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REPORTS OF ORIGINAL INVESTIGATIONS

Competencies for proficiency in basic point-of-care ultrasound in anesthesiology: national expert recommendations using Delphi methodology

Compétences pour la maîtrise de l'échographie ciblée de base en anesthésiologie : recommandations d'expert·es au Canada utilisant la méthodologie Delphi

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Abstract

Purpose *Point-of-care ultrasound (POCUS) allows for rapid bedside assessment and guidance of patient care. Recently, POCUS was included as a mandatory component of Canadian anesthesiology training; however, there is no national consensus regarding the competencies to guide curriculum development. We therefore aimed to define national residency competencies for basic perioperative POCUS proficiency.*

Methods *We adopted a Delphi process to delineate relevant POCUS competencies whereby we circulated an online survey to academic anesthesiologists identified as POCUS leads/experts (n = 25) at all 17 Canadian anesthesiology residency programs. After reviewing a list of competencies derived from the Royal College of Physicians and Surgeons of Canada's National Curriculum, we asked participants to accept, refine, delete, or add competencies. Three rounds were completed between 2022 and 2023. We discarded items with < 50% agreement, revised those with 50–79% agreement based upon feedback provided, and maintained unrevised those items with ≥ 80% agreement.*

The names of collaborators from the Canadian Anesthesiology POCUS Consortium and their affiliations appear at the end of this article.

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Results *We initially identified and circulated (Round 1) 74 competencies across 19 clinical domains (e.g., basics of ultrasound [equipment, nomenclature, clinical governance, physics]; cardiac [left ventricle, right ventricle, valve assessment, pericardial effusion, intravascular volume status] and lung ultrasound anatomy, image acquisition, and image interpretation; and clinical applications [monitoring and serial assessments, persistent hypotension, respiratory distress, cardiac arrest]). After three Delphi rounds (and 100% response rate maintained), panellists ultimately agreed upon 75 competencies.*

Conclusion *Through national expert consensus, this study identified POCUS competencies suitable for curriculum development and assessment in perioperative anesthesiology. Next steps include designing and piloting a POCUS curriculum and assessment tool(s) based upon these nationally defined competencies.*

Résumé

Objectif *L'échographie ciblée (POCUS) permet une évaluation rapide au chevet des patient·es et l'orientation des soins aux patient·es. Récemment, l'échographie ciblée a été incluse en tant que composante obligatoire de la formation en anesthésiologie au Canada; cependant, il n'y a pas de consensus national sur les compétences qui guideront l'élaboration des programmes d'études. Nous avons donc cherché à définir les compétences à inclure dans les programmes de résidence nationaux pour acquérir des compétences de base en échographie ciblée périopératoire.*

Méthode *Nous avons adopté un processus Delphi pour délimiter les compétences pertinentes en échographie ciblée, processus dans le cadre duquel nous avons fait circuler un sondage en ligne auprès d'anesthésiologistes universitaires identifié·es comme des responsables/expert·es en échographie ciblée (n = 25) dans les 17 programmes canadiens de résidence en anesthésiologie. Après avoir examiné une liste de compétences tirées du programme d'études national du Collège royal des médecins et chirurgiens du Canada, nous avons demandé aux participant·es d'accepter, de peaufiner, de supprimer ou d'ajouter des compétences. Trois rondes ont été complétées entre 2022 et 2023. Nous avons écarté les éléments ayant < 50 % d'accord, révisé ceux avec 50 à 79 % d'accord en fonction des commentaires fournis, et maintenu sans révision les éléments obtenant ≥ 80 % d'accord.*

Résultats *Nous avons d'abord identifié et diffusé (ronde 1) 74 compétences dans 19 domaines cliniques (p. ex., les bases de l'échographie [équipement, nomenclature, gouvernance clinique, physique]; anatomie échographique cardiaque [ventricule gauche, ventricule droit, évaluation valvulaire, épanchement péricardique, état du volume intravasculaire] et pulmonaire [acquisition et interprétation d'images]; et applications cliniques [surveillance et évaluations en série, hypotension persistante, détresse respiratoire, arrêt cardiaque]). Après trois rondes Delphi (et un taux de réponse de 100 % maintenu), les panélistes se sont finalement mis·es d'accord sur 75 compétences.*

Conclusion *Grâce à un consensus d'expert·es au pays, cette étude a permis d'identifier les compétences en échographie ciblée adaptées à l'élaboration et à l'évaluation de programmes d'études en anesthésiologie périopératoire. Les prochaines étapes comprennent la conception et la mise à l'essai d'un programme d'études et d'outils d'évaluation en échographie ciblée basés sur ces compétences définies à l'échelle nationale.*

Keywords anesthesia residency · anesthesia training · assessment tool · Delphi · medical education · POCUS · point-of-care ultrasound

