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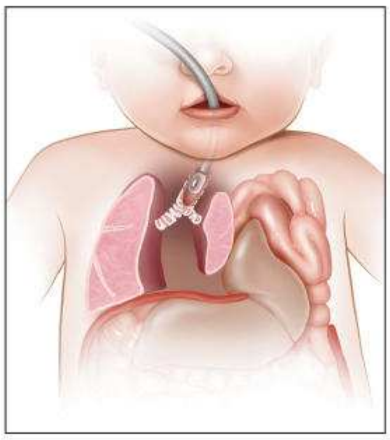

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Defining Competencies for Ultrasound-Guided Bedside Procedures

Consensus Opinions From Canadian Physicians

G. Mark Brown, MD, Mirek Otremba, MD, Luke A. Devine, MD, MHPE, Catherine Gray, MD, MSc, Scott J. Millington, MD, Irene W. Y. Ma, MD, MSc, PhD

Objectives—This study sought to define the competencies in ultrasound knowledge and skills that are essential for medical trainees to master to perform ultrasound-guided central venous catheterization, thoracentesis, and paracentesis.

Methods—Experts in the 3 procedures were identified by a snowball technique through 3 Canadian tertiary academic health centers. Experts completed 2 rounds of surveys, including an 88-item central venous catheterization survey, a 96-item thoracentesis survey, and an 89-item paracentesis survey. For each item, experts were asked to determine whether the knowledge/skill described was essential, important, or marginal. Consensus on an item was defined as agreement by at least 80% of the experts. For items on which consensus was not reached during the first round of surveys, a second survey was created in which the experts were asked to rate the item in a binary fashion (essential/important versus marginal/unimportant).

Results—Of the 27 experts invited to complete each survey, 25 (93%) completed the central venous catheterization survey; 22 (81%) completed the thoracentesis survey; and 23 (85%) completed the paracentesis survey. The experts represented 8 specialties from 8 cities within Canada. A total of 22, 32, and 28 items were determined to be essential competencies for central venous catheterization, thoracentesis, and paracentesis, respectively, whereas 47, 38, and 42 competencies were determined to be important, and 8, 13, and 10 were determined to be marginal. The ability to perform real-time direct ultrasound guidance was considered essential only for the performance of central venous catheterization insertion.

Conclusions—Our study presents expert consensus-derived ultrasound competencies that should be considered during the design and implementation of procedural skills training for learners.

Key Words—competencies; point-of-care ultrasound; procedures; ultrasound; ultrasound education

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For many medical bedside procedures such as central venous catheterization and thoracentesis, the use of ultrasound guidance has improved the safety and decreased the complication rates of these procedures.[1–6] In performing central venous catheterization, the use of ultrasound guidance is increasingly considered the standard of care[7] and is recommended by the American College of Surgeons,[8] the National Institute for Health and Care Excellence,[9] and jointly by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists.[10] For thoracentesis, the use of ultrasound is recommended by the British Thoracic Society

Pleural Disease Guideline Group.[11] Last, for paracentesis, existing data suggest that the use of ultrasound improves the success rate and safety of the procedure.[12,13]

To optimally acquire and interpret ultrasound images, a variety of ultrasound functions and imaging modalities are available.[14] The extent to which these functions apply to the use of ultrasound in guiding procedures is not clear. For example, whereas power Doppler ultrasound is available on many devices, it is unclear to what extent it is essential that trainees have competencies in the use of power Doppler ultrasound in the context of performing an ultrasound-guided procedure. A number of guidelines recommend that those who use ultrasound to guide procedures receive sufficient training to achieve competency in the safe and effective use of ultrasound.[9,15] However, specific competencies that must be mastered by medical trainees when performing ultrasound-guided procedures have not been defined. Without explicit guidance as to the specific ultrasound functionalities and competencies that must be learned, it is difficult for educators to design effective procedural training sessions.

This study aimed to establish a set of consensus-based ultrasound competencies for ultrasound-guided central venous catheterization, thoracentesis, and paracentesis by seeking input from Canadian experts in ultrasound-guided procedures using a modified Delphi process.[16]

Materials and Methods

Participants

A total of 37 consenting experts in ultrasound-guided procedures were invited to participate in this study, which involved completion of 2 rounds of an online survey specific to each procedure. Of these 37 experts, 22 were invited to complete surveys on all 3 procedures. For each of the 3 procedures, 5 additional individuals with expertise in 1 of the 3 procedures were invited to participate (27 experts for each procedure: central venous catheterization insertion, thoracentesis, and paracentesis). Experts were only invited to complete the survey on the procedure in which they had expertise. Participants were considered experts if they routinely performed the specified procedure under ultrasound guidance, had received dedicated postgraduate ultrasound training or both. Experts were identified by a nonprobabilistic sampling strategy (snowball technique) through 3 Canadian tertiary academic health centers (University of Toronto, University of Ottawa, and University of Calgary). Experts were recruited from a variety of specialties to broaden the basis for census. Experts were permitted to complete surveys for multiple procedures if they had expertise in each area. No payment was provided for completing the online surveys.

