epidural anaesthesia +/- ultrasonography (lumbar and thoracic) with median and paramedian technique, epi-spinal anaesthesia, epidural blood patch, tunneling of epidural catheter
15	Supraglottic airway devices	Laryngeal mask airway, 2nd gen. laryngeal mask airway (iGel, ProSeal etc.), intubating laryngeal mask airway, nasogastric tube through 2nd gen. laryngeal mask airway
16	Spinal anaesthesia	Spinal anaesthesia +/- ultrasonography with median and paramedian technique, saddle block, hemiblock, spinal catheter, spinal drain, lumbar puncture
17	Umbilical catheter insertion	Catheterisation of umbilical vein and artery in newborn infants

18	Percutaneous transtracheal jet-oxygenation	Percutaneous transtracheal jet-oxygenation
19	External haemorrhage control	Control ongoing haemorrhage with tourniquet, compression, aorta compression, pelvic circumferential compression devices
20	FAST ultrasonography	Focussed Assessment with Sonography for Trauma incl. knobology of US machine
21	Lower extremity nerve blocks	Lower extremity nerve blocks (single shot block and catheters): Femoral block, subgluteal sciatic nerve block, distal sciatic nerve block, adductor channel block, saphenous nerve block
22	Bronchoscopy	Bronchoscopy incl. bronchoalveolar lavage, removal of foreign body from airways
23	Focused cardiac ultrasonography	Focused cardiac ultrasonography (e.g. focused echocardiography, critical care echocardiography etc.)
24	Focused lung ultrasonography	Focussed lung ultrasonography (FLUS) to diagnose pneumothorax, pleural effusion etc.
25	Double-lumen endotracheal tube insertion	Double-lumen endotracheal tube insertion incl. use of bronchial blocker and one-lung ventilation
26	Retrograde intubation	Retrograde intubation
27	Finger thoracostomy	Finger thoracostomy (alternative to needle thoracostomy for pneumothorax)
28	Pericardiocentesis	Pericardiocentesis +/- ultrasonography
29	Midwifery	Midwifery, perimortem sectio (prehospital)
30	Abdominal and truncal nerve blocks	Transversus abdomins plan block (TAP) high and low, rectus sheath block, Ilioinguinal nerve block, pectoralis plane block, intercostal block, paravertebral block



aas_13344_f1.jpg



aas_13344_f2.jpg