Point-of-care ultrasound (POCUS) is an important and noninvasive diagnostic tool that allows rapid assessment and guidance of patient care at the bedside. For instance, in the acute care setting (e.g., emergency medicine, critical care, anesthesiology), POCUS allows physicians to assess hemodynamically unstable patients in a binary (yes/no) fashion and answer multiple clinical questions to rule in/out important differential diagnoses that often have conflicting management goals. Point-of-care ultrasound has the additional benefit of 1) being highly sensitive; 2) not emitting ionizing radiation; 3) having lower associated costs compared with other diagnostic imaging modalities (e.g., computed tomography); 4) being immediately available at the bedside (thereby precluding the need to transfer unstable patients to the radiology department); and 5) allowing for serial real-time assessments to determine responsiveness to treatment and re-evaluation of the diagnosis in light of treatment response. When compared with physical examination, POCUS has improved accuracy in detecting cardiac[1] and lung[2] abnormalities, as well as free fluid in the abdomen.[3] Such benefits, combined with increasing advocacy[4,5] and adoption[6,7] of POCUS in the perioperative setting, led the Royal College of Physicians and Surgeons of Canada (RCPSC) to recently include POCUS as a mandatory component of Canadian anesthesiology training.[8] Currently, however, there is no national consensus regarding competencies of perioperative POCUS to guide curriculum development. Similarly, little consensus exists pertaining to the assessment of POCUS expertise/competence in clinical practice.[5] While some progress has been made with respect to the development and validation of competency-based assessments in critical care for cardiac[9] and thoracic[10] POCUS, similar tools specific to anesthesiology are still lacking,[5] leading to high variability in POCUS training among anesthesiology residency programs in Canada[6] and elsewhere.[11] To this end, a group of 55 anesthesiologists serving as POCUS leads at 12 Canadian universities recently published recommendations for training and performance in basic perioperative POCUS, providing a framework for the development of a standardized national POCUS curriculum in anesthesiology.[12]

Given the Competence by Design (CBD) paradigm recently adopted into Canadian medical education, the lack of a structured national POCUS curriculum[5–7] represents a significant gap in the specialty of anesthesiology both for resident trainees and practicing anesthesiologists, highlighting the need for urgent development of standardized and validated methods for assessing perioperative POCUS competencies in anesthesia. Indeed, without standardized, validated tools, assessments of competence are of limited value. Additionally, there is a clear need to define a series of agreed-upon competencies that can be used nationally to better inform POCUS curricula development in anesthesiology programs. The present investigation, therefore, aimed to define residency competencies for proficiency in basic perioperative POCUS using the Delphi method with expert consensus at the national level.[13] Notably, this study represents the first stage of a three-phase investigation and will serve as the basis for the development of a national standardized curriculum and for the creation of assessment tool(s) to measure these defined competencies (phase 2). Phase 3 will focus on the collection of validity evidence (i.e., related to content, response process, internal structure, etc.) from anesthesiology learners (residents and attending anesthesiologists) to support/refute the use of these assessment tool(s) as measures of POCUS competency using Messick's unified theory of validation.[14]

Methods

We obtained ethical approval from the Queen's University and Affiliated Teaching Hospital's Research Ethics Board (Kingston, ON, Canada; TRAQ #6026771) to conduct a Delphi study[15] to reach national consensus regarding competencies required for proficiency in basic perioperative POCUS. We circulated an initial set of competencies informed by the RCPSC's National Curriculum[8] and other relevant literature to experts across Canada for ongoing feedback (via iterative rounds of Delphi survey) until consensus was reached.

Setting and participants

We recruited panellists using purposive sampling, as recommended for the Delphi method.[16] Panellists were expert academic anesthesiologists who were identified (based upon coauthorship on previous relevant Canadian literature,[12] as well as through direct contact with anesthesiology department chairs and residency program directors) as POCUS leads at each of the 17 Canadian medical schools. Notably, larger residency programs with multiple hospitals/training sites may have been represented by more than one panel member depending on the number of individuals recognized as POCUS leads at that academic centre. All participants provided informed consent.

Data collection and analysis

Data were collected between April 2022 and February 2023. We administered all surveys via the Qualtrics platform (www.qualtrics.com; Seattle, WA, USA) to 25 panellists representing all 17 Canadian anesthesiology residency programs. The Round 1 survey (Electronic Supplementary Material [ESM] eAppendix 1) contained 74 proposed competencies required for proficiency in perioperative POCUS as determined by local experts (G. B. M., R. A., S. M.). We derived such competencies primarily from the RCPSC's National Curriculum[8] and other relevant sources[12,17] originating from a PubMed® search on POCUS Canadian competencies/curricula and assessment tools relevant to anesthesiology. The competencies spanned 19 clinical domains. The survey also included demographic (age, sex, specialty and/or subspecialty) and contextual (number of years in independent practice, number of years using/practicing POCUS, POCUS certifications or courses) information. For each competency, we asked panellists to rate their level of agreement (agree or disagree) with including the item in the final list of perioperative POCUS competencies, and/or indicate the need for revision (should be revised to …), with an opportunity to describe the revised statement for each competency. Additionally, we asked participants to identify any additional areas of expertise required that had not yet been captured and share any other comments about the competencies in each clinical domain.