Survey Development

After review of textbooks on ultrasound and point-of-care ultrasound,[14,17–20] 2 investigators (G.M.B. and I.W.Y.M.) independently generated and then revised lists of all potentially relevant ultrasound competencies for each of the 3 ultrasound-guided procedures. Each competency was included in the surveys for each procedure, resulting in an 82-item central venous catheterization survey, a 91-item thoracentesis survey, and an 83-item paracentesis survey (see online supplemental material). These draft surveys were then circulated to 3 additional investigators (M.O., L.A.D., and C.G.) for review of content validity and item clarity, resulting in a final 88-item survey for central venous catheterization, 96-item survey for thoracentesis, and 89-item survey for paracentesis. These surveys were then piloted to 6 internal medicine trainees who provided additional input regarding item wording and clarity.

The final surveys were administered to the expert participants using an electronic survey instrument (SurveyMonkey, Inc, Seattle, WA; www.surveymonkey.com). Surveys were administered over a 9-month period (January–May 2014 for round 1 and July–September 2014 for round 2). For each item, experts were asked to determine whether they thought the knowledge or skill described was essential, important, or marginal for an internal medicine resident to possess before the resident can be considered to have achieved the minimal level of competence required to perform the ultrasound-guided procedure. Essential knowledge and skills were defined as those that are required for competence, important as those that are important but not necessary for performing the procedure safely or effectively, and marginal as those that are superfluous, extraneous, or irrelevant to performing the procedure.

Outcomes

We used a modified Delphi process in establishing consensus.[16] Consensus for each item was defined as agreement by at least 80% of the experts. We chose 80% as the threshold as this rate is in keeping with what is commonly used in the literature and is consistent with guideline recommendations.[21,22] For items on which consensus was not reached during the first round of surveys, a second survey was created in which the experts were asked to rate the item in a binary fashion (important/essential versus unimportant/marginal).

Statistical Methods

Descriptive statistics were used to analyze survey responses. All analyses were performed with SAS version 9.3 software (SAS Institute Inc, Cary, NC). This study was approved by the Conjoint Health Research Ethics Board at the University of Calgary (ethics identification number E25052).

Results

Expert Panel

Of the 27 experts invited to complete each survey, 25 (93%) completed the first round of the central venous catheterization survey, and 19 of these (73%) completed the second round of the survey. For thoracentesis, 22 (81%) completed the first round, and 15 of these (68%) completed the second round. For paracentesis, 23 (85%) completed the first round, and 16 (70%) completed the second round. The experts (n = 31 unique individuals) represented 8 specialties from 8 cities across Canada (Table 1). Twenty-one experts completed all 3 surveys. Of the 31 total experts who completed the surveys, 29 experts provided information on their expertise. Of these, 3 individuals had Registered Diagnostic Medical Sonographer credentials; 1 had the Canadian Association of Registered Diagnostic Ultrasound Professionals credential; 18 had a minimum of 1 year of postgraduate training in ultrasound; and 4 had certification by the National Board of Echocardiography. All individuals without at least 1 of these training or credentials had completed or taught more than 2 of the following certification courses: the Canadian Emergency Ultrasound Society (n = 7), the American College of Chest Physicians Critical Care ultrasonography certification (n = 4), or World Interactive Network Focused On Critical Ultrasound provider certification (n = 1). Collectively, our experts report a median of 8 years of practice (interquartile range, 4–11 years).

Survey Consensus

In round 1 of the central venous catheterization survey (88 items), consensus was reached for 22 items rated as essential and 42 items as important. Consensus was not reached for the remaining 24 items. These items were readdressed in round 2, in which consensus deemed 5 of these items as important/essential and 8 of these as unimportant/marginal, whereas 11 remained without consensus (Table 2).

In round 1 of the thoracentesis survey (96 items), consensus was reached for 32 items rated as essential and 31 items as important. Of the remaining 33 items, in round 2, 7 items were deemed important/essential, and 13 were determined to be unimportant/marginal, whereas 13 remained without consensus (Table 3).

In round 1 of the paracentesis survey (89 items), consensus was reached for 28 items rated as essential and 38 items as important. During round 2, which involved the remaining 23 items, consensus was reached for 4 items being deemed important/essential and 10 items as unimportant/marginal, whereas 9 remained without consensus (Table 4).

Discussion

In this study, we defined essential competencies for 3 ultrasound-guided procedures through consensus among more than 20 experts from various specialties across Canada. Our study identified 22 essential competencies for ultrasound-guided central venous catheterization, 32 for thoracentesis, and 28 for paracentesis. To our knowledge, these results present, for the first time, a set of competencies on ultrasound skills and knowledge required for these procedures and may serve to assist educators in curriculum design and development. For example, competencies that are considered marginal could be deferred for more senior-level trainees, whereas those that are considered essential should be focused on earlier in the training process. Competencies that are considered important may

Table 1. Specialties and Practice Locations of Experts Who Responded to the Surveys

Parameter	Central Venous Catheterization (n = 25)	Thoracentesis (n = 22)	Paracentesis (n = 23)
Self-identified specialty[a,b]			
Critical care medicine	12	11	11
Internal medicine	10	8	8
Emergency medicine	5	5	5
Anesthesia	3	2	2
Respirology	2	3	3
Surgery	2	2	2
Diagnostic imaging	1	1	2
Cardiology	2	2	2
City[b]			
Calgary, Alberta	10	7	7
Ottawa, Ontario	4	4	4
Toronto, Ontario	4	4	5
Vancouver, British Columbia	3	3	3
Winnipeg, Manitoba	1	1	1
Edmonton, Alberta	1	1	1
Hamilton, Ontario	1	1	1
London, Ontario	1	1	1

[a] Some participants indicated multiple specialties.
[b] Not all experts indicated their practice locations or specialties.