We used the results from Round 1 to generate the survey for Round 2. In addition to modified POCUS-specific items based on qualitative feedback provided in Round 1, the survey for Round 2 also included a question about any assessment tools currently in place at the panellists' centre (ESM eAppendix 2). Any items that did not meet the necessary agreement level were discarded. We repeated this process for a third round (ESM eAppendix 3), after which consensus was reached.

We analyzed the quantitative data descriptively in the form of frequency and percentage of participants for each competency. For each round, we discarded items with < 50% agreement; revised those with 50–79% agreement based upon the qualitative feedback provided; and maintained unrevised those items with ≥ 80% agreement. The research team reviewed and revised any/all competencies that did not meet the agreement level but were above the discard level. Additionally, the research team also reviewed the qualitative data (feedback provided through the open-ended items) to identify and develop any new competencies as necessary.

Results

Three rounds were required for this Delphi process. Twenty-five individuals participated in each of the three rounds, of whom 64% identified as male and 36% as female. The mean age was 41 yr (range, 33–60 yr). There was a range of clinical experience, from between two and 32 years in independent practice, with a mean of nine years. The number of years using or practicing POCUS also ranged from four to 12 years, with a mean of 7.7 years. We achieved a response rate of 100% for each round. Table 1 details the Delphi process with the POCUS competencies organized according to clinical domain. A full list of competencies for Round 1 is available in ESM eAppendix 1, Round 2 in ESM eAppendix 2, Round 3 in ESM eAppendix 3, and a final list in Table 2.

In summary, we initially identified 74 competencies spanning 19 clinical domains that were circulated for Round 1, at the end of which 56 were accepted unchanged, 15 were revised, and three were discarded; in addition, four new competencies were added. For Round 2, 19 competencies were circulated, after which 12 were accepted and seven revised and recirculated for Round 3. After all three rounds, 75 competencies were ultimately agreed upon (Table 2).

Discussion

As access to ultrasound machines and POCUS expertise grows, so does POCUS use in clinical practice by both attending physicians and trainees of all levels. As such, there has been strong advocacy[4,5,18] for formally incorporating POCUS into residency training programs across multiple medical specialties, leading to the development of consensus statements of key POCUS competencies (as well as assessment tools) from numerous disciplines (e.g., internal medicine,[19] emergency medicine,[17,20] critical care medicine[9,10,21]) that have been early adopters both in Canada[17,19] and elsewhere.[9,10,20–22]

Accordingly, the RCPSC has recently recognized focused cardiac and lung ultrasound as an essential skill expected of anesthesiologists entering practice in Canada.[8] To ensure evidence-based use of POCUS and a standardized level of expertise of Canadian anesthesiology graduates, however, it is imperative to have nationally defined competencies upon which to base training curricula. The present article builds on pre-existing work done in the Canadian anesthesiology context[12] and serves as the most up to date and comprehensive set of competencies relevant to anesthesiology training programs and expands on the POCUS domains outlined in the Royal College curriculum.[8]

One notable strength of the current investigation lies on the use of a validated Delphi process[13] including a panel of POCUS experts from every anesthesiology training program across the country, thereby making the resulting competencies highly applicable to the Canadian context. The 100% response rate across all three rounds of questionnaires combined with the inclusion of every training centre in Canada may also increase buy-in and national implementation of these competencies going forward. In addition, given the broad nature of the competencies generated in this study (i.e., 75 competencies across 19 clinical domains), our results are more comprehensive than previous resources[12] and can serve as a robust starting point for the development of a standardized national curriculum and the creation and validation of assessment tool(s) to test proficiency in basic perioperative POCUS.

Importantly, while the competencies described herein are intended to serve as a *minimum* standard for Canadian anesthesiology graduates, individual trainees and residency programs are encouraged to expand their POCUS skillset beyond this core set of competencies. For example, competencies (e.g., Doppler assessment of aortic valve gradients) that wound up being discarded for a variety of reasons (e.g., "too advanced for the purposes of this document") during the Delphi iterations would, nevertheless, be valuable skills for the practice of anesthesiology and perioperative medicine. Notably, and in accordance with the formal Delphi process, we did not formally address some narrative feedback from the Delphi rounds in the final version of competencies once consensus was achieved. The majority of such comments expressed conflicting concerns that some of the expectations related to cardiac assessment were too advanced for the purposes of this manuscript. For instance, one expert commented that only *qualitative* assessment of stenotic and regurgitant valvular lesions using B-mode and colour Doppler should

Table 1 Delphi process for defining anesthesiology residency point-of-care ultrasound competencies organized according to clinical domain

Clinical domain	Competency
1.0 Basics of ultrasound equipment, nomenclature and clinical governance	Thirteen of the 14 competencies reached consensus in Round 1. There was one item that required revision for Round 2 given that it was > 50% but < 80% agreement. No new competencies were added for Round 2. Consensus was reached for the revised item during Round 2. Therefore, this domain contained 14 competencies after Round 3.
2.0 Basics of ultrasound physics	Only three items were circulated in Round 1 within this domain and consensus was obtained for all items. A new item was added and approved in Round 2. Thus, this domain consisted of four competencies after Round 3.
3.0 Cardiac ultrasound anatomy	Five competencies were circulated for the first round, one of which required rewording before consensus was reached in Round 3 resulting in five competencies after Round 3.
4.0 Cardiac image acquisition	For Round 1, nine competencies were circulated, of which four were revised, two were discarded, and one was added based upon the narrative feedback. Only one item required rewording for Round 3 before consensus was reached. There were eight competencies in this domain at the end of Round 3.
5.0 Cardiac image interpretation: general concepts	Three items were circulated for Round 1, all of which remained unchanged.
6.0 Cardiac image interpretation: left ventricular systolic dysfunction	Only two items were drafted for this clinical domain and circulated in Round 2, both of which remained unchanged.
7.0 Cardiac image interpretation: underfilled left ventricle	Only one item was drafted for Round 1, for which consensus was reached. A new item was added and approved in Round 2 resulting, ultimately, in two items for this domain.
8.0 Cardiac image interpretation: right ventricular failure	Only one item was circulated for Round 1 and consensus was reached.
9.0 Cardiac image interpretation: pericardial effusion and cardiac tamponade	Four competencies were circulated for Round 1, of which three reached consensus and one required rewording before circulation in Round 2, during which consensus was reached. In total, four competencies were finalized for this domain.
10.0 Cardiac image interpretation: intravascular volume status	Two competencies were circulated and agreed upon in Round 1.
11.0 Cardiac image interpretation: valve assessment	Six competencies were circulated for Round 1, all of which required rewording, and one new competency was added for Round 2, after which five were reworded and two were accepted. The remaining five were accepted in Round 3 after additional rewording. Therefore, seven competencies were finalized for this domain.
12.0 Focused lung ultrasound: anatomy	For this clinical domain, three competencies were circulated and agreed upon in Round 1.
13.0 Focused lung ultrasound: imaging	Only two competencies were circulated, and both reached consensus in Round 1.
14.0 Focused lung ultrasound: interpretation	Nine competencies were circulated in Round 1, eight of which were agreed upon. Only one item required rewording, which experts agreed upon in Round 2. In total, nine competencies were finalized for this domain.
15.0 POCUS: clinical applications—general statements	Four competencies were circulated for Round 1 and reached consensus.
16.0 POCUS: clinical applications—monitoring and serial assessments	There was only one competency for this area, which reached agreement in Round 1.
17.0 Clinical applications: persistent hypotension	There were two competencies for this domain for Round 1, after which one was discarded and the other required rewording. Thus, only one item was finalized for this domain.
18.0 Clinical applications: respiratory distress	There was only one competency, which experts agreed upon during Round 1.
19.0 Clinical applications: cardiac arrest	Two competencies were circulated, and consensus was reached during Round 1.

POCUS = point-of-care ultrasound

be included, whereas another one not only suggested the implementation of a *quantitative* assessment but also that there should be "… *objective criteria for peak velocities and gradients associated with severe aortic stenosis and mitral stenosis*" included in the competencies. Conversely, two experts felt that colour Doppler should not be used to identify stenotic valvular lesions because of the advanced nature of this technique, whereas another expert (and for similar reasons) suggested that mitral stenosis and identification of systolic anterior motion of the mitral valve should be excluded. Similarly, identification of tricuspid stenosis was deemed of low prevalence by one expert and, therefore, unnecessary as part of these competencies. All in all, while the narrative feedback provided by the expert panel was of great value, conflicting (and often isolated) comments did not generate enough priority to discard competencies and/or generate new ones, and possibly reflected the heterogeneity in use of POCUS

Table 2 Final list of anesthesiology residency competencies for proficiency in basic perioperative point-of-care ultrasound using a Delphi method with expert consensus at the national level