Table 2. Ultrasound-Guided Central Venous Catheterization Competencies: Consensus of 25 Experts

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Essential competencies					
Knows when to abort procedure to ensure patient safety	1	24 (100)	0	0	3 (3–3)
Able to select desired transducer on ultrasound machine	1	24 (96)	1 (4)	0	3 (2–3)
Aware of which transducer to use based on procedure (linear transducer, 5–14 MHz for central lines)	1	21 (84)	3 (12)	1 (4)	3 (1–3)
Able to identify probe orientation (mark on probe as it relates to dot on screen)	1	23 (92)	2 (8)	0	3 (2–3)
Able to hold probe with stability (does not dangle probe)	1	23 (92)	2 (8)	0	3 (2–3)
Able to maneuver probe to define structural characteristics	1	25 (100)	0	0	3 (3–3)
Uses sufficient gel and appropriate probe pressure	1	24 (96)	1 (4)	0	3 (2–3)
Able to sheath and handle probe in sterile manner	1	23 (92)	2 (8)	0	3 (2–3)
Able to adjust depth	1	23 (92)	2 (8)	0	3 (2–3)
Able to identify superficial structures as appearing at top of display and deeper structures at bottom of display	1	24 (96)	1 (4)	0	3 (2–3)
Able to subsequently decrease depth to hone in on area of interest	1	20 (80)	5 (20)	0	3 (2–3)
Able to adjust gain to obtain best image possible	1	21 (84)	4 (16)	0	3 (2–3)
Able to differentiate carotid from vein on B-mode imaging (location, wall thickness, compressibility, single vs double pulsations)	1	22 (88)	2 (8)	1 (4)	3 (1–3)
Able to identify safe needle insertion site (away from underlying lung apex and carotid)	1	25 (100)	0	0	3 (3–3)
Able to use direct real-time ultrasound guidance	1	20 (83)	4 (17)	0	3 (2–3)
Able to position target in center of screen	1	22 (88)	3 (12)	0	3 (2–3)
Able to hold ultrasound probe in nondominant hand during active needle guidance	1	20 (80)	4 (16)	1 (4)	3 (1–3)
Recognizes needle tip	1	24 (96)	1 (4)	0	3 (2–3)
Able to direct needle tip to target using ultrasound	1	24 (96)	1 (4)	0	3 (2–3)
Able to maintain direct visualization of full path of needle tip from point of entry to vein entry	1	25 (100)	0	0	3 (3–3)
Able to recognize vein entry	1	25 (100)	0	0	3 (3–3)
Able to perform procedure in at least transverse approach	1	20 (80)	5 (20)	0	3 (2–3)
Important competencies					
Aware of current evidence for any clinical benefits of ultrasound guidance for central line insertion	1	11 (44)	14 (56)	0	2 (2–3)
Positions ultrasound machine so that screen is directly in line of sight (rather than needing to turn around to see screen)	1	16 (64)	9 (36)	0	3 (2–3)
Positions patient such that left-hand side of patient correlates to left-hand side of screen	1	17 (68)	5 (20)	3 (12)	3 (1–3)
Able to describe differences in transducer characteristics	1	14 (56)	10 (40)	1 (4)	3 (1–3)
Able to describe how frequency relates to resolution and penetration	1	13 (52)	9 (36)	3 (12)	3 (1–3)
Able to identify which transducer is selected based on shape of field or view displayed on screen	1	14 (56)	9 (36)	2 (8)	3 (1–3)
Able to change probe orientation to radiology convention (eg, change dot on screen to top left-hand side of screen)	1	7 (28)	14 (56)	4 (16)	2 (1–3)
Recognizes the role of "presets" in preoptimized settings (depth, gain, power, focal zones, frame rates)	1	10 (40)	14 (56)	1 (4)	2 (1–3)
Able to choose appropriate preset for central line insertion (eg, vascular or vascular access)	1	14 (56)	10 (40)	1 (4)	3 (1–3)
Starts scanning with sufficient depth in order to avoid missing far-field findings	1	19 (76)	6 (24)	0	3 (2–3)
Able to identify exact depth required for needle to advance	1	17 (68)	7 (28)	1 (4)	3 (1–3)
Able to adjust time-gain compensation (adjusting far-field/near-field gain selectively)	1	10 (40)	12 (48)	3 (12)	2 (1–3)

(continued)

Table 2. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Able to adjust focal zone	1	5 (20)	16 (64)	4 (16)	2 (1–3)
Understand difference between 2-dimensional B-mode and M-mode	1	13 (52)	8 (32)	4 (16)	3 (1–3)
Able to select different Doppler modes (color, pulsed, continuous wave, power)	1	10 (40)	12 (48)	3 (12)	2 (1–3)
Able to archive images or cine clips	2	6 (24)	13 (52)	6 (24)	2 (1–3)
Knowledge and understanding of					
Reverberation artifact	1	15 (60)	8 (32)	2 (8)	3 (1–3)
Ring-down artifact	1	18 (72)	4 (16)	3 (12)	3 (1–3)
Beam width artifact	1	10 (40)	11 (44)	4 (16)	2 (1–3)
Side-lobe artifact	1	10 (40)	10 (40)	5 (20)	2 (1–3)
Mirror image artifact	1	15 (60)	7 (28)	3 (12)	3 (1–3)
Speed displacement artifact	1	6 (24)	16 (64)	3 (12)	2 (1–3)
Shadowing	1	17 (68)	7 (28)	1 (4)	3 (1–3)
Posterior acoustic enhancement	1	13 (52)	9 (36)	3 (12)	3 (1–3)
Performs initial nonsterile scan	1	18 (72)	4 (16)	3 (12)	3 (1–3)
Understands degree of head rotation may affect relative anatomy	1	19 (76)	6 (24)	0	3 (2–3)
Able to differentiate carotid from vein on Doppler imaging (either color flow or spectral)	1	11 (44)	10 (40)	4 (16)	2 (1–3)
Able to obtain true longitudinal (nonoblique) image of carotid and jugular vein	1	14 (56)	9 (36)	2 (8)	3 (1–3)
Able to rule out intravascular thrombus	1	18 (72)	7 (28)	0	3 (2–3)
Able to identify exact depth of vessel	1	19 (76)	6 (24)	0	3 (2–3)
Understands advantages/disadvantages of in-plane or perpendicular imaging guidance technique	1	19 (76)	5 (20)	1 (4)	3 (1–3)
Able to perform procedure in both longitudinal (in-plane) and transverse (out-of-plane) approaches	1	7 (28)	16 (64)	2 (8)	2 (1–3)
Able to perform procedure in at least longitudinal approach	1	6 (24)	16 (64)	3 (12)	2 (1–3)
Able to avoid posterior vessel wall puncture	1	11 (46)	12 (50)	1 (4)	2 (1–3)
Confirms wire placement by direct ultrasound visualization	1	16 (64)	7 (28)	2 (8)	3 (1–3)
Confirms catheter placement by direct ultrasound visualization	1	11 (44)	12 (48)	2 (8)	2 (1–3)
Rules out pneumothorax with B-mode (lung sliding)	1	9 (36)	12 (48)	4 (16)	2 (1–3)
Rules out pneumothorax with ultrasound after procedure only	1	7 (28)	14 (56)	4 (16)	2 (1–3)
Color flow					
Able to apply appropriate angle of insonation (as parallel as possible)	1	16 (64)	7 (28)	2 (8)	3 (1–3)
Able to determine direction of blood flow	1	16 (64)	7 (28)	2 (8)	3 (1–3)
Able to identify presence of aliasing	1	7 (28)	13 (52)	5 (20)	2 (1–3)
Able to adjust color flow region size	1	7 (28)	13 (52)	5 (20)	2 (1–3)
Able to steer color flow region box	1	10 (40)	10 (40)	5 (20)	2 (1–3)
Able to adjust color gain when using color Doppler	2	10 (40)	9 (36)	6 (24)	2 (1–3)
M-mode					
Able to select M-mode	2	10 (40)	9 (36)	6 (24)	2 (1–3)
Able to use M-mode	2	8 (33)	10 (42)	6 (25)	2 (1–3)
Able to adjust scan line to area of interest when using M-mode	2	8 (32)	10 (40)	7 (28)	2 (1–3)
Marginal competencies					
Checks that mechanical or thermal index is within acceptable limits	2	4 (16)	8 (32)	13 (52)	1 (1–3)
Able to use multiple focal zones	2	3 (12)	11 (44)	11 (44)	2 (1–3)
Able to articulate that the use of multiple focal zones will reduce frame rate	2	1 (4)	9 (36)	15 (60)	1 (1–3)
Able to articulate effect of adjusting dynamic range on image	2	2 (8)	10 (40)	13 (52)	1 (1–3)
Able to adjust dynamic range to optimize image	2	3 (12)	11 (44)	11 (44)	2 (1–3)
Able to adjust sample volume when using pulsed wave Doppler	2	8 (33)	7 (29)	9 (38)	2 (1–3)
Able to control Doppler mirror image artifact when using pulsed wave Doppler	2	3 (12)	12 (50)	9 (38)	2 (1–3)
Rules out pneumothorax with M-mode	2	4 (16)	12 (48)	9 (36)	2 (1–3)

(continued)

Table 2. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Items without consensus					
Understands difference between color Doppler and pulsed wave/continuous wave Doppler		8 (33)	11 (46)	5 (21)	2 (1–3)
Able to adjust Doppler gain when using pulsed wave Doppler		7 (29)	11 (46)	6 (25)	2 (1–3)
Able to differentiate between arterial and venous waveforms using spectral Doppler		8 (33)	11 (46)	5 (21)	2 (1–3)
Adheres to ALARA principle (exposing patient to lowest ultrasound energy possible)		8 (32)	8 (32)	9 (36)	2 (1–3)
Able to articulate benefit of setting focus in improving lateral resolution		5 (20)	14 (56)	6 (24)	2 (1–3)
Able to adjust frequency within range of selected transducer		3 (12)	13 (52)	9 (36)	2 (1–3)
Able to control aliasing when using color flow Doppler		4 (16)	13 (52)	8 (32)	2 (1–3)
Able to adjust pulse repetition frequency when using color flow Doppler		6 (25)	9 (37.5)	9 (37.5)	2 (1–3)
Understands when to use power Doppler vs color Doppler		5 (20)	11 (44)	9 (36)	2 (1–3)
Aware that power Doppler does not offer velocity or direction information		5 (20)	12 (48)	8 (32)	2 (1–3)
Rules out pneumothorax with ultrasound both before and after procedure		6 (24)	10 (40)	9 (36)	2 (1–3)

be introduced at the same time as essential competencies or deferred in a stepwise approach. For faculty members who have been tasked with the role of supervising procedures despite having limited ultrasound training themselves, these results may also help focus their faculty development efforts.