Clinical domain	Competency
1.0 Basics of ultrasound equipment, nomenclature, and clinical governance	1.1 Anesthesiologists must be able to show appropriate care of ultrasound equipment.
	1.2 Anesthesiologists must ensure proper infection control measures (i.e., hand washing, use of procedural gloves, ultrasound probe is clean and disinfected) whenever using ultrasound equipment.
	1.3 Anesthesiologists must ensure the ultrasound machine is cleaned and appropriately stored after each use.
	1.4 Anesthesiologists using/practicing POCUS must obtain informed consent prior to every scan in nonemergent clinical situations.
	1.5 Anesthesiologists using/practicing POCUS must be aware of proper patient positioning for each POCUS modality to optimize image acquisition while respecting patient dignity, privacy, and comfort.
	1.6 Anesthesiologists using/practicing POCUS must select the most appropriate ultrasound probe (linear, curvilinear, phased-array) for a given POCUS modality.
	1.7 Anesthesiologists using/practicing POCUS must have a basic knowledge of the following ultrasound-related terminologies and functionalities to optimize POCUS images: knobology, depth, gain, time gated compensation, focus, sector size, zoom, frame rate, and frequency.
	1.8 Anesthesiologists using/practicing POCUS must be able to appropriately apply the ultrasound orientation marker for a given POCUS exam, and to differentiate between cardiac and general/radiology convention.
	1.9 Anesthesiologists using/practicing POCUS must be able to apply the principles of probe manipulation (i.e., tilting, sweeping, rotating, sliding, rocking, angling) to optimize POCUS images.
	1.10 Anesthesiologists using/practicing POCUS must be able to archive POCUS images while respecting patient confidentiality and privacy.
	1.11 Anesthesiologists using/practicing POCUS must be able to consistently report the relevant POCUS findings in the patient's medical record using the local institution's method (electronic, handwriting, etc.) of reporting.
	1.12 When appropriate, anesthesiologists using/practicing POCUS must be able to communicate the POCUS findings to the patient (and/or patient's responsible/next of kin) using accessible language.
	1.13 Anesthesiologists using/practicing POCUS must be able to communicate the POCUS findings to other relevant health care providers.
	1.14 Anesthesiologists using/practicing POCUS must be aware of its limitations and know when to seek assistance from other colleagues and/or when to apply other diagnostic modalities.
2.0 Basics of ultrasound physics	2.1 Anesthesiologists using/practicing POCUS must show basic knowledge of the following sound wave characteristics: amplitude, wavelength, frequency, and velocity.
	2.2 Anesthesiologists using/practicing POCUS must have basic knowledge of how ultrasound interacts with tissue, and understand the following terminology: shadowing, attenuation, reflection, refraction, scattering, enhancement, mirror image, reverberation.
	2.3 Anesthesiologists using/practicing POCUS must be able to describe the effect of transducer frequency on image resolution and tissue penetration.
	2.4 Anesthesiologists using/practicing POCUS should have a basic understanding of Doppler physics, including understanding the basics of colour flow and continuous and pulse wave Doppler, and their limitations.
3.0 Cardiac ultrasound anatomy	3.1 Anesthesiologists using/practicing focused cardiac ultrasound (FoCUS) must be able to correctly identify the following cardiac structures using two-dimensional B-mode: left ventricle, left ventricular outflow tract (LVOT), right ventricle, right ventricular outflow tract, interventricular septum, right atrium, left atrium, interatrial septum, mitral valve, tricuspid valve, aortic valve, pulmonic valve, pericardium and pericardial space, ascending aorta, descending thoracic aorta, abdominal aorta, inferior vena cava, and hepatic veins.
	3.2 Anesthesiologists using/practicing FoCUS must be able to identify the left ventricular segments (base, mid, and apex) and walls (anterior, inferior, anteroseptal, inferolateral, anterolateral, inferoseptal) using two-dimensional B-mode.
	3.3 Anesthesiologists using/practicing FoCUS must be able to correlate different left ventricular segments and walls to their respective coronary artery (left anterior descending, circumflex, right coronary artery) supply using two-dimensional B-mode.
	3.4 Anesthesiologists using/practicing FoCUS should be able to identify severe (hemodynamically significant) valvular abnormalities.
	3.5 Anesthesiologists using/practicing FoCUS must be able to identify the left pleural space and, if present, a left pleural effusion using two-dimensional B-mode.