For a number of items, we were not able to establish consensus. For example, for all 3 procedures, experts were not able to agree on the importance of attaining the ability to adjust the pulse repetition frequency when using color flow Doppler ultrasound, differentiate between arterial and venous waveforms using spectral Doppler ultrasound, control aliasing when using color flow Doppler ultrasound, understand the difference between color Doppler and pulsed wave/continuous wave Doppler ultrasound, know when to use power Doppler versus color Doppler ultrasound, and aware that power Doppler ultrasound does not offer velocity or direction information. We hypothesize that these items may be considered higher-level knowledge and skills that are less critical to the performance of the procedure for a junior learner. Indeed, for a number of items on which no consensus was reached in one procedure, the same items were deemed marginal in another procedure. For example: adhering to the ALARA (as low as reasonably achievable) principle, articulating the benefit of setting focus in improving lateral resolution, and adjusting the frequency of a transducer were without consensus for central venous catheterization; these same items reached consensus as marginal items for paracentesis and thoracentesis. This finding was in distinct contrast to the items on more basic-level knowledge and skills, for which experts readily agreed on being essential and were able to establish consensus within the first round. Alternative explanations for why these items did not reach consensus include the fact that we only conducted 2 rounds of surveys. Given the onerous nature of our lengthy surveys, it was thought that further rounds may have led to an artificial consensus or a lower response rate, without improving the quality of the results.[23] Future studies should consider establishing consensus for higher-level knowledge/skill items.

Our study had a number of limitations that should be considered. First, these results represent expert-based opinions, and they may differ from evidence-based competencies. However, given the paucity of evidence supporting specific elements of ultrasound competencies, our results form a foundation for initiating curriculum development efforts. Second, our experts were based only in Canada. How the patterns of ultrasound practice differ between Canadian practitioners and those from other countries are unclear and should be evaluated in future research. Furthermore, we did not impose strict criteria for what constituted an "expert" in our study. Rather, we relied on the snowball technique to identify individuals known to be experts in the field. Although in retrospect, our experts did seem well qualified, future studies should consider a more clearly defined group. Third, many of our experts had expertise in more than 1 skill (eg, critical care specialists, emergency physicians, and internists), and their

Table 3. Ultrasound-Guided Thoracentesis Competencies: Consensus of 22 Experts

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Essential competencies					
Knows when to abort procedure to ensure patient safety	1	21 (100)	0	0	3 (3–3)
Aware of which transducer to use based on procedure (curvilinear transducer, 2–5 MHz or phased array 2–4 MHz preferred, although linear transducer, 5–14, MHz may be acceptable for thoracentesis)	1	18 (82)	3 (14)	1 (4)	3 (1–3)
Able to select desired transducer on ultrasound machine	1	21 (95)	1 (5)	0	3 (2–3)
Able to identify probe orientation (mark on probe as it relates to dot on screen)	1	21 (95)	1 (5)	0	3 (2–3)
Able to hold probe with stability (does not dangle probe)	1	19 (86)	3 (14)	0	3 (2–3)
Able to maneuver probe to define structural characteristics	1	22 (100)	0	0	3 (3–3)
Uses sufficient gel and appropriate probe pressure	1	21 (95)	1 (5)	0	3 (2–3)
Able to sheath and handle probe in sterile manner	1	21 (95)	1 (5)	0	3 (2–3)
Able to adjust depth	1	22 (100)	0	0	3 (3–3)
Able to identify superficial structures as appearing at top of display and deeper structures at bottom of display	1	22 (100)	0	0	3 (3–3)
Starts scanning with sufficient depth to avoid missing far-field findings	1	19 (86)	3 (14)	0	3 (2–3)
Able to subsequently decrease depth to hone in on area of interest	1	20 (91)	2 (9)	0	3 (2–3)
Able to adjust gain to obtain best image possible	1	20 (91)	2 (9)	0	3 (2–3)
Performs initial nonsterile scan 1–2 intercostal spaces below level of percussed dullness	1	17 (81)	3 (14)	1 (5)	3 (1–3)
Performs longitudinal scan	1	18 (82)	4 (18)	0	3 (2–3)
Able to locate hypoechoic pleural fluid	1	20 (91)	2 (9)	0	3 (2–3)
Able to identify absence of fluid	1	20 (91)	2 (9)	0	3 (2–3)
Able to characterize fluid as homogeneous or heterogeneous	1	18 (82)	3 (14)	1 (4)	3 (1–3)
Able to identify dynamic findings of pleural fluid (diaphragmatic motion, floating lung, dynamic fluid motion, respire-phasic shape change)	1	18 (82)	4 (18)	0	3 (2–3)
Able to identify ribs and rib shadows	1	21 (95)	1 (5)	0	3 (2–3)
Able to differentiate between lung tissue and effusion	1	22 (100)	0	0	3 (3–3)
Able to identify diaphragm	1	21 (95)	1 (5)	0	3 (2–3)
Able to identify liver, spleen, kidneys	1	22 (100)	0	0	3 (3–3)
Able to identify safe needle insertion site (away from organs, lungs, diaphragm, above ribs)	1	21 (95)	1 (5)	0	3 (2–3)
Able to measure depth of fluid from skin	1	20 (91)	1 (4.5)	1 (4.5)	3 (1–3)
Able to use ultrasound to determine appropriate site of needle entry and depth (static technique) but not under direct real-time guidance	1	21 (95)	1 (5)	0	3 (2–3)
Able to position target in center of screen	1	22 (100)	0	0	3 (3–3)
Recognizes needle tip	1	19 (86)	0	3 (14)	3 (1–3)
Able to direct needle tip to fluid using ultrasound	1	18 (82)	1 (4)	3 (14)	3 (1–3)
Able to recognize access into fluid	1	21 (95)	1 (5)	0	3 (2–3)
Able to avoid organ puncture (liver, spleen, diaphragm, lung)	1	21 (95)	1 (5)	0	3 (2–3)
Able to ensure needle path is above rib	1	20 (91)	2 (9)	0	3 (2–3)
Important competencies					
Aware of current evidence for any clinical benefits of ultrasound guidance for thoracentesis	1	9 (41)	12 (55)	1 (4)	2 (1–3)
Positions ultrasound machine so that screen is directly in line of sight (rather than needing to turn around to see screen)	1	14 (64)	8 (36)	0	3 (2–3)
Able to describe differences in transducer characteristics	1	14 (64)	8 (36)	0	3 (2–3)
Able to describe how frequency relates to resolution and penetration	1	13 (59)	7 (32)	2 (9)	3 (1–3)
Able to identify which transducer is selected based on shape of field or view displayed on screen	1	12 (54)	7 (32)	3 (14)	3 (1–3)
Able to change probe orientation to radiology convention (eg, change dot on screen to top left-hand side of screen)	1	6 (27)	14 (64)	2 (9)	2 (1–3)