Table 2 continued

Clinical domain	Competency
4.0 Cardiac image acquisition	4.1 Anesthesiologists using/practicing FoCUS should be able to obtain the following views and recognize their respective limitations in all FoCUS exams: parasternal long axis, parasternal short axis (at the papillary muscle level), apical four-chamber, subcostal four-chamber, and subcostal inferior vena cava.
	4.2 In addition to basic FoCUS views, anesthesiologists using/practicing FoCUS may consider the following advanced views as applicable to selected cases: parasternal long axis right ventricle inflow, parasternal short axis at the aortic valve level, parasternal short axis at the mitral valve level, parasternal short axis at the apical level, apical five-chamber, apical two-chamber, apical three-chamber, subcostal short axis, and suprasternal aortic arch long axis.
	4.3 Anesthesiologists using/practicing FoCUS should be able to assess the right ventricular systolic function (tricuspid annular plane systolic excursion [TAPSE] and right ventricular fractional area change).
	4.4 Anesthesiologists using/practicing FoCUS must be able to assess fluid responsiveness through interrogation of the inferior vena cava using either M-mode and/or two-dimensional B-mode.
	4.5 Anesthesiologists using/practicing FoCUS must be able to describe the following two basic principles involving colour flow Doppler assessment: flow direction and turbulence.
	4.6 Anesthesiologists using/practicing FoCUS should be able to adequately apply colour flow Doppler to identify gross regurgitant and/or stenotic valvular abnormalities.
	4.7 In addition to basic FoCUS assessment, anesthesiologists using/practicing FoCUS may consider estimating the right ventricular systolic pressure through interrogation of the tricuspid valve regurgitant flow using continuous wave Doppler.
	4.8 In addition to basic FoCUS assessment, anesthesiologists may consider measuring velocity time integral across the LVOT for estimating stroke volume/cardiac output.
5.0 Cardiac image interpretation: general concepts	5.1 Anesthesiologists using/practicing FoCUS must be able to identify normal cardiac anatomy and function.
	5.2 Quantitative measurements of cardiac chamber dimensions are beyond the scope of FoCUS training for anesthesiologists.
	5.3 Anesthesiologists must be able to describe the size correlation between normal-sized cardiac chambers (e.g., left ventricle $>$ right ventricle).
6.0 Cardiac image interpretation: left ventricular systolic dysfunction	6.1 Anesthesiologists using/practicing FoCUS must be able to recognize findings consistent with gross left ventricular systolic dysfunction such as gross wall motion abnormalities (hypokinesis or akinesis), grossly dilated left ventricle, and gross left ventricular systolic dysfunction (i.e., significantly decreased ejection fraction).
	6.2 Anesthesiologists using/practicing FoCUS must be able to recognize the distribution of gross wall motion abnormalities (hypokinesis or akinesis) according to the left ventricular (anterior, inferior, anteroseptal, inferolateral, anterolateral, inferoseptal) walls.
7.0 Cardiac image interpretation: underfilled left ventricle	7.1 Anesthesiologists using/practicing FoCUS must be able to recognize findings that are often present in the setting of a grossly underfilled left ventricle, such as hyperdynamic left ventricular systolic function (ejection fraction $>$ 70%), reduced left ventricular internal diameter at end-diastole and end-systole, and left ventricular systolic cavity obliteration ("kissing papillary muscles").
	7.2 Anesthesiologists using/practicing FoCUS must be able to recognize findings that are often present in the setting of a grossly underfilled left ventricle in the setting of reduced afterload, such as hyperdynamic left ventricular systolic function (ejection fraction $>$ 70%), reduced left ventricular internal diameter at end-systole, and left ventricular systolic cavity obliteration ("kissing papillary muscles").
8.0 Cardiac image interpretation: right ventricular failure	8.1 Anesthesiologists using/practicing FoCUS must be able to recognize findings consistent with right ventricular failure such as gross right ventricular dilatation, gross right ventricular systolic dysfunction, McConnell's sign, D-shaped interventricular septum associated with pressure or volume overload, TAPSE $<$ 17 mm (indicative of right ventricular systolic dysfunction).
9.0 Cardiac image interpretation: pericardial effusion and cardiac tamponade	9.1 Anesthesiologists using/practicing FoCUS must be able to qualitatively describe the size of a pericardial effusion using the simple grading system: small, moderate, and large.
	9.2 Anesthesiologists using/practicing FoCUS must be able to describe the fluid characteristics of a pericardial effusion based on the following descriptors: simple, complex/loculated, hypoechoic, or hyperechoic.
	9.3 Anesthesiologists using/practicing FoCUS must be able to describe the location of a pericardial effusion following a simple dichotomized system: global *vs* localized.
	9.4 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs (e.g., large/global pericardial effusion, right atrial systolic collapse, right ventricular diastolic collapse, dilated inferior vena cava without any collapse, etc.) consistent with a pericardial effusion causing/contributing to hemodynamic compromise (pericardial tamponade).