(continued)

Table 3. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Important competencies (continued)					
Recognizes role of "presets" in preoptimized settings (depth, gain, power, focal zones, frame rates)	1	10 (45)	12 (55)	0	2 (2–3)
Able to choose appropriate preset for thoracentesis (eg, thoracic)	1	13 (59)	8 (36)	1 (5)	3 (1–3)
Able to identify exact depth required for needle to advance	1	17 (77)	4 (18)	1 (5)	3 (1–3)
Able to adjust time-gain compensation (adjusting far-field/near-field gain selectively)	1	9 (41)	10 (45)	3 (14)	2 (1–3)
Able to adjust focal zone	1	4 (18)	14 (64)	4 (18)	2 (1–3)
Understand difference between 2-dimensional B-mode and M-mode	1	14 (64)	5 (23)	3 (14)	3 (1–3)
Able to select different Doppler modes (color, pulsed, continuous wave, power)	1	9 (41)	11 (50)	2 (9)	2 (1–3)
Able to archive images or cine clips	1	6 (27)	13 (59)	3 (14)	2 (1–3)
Knowledge and understanding of					
Reverberation artifact	1	13 (59)	8 (36)	1 (5)	3 (1–3)
Ring-down artifact	1	16 (73)	3 (14)	3 (14)	3 (1–3)
Mirror image artifact	1	14 (64)	5 (23)	3 (14)	3 (1–3)
Shadowing	1	16 (73)	5 (23)	1 (4)	3 (1–3)
Posterior acoustic enhancement	1	11 (50)	8 (36)	3 (14)	2.5 (1–3)
B-lines	2	7 (32)	10 (45)	5 (23)	2 (1–3)
Performs semiquantitative assessment of fluid volume	1	10 (45.5)	10 (45.5)	2 (9)	2 (1–3)
Able to identify presence of strands/debris/septations	1	15 (68)	6 (27)	1 (5)	3 (1–3)
Able to identify loculations	1	15 (68)	7 (32)	0	3 (2–3)
Demonstrates knowledge of sliding lung	1	16 (73)	4 (18)	2 (9)	3 (1–3)
Able to image fluid in at least 2 views	1	16 (73)	5 (23)	1 (4)	3 (1–3)
Able to hold ultrasound probe in nondominant hand during active needle guidance	1	17 (77)	3 (14)	2 (9)	3 (1–3)
Able to maintain direct visualization of full path of needle tip from point of entry into fluid pocket	1	14 (64)	4 (18)	4 (18)	3 (1–3)
Able to perform procedure in both longitudinal and transverse approaches	1	7 (32)	12 (54)	3 (14)	2 (1–3)
Able to perform procedure in at least longitudinal approach	1	11 (50)	10 (45)	1 (5)	2.5 (1–3)
Able to perform procedure in at least transverse approach	1	14 (64)	5 (23)	3 (14)	3 (1–3)
Able to use direct real-time ultrasound-guidance for thoracentesis	2	9 (41)	9 (41)	4 (18)	2 (1–3)
Color flow					
Able to apply appropriate angle of insonation (as parallel as possible)	1	14 (64)	6 (27)	2 (9)	3 (1–3)
Able to determine direction of blood flow	1	14 (64)	5 (23)	3 (14)	3 (1–3)
Able to identify presence of aliasing	2	7 (32)	11 (50)	4 (18)	2 (1–3)
Able to adjust color gain when using color Doppler	2	10 (45)	7 (32)	5 (23)	2 (1–3)
M-mode					
Able to select M-mode	2	10 (45)	7 (32)	5 (23)	2 (1–3)
Able to use M-mode	2	8 (38)	8 (38)	5 (24)	2 (1–3)
Able to adjust scan line to area of interest when using M-mode	2	8 (38)	7 (33)	6 (29)	2 (1–3)
Marginal competencies					
Adheres to ALARA principle (exposing patient to lowest ultrasound energy possible)	2	7 (32)	6 (27)	9 (41)	2 (1–3)
Checks that mechanical or thermal index is within acceptable limits	2	3 (14)	7 (32)	12 (55)	1 (1–3)
Able to articulate benefit of setting focus in improving lateral resolution	2	4 (18)	12 (55)	6 (27)	2 (1–3)
Able to use multiple focal zones	2	2 (9)	10 (45.5)	10 (45.5)	2 (1–3)
Able to articulate that use of multiple focal zones will reduce frame rate	2	1 (4)	7 (32)	14 (64)	1 (1–3)
Able to adjust frequency within range of selected transducer	2	3 (14)	11 (50)	8 (36)	2 (1–3)
Able to articulate effect of adjusting dynamic range on image	2	2 (9)	9 (41)	11 (50)	1.5 (1–3)
Able to adjust dynamic range to optimize image	2	3 (14)	8 (36)	11 (50)	1.5 (1–3)
Able to adjust sample volume when using pulsed wave Doppler	2	7 (33)	5 (24)	9 (43)	2 (1–3)
Able to control Doppler mirror image artifact	2	3 (14)	9 (43)	9 (43)	2 (1–3)

opinions may not be generalizable to those who subspecialize in only a single procedure. Nonetheless, given that the goal of many training programs is to teach multiple procedural competencies, we think that the results of our survey will have broad applicability. Fourth, about one-third of our experts were drawn from a single site (Calgary). Although the population of Calgary (1,406,700) approximates the median population of the 8 centers represented in this study (median, 1,323,200; interquartile range, 778,250–1,672,600),[24] a limitation remains that our results are overrepresented by one site. However, adjusted for multiple comparisons, there were no significant differences in the responses from experts in Calgary compared with those outside Calgary (data not shown), suggesting that regional differences between the groups are less likely to be profound. Last, by choosing experts to complete these surveys, we cannot exclude the possibility that automaticity in their knowledge/skills may have paradoxically made them more susceptible than nonexperts to omitting the most basic competencies.[25,26]

Despite these limitations, our study had a number of strengths. First, there were a large number of experts who participated in the study. Although most expert panels typically seek the opinions of 3 to 10 experts,[27] our study had more than 20 experts for each of the procedures. Second, our experts were drawn from a number of specialties and from 8 cities across Canada; thus, their opinions were intended to represent a broad range of expertise. Third, our response rate was relatively high, despite the onerous nature of the survey.

In conclusion, our study presents expert consensus-derived competencies for ultrasound skills and knowledge that should be considered during the design and implementation of procedural skills training for learners. Overall, we identified 22, 32, and 28 essential competencies for ultrasound-guided central venous catheterization, thoracentesis, and paracentesis, respectively. We recommend that educators, at a minimum, cover these essential ultrasound competencies in their procedural curricula. For example, real-time guidance should be considered essential for teaching central venous catheterization, whereas the static technique would suffice for both paracentesis and thoracentesis. For items that did not reach consensus, we hypothesize that these may be higher-level skills that are considered less essential for the medical trainee to master.

Table 3. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Marginal competencies (continued)					
Demonstrates knowledge of A-lines	2	5 (23)	11 (50)	6 (27)	2 (1–3)
Demonstrates knowledge of Z-lines	2	4 (18)	10 (45)	8 (36)	2 (1–3)
Demonstrates knowledge and understanding of speed displacement artifact	2	5 (23)	14 (64)	3 (14)	2 (1–3)
Items without consensus					
Able to adjust color flow region size when using color Doppler		6 (27)	11 (50)	5 (23)	2 (1–3)
Able to steer color flow region box when using color Doppler		9 (41)	8 (36)	5 (23)	2 (1–3)
Able to control aliasing when using color flow Doppler		4 (18)	11 (50)	7 (32)	2 (1–3)
Able to adjust pulse repetition frequency when using color flow Doppler		6 (27)	7 (32)	9 (41)	2 (1–3)
Has knowledge and understanding of beam width artifact		9 (41)	9 (41)	4 (18)	2 (1–3)
Has knowledge and understanding of side-lobe artifact		9 (41)	9 (41)	4 (18)	2 (1–3)
Able to demonstrate Seashore sign with M-mode		9 (41)	8 (36)	5 (23)	2 (1–3)
Understands when to use power Doppler vs color Doppler		3 (14)	10 (45)	9 (41)	2 (1–3)
Understands difference between color Doppler and pulsed wave/continuous wave Doppler		7 (33)	9 (43)	5 (24)	2 (1–3)
Able to adjust Doppler gain when using pulsed wave Doppler		6 (29)	9 (43)	6 (29)	2 (1–3)
Aware that power Doppler does not offer velocity or direction information		3 (14)	11 (50)	8 (36)	2 (1–3)
Able to differentiate between arterial and venous waveforms from spectral waveforms		7 (33)	9 (43)	5 (24)	2 (1–3)
Confirms needle position within pleural cavity with ultrasound after flashback is seen		10 (45)	7 (32)	5 (23)	2 (1–3)

[a]Consensus for each item was defined as agreement by at least 80% of the experts.
[b]1 = marginal; 3 = essential.