Table 2 continued

Clinical domain	Competency
10.0 Cardiac image interpretation: intravascular volume status	10.1 Anesthesiologists using/practicing FoCUS must be able to estimate the intravascular volume status using a simple ("eye-ball/visual") assessment of the left ventricular end diastolic dimension.
	10.2 Anesthesiologists using/practicing FoCUS must be able to estimate intravascular volume status and fluid responsiveness based on the assessment of the inferior vena cava (size, respiratory variation, collapsibility index, etc.).
11.0 Cardiac image interpretation: valve assessment	11.1 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs consistent with gross (severe/critical) aortic stenosis such as valve leaflet morphology (severely thickened/calcified), obvious systolic restriction of aortic valve on two-dimensional B-mode, and left-ventricular hypertrophy.
	11.2 Anesthesiologists using/practicing FoCUS must be able to recognize echocardiographic signs consistent with gross aortic insufficiency such as obvious leaflet flail/prolapse on two-dimensional B-mode and gross diastolic turbulent regurgitant colour flow Doppler.
	11.3 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs consistent with gross mitral valve stenosis such as valve leaflet morphology (severely thickened/calcified) and obvious diastolic restriction on two-dimensional B-mode, and may consider using continuous wave Doppler to estimate elevated mitral valve gradient.
	11.4 Anesthesiologists using/practicing FoCUS must be able to recognize echocardiographic signs consistent with gross mitral regurgitation such as left atrial dilation, obvious systolic leaflet flail/prolapse/billowing on two-dimensional B-mode, and gross systolic colour flow Doppler.
	11.5 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs consistent with gross tricuspid stenosis such as valve leaflet morphology (severely thickened/calcified), and obvious diastolic restriction on two-dimensional B-mode.
	11.6 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs consistent with gross tricuspid regurgitation such as right atrial dilation, obvious systolic leaflet flail/prolapse on two-dimensional B-mode, and gross systolic regurgitation on colour flow Doppler.
	11.7 Anesthesiologists using/practicing FoCUS should be able to recognize echocardiographic signs consistent with significant systolic anterior motion of the mitral valve and left ventricular outflow tract obstruction.
12.0 Focused lung ultrasound: anatomy	12.1 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the anatomical structures that comprise the chest wall (e.g., ribs, muscular layers, pleurae) using two-dimensional B-mode.
	12.2 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the pleural space and its anatomical relation with surrounding structures (e.g., diaphragm, kidneys, liver, spleen, spine) using two-dimensional B-mode.
	12.3 Anesthesiologists using/practicing focused lung ultrasound must understand the artifacts generated by aerated lungs using two-dimensional B-mode.
13.0 Focused lung ultrasound: imaging	13.1 Anesthesiologists using/practicing focused lung ultrasound must be able to describe the importance of having a standardized scanning approach of each hemithorax (i.e., anterior, midaxillary, and posterior-lateral aspects.
	13.2 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the advantages and limitations of M-mode and two-dimensional B-mode when applied to this specific POCUS modality.
14.0 Focused lung ultrasound: interpretation	14.1 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts most commonly applied in the clinical setting (A-lines, B-lines, lung sliding, lung pulse, and lung point) and their respective clinical applications.
	14.2 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with a normally aerated lung: lung sliding, lung pulse, A-lines, "Curtain sign", and "Seashore sign" (M-mode).
	14.3 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with pneumothorax: A-lines, lung point, absence of lung sliding, absence of lung pulse, absence of B-lines, "bar code sign" (M-mode).
	14.4 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with interstitial syndromes (e.g., pulmonary edema, interstitial fibrosis, pulmonary contusion, etc.): lung sliding, more than three B-lines within the same intercostal space, "lung rockets."
	14.5 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with consolidation/atelectasis: lung hepatization, air bronchograms (dynamic and static), and "shred sign."
	14.6 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with pleural effusion: "jellyfish sign," and "spine sign."
	14.7 Anesthesiologists using/practicing focused lung ultrasound must be able to describe the fluid characteristics of a pleural effusion based on the following descriptors: simple, complex/loculated, hypoechoic, or hyperechoic.
	14.8 Anesthesiologists using/practicing focused lung ultrasound must be able to identify the signs/artifacts consistent with endobronchial intubation: lack of lung sliding, presence of B-lines or lung pulse, "bar code sign" (M-mode).
	14.9 Anesthesiologists using/practicing focused lung ultrasound may be able to identify the signs/artifacts consistent with diaphragmatic paresis (e.g., measure diaphragmatic excursion).

Table 2 continued

Clinical domain	Competency
15.0 POCUS: clinical applications—general statements	15.1 Anesthesiologists using/practicing POCUS must be able to competently direct the clinical management of hemodynamically unstable and/or critically ill patients by qualitatively (yes/no) ruling in/out important differential diagnoses in a timely and accurate fashion, while recognizing the limitations of POCUS scanning. 15.2 Anesthesiologists using/practicing POCUS must be able to competently direct the clinical management of patients presenting with respiratory compromise by qualitatively (yes/no) ruling in/out important differential diagnoses in a timely and accurate fashion, while recognizing the limitations of POCUS scanning. 15.3 Anesthesiologists using/practicing POCUS must be able to competently guide management during cardiac arrest. 15.4 Anesthesiologists using/practicing POCUS must show a high level of vigilance to avoid fixation/distraction from patient care associated with POCUS scanning.
16.0 POCUS: clinical applications—monitoring and serial assessments	16.1 Anesthesiologists using/practicing POCUS must be able to perform serial/sequential scanning to assess the effectiveness of implemented interventions.
17.0 Clinical applications—persistent hypotension	17.1 Anesthesiologists using/practicing POCUS must be able to promptly recognize the following causes of persistent hypotension: severe hypovolemia, pneumothorax, global and gross left ventricular systolic dysfunction (hypokinesis/akinesis), global and gross right ventricular systolic dysfunction (hypokinesis/akinesis), severe right ventricular systolic pressure overload, right ventricular diastolic volume overload, and large/global pericardial effusion/cardiac tamponade. Furthermore, anesthesiologists using/practicing POCUS may be able to promptly recognize gross valvular abnormalities causing persistent hypotension.
18.0 Clinical applications: respiratory distress	18.1 Anesthesiologists using/practicing POCUS must be able to promptly recognize the following causes of respiratory distress: pneumothorax, interstitial syndromes, pleural effusion.
19.0 Clinical applications: cardiac arrest	19.1 Anesthesiologists using/practicing POCUS must be able to differentiate between asystole and fine ventricular fibrillation to guide management during cardiac arrest. 19.2 Anesthesiologists using/practicing POCUS must be able to promptly recognize the following conditions as reversible causes of a cardiac arrest: large pericardial effusion suggesting cardiac tamponade, tension pneumothorax, severe hypovolemia, signs commonly seen in pulmonary embolus (e.g., severe right ventricular systolic dysfunction and/or dilatation, D-shaped interventricular septum, severe acute tricuspid regurgitation, etc.).

FoCUS = focused cardiac ultrasound; LVOT = left ventricular outflow tract; POCUS = point-of-care ultrasound; TAPSE = tricuspid annular plane systolic excursion

(with differing expectations from learners) across various institutions. The consensus competencies generated herein could, therefore, contribute to closing this gap and making POCUS training/practice more homogeneous across Canadian academic institutions moving forward.

Current variability and time constraints among different residency programs may limit trainees' clinical exposure to some pathology-related competencies. It is understandable (and expected), therefore, that not all residents would experience (in the clinical setting) every one of the competencies described herein. Nevertheless, theoretical/conceptual knowledge of all pathology-related competencies (particularly with regards to image acquisition and interpretation) should be mandatory, and may need to rely on alternative (e.g., simulation, videoclip-based modules, etc.) training modalities. For instance, while an extensive pulmonary embolism is a rare condition that many anesthesiologists may not experience during training, POCUS practitioners should be able to recognize the McConnell's sign to facilitate diagnosis and management. This is akin to other rare clinical conditions (e.g., malignant hyperthermia) in anesthesiology where the theoretical knowledge (e.g., clinical presentation, diagnosis, management) is often "enforced" upon trainees through alternative (simulation education) teaching modalities. Similarly, we acknowledge that the 75 competencies proposed herein may not be all easily shown/achieved by a routine bedside POCUS exam; rather, some may need to rely on alternative teaching modalities to be mastered.

There are several limitations to this study. Since our expert panel consisted exclusively of academic anesthesiologists practicing in Canada, there is a potential lack of generalizability outside of the Canadian context, as well as to Canadian anesthesiologists practicing in community hospitals and rural areas. Likewise, it is unclear how these competencies would apply to attending anesthesiologists who entered practice prior to the widespread use of POCUS in perioperative medicine. Another important consideration is the likely inclusion of focused assessment with sonography in trauma, gastric ultrasound, and airway ultrasound in the next (updated) version of the RCPSC National Curriculum. As such, these guidelines will require iterative revisions and updates to increase generalizability and keep up with changing use of POCUS in anesthesia/perioperative practice.

The next stage of the present investigation will involve the development of assessment tools designed to measure POCUS proficiency among anesthesiology learners using the competencies outlined herein, to be implemented as part of the CBD assessments already in place in Canadian anesthesiology training programs. Once developed, validity evidence related to these assessment instruments will be generated using Messick's unified framework of construct validity, in both a high-fidelity simulation environment as well as in the clinical context. The goal of this work is to create the first Canadian assessment tool(s) on perioperative POCUS based on national expert consensus.

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