Table 4. Ultrasound-Guided Paracentesis Competencies: Consensus of 23 Experts

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Essential competencies					
Knows when to abort procedure to ensure patient safety	1	22 (100)	0	0	3 (3–3)
Aware of which transducer to use for paracentesis (curvilinear, 2–5 MHz, or phased array, 2–4 MHz)	1	19 (83)	3 (13)	1 (4)	3 (1–3)
Able to select desired transducer on ultrasound machine	1	22 (96)	1 (4)	0	3 (2–3)
Able to identify probe orientation (mark on probe as it relates to dot on screen)	1	21 (91)	2 (9)	0	3 (2–3)
Able to hold probe with stability (does not dangle probe)	1	19 (83)	4 (17)	0	3 (2–3)
Able to maneuver probe to define structure characteristics	1	22 (96)	1 (4)	0	3 (2–3)
Uses sufficient gel and appropriate probe pressure	1	22 (96)	1 (4)	0	3 (2–3)
Able to sheath and handle probe in sterile manner	1	22 (96)	1 (4)	0	3 (2–3)
Able to adjust depth	1	23 (100)	0	0	3 (3–3)
Able to identify superficial structures as appearing at top of display and deeper structures at bottom of display	1	23 (100)	0	0	3 (3–3)
Starts scanning with sufficient depth to avoid missing far-field findings	1	20 (87)	3 (13)	0	3 (2–3)
Able to subsequently decrease depth to hone in on area of interest	1	21 (91)	2 (9)	0	3 (2–3)
Able to adjust gain to obtain best image possible	1	21 (91)	2 (9)	0	3 (2–3)
Able to locate hypoechoic area within abdomen	1	21 (91)	2 (9)	0	3 (2–3)
Able to identify absence of fluid	1	21 (91)	2 (9)	0	3 (2–3)
Able to identify overlying bowel	1	22 (96)	1 (4)	0	3 (2–3)
Able to identify location of spleen, liver, kidneys	1	23 (100)	0	0	3 (3–3)
Able to differentiate between subphrenic fluid and pleural fluid	1	23 (100)	0	0	3 (3–3)
Able to identify bladder and aware of mitigating strategies to avoid inappropriate aspiration of bladder	1	21 (91)	2 (9)	0	3 (2–3)
Able to identify safe needle insertion site (away from organs, bowel, vessels)	1	22 (96)	1 (4)	0	3 (2–3)
Able to measure depth of fluid from skin	1	20 (87)	2 (9)	1 (4)	3 (1–3)
Able to use ultrasound to determine appropriate site of needle entry and depth (static technique) but not under direct real-time guidance	1	22 (96)	1 (4)	0	3 (2–3)
Able to position target in center of screen	1	23 (100)	0	0	3 (3–3)
Recognizes needle tip	1	20 (87)	3 (13)	0	3 (2–3)
Able to recognize access into fluid	1	22 (96)	1 (4)	0	3 (2–3)
Able to avoid organ puncture (liver, spleen, kidneys)	1	22 (96)	1 (4)	0	3 (2–3)
Able to avoid bowel puncture	1	22 (96)	1 (4)	0	3 (2–3)
Able to avoid inferior epigastric artery puncture	1	19 (83)	3 (13)	1 (4)	3 (1–3)
Important competencies					
Aware of current evidence for any clinical benefits of ultrasound guidance for thoracentesis	1	10 (43)	12 (52)	1 (4)	2 (1–3)
Positions ultrasound machine so that screen is directly in line of sight (rather than needing to turn around to see screen)	1	14 (61)	9 (39)	0	3 (2–3)
Able to describe differences in transducer characteristics	1	14 (61)	9 (39)	0	3 (2–3)
Able to describe how frequency relates to resolution and penetration	1	13 (56)	8 (35)	2 (9)	3 (1–3)
Able to identify which transducer is selected based on shape of field or view displayed on screen	1	12 (52)	8 (35)	3 (13)	3 (1–3)
Able to change probe orientation to radiology convention (eg, change dot on screen to top left-hand side of screen)	1	7 (30)	14 (61)	2 (9)	2 (1–3)
Recognizes role of "presets" in preoptimized settings (depth, gain, power, focal zones, frame rates)	1	10 (43)	13 (57)	0	2 (2–3)
Able to choose appropriate preset for paracentesis (eg, abdominal)	1	13 (57)	9 (39)	1 (4)	3 (1–3)
Able to identify exact depth required for needle to advance	1	17 (74)	5 (22)	1 (4)	3 (1–3)
Able to adjust time-gain compensation (adjusting far-field/near-field gain selectively)	1	10 (43.5)	10 (43.5)	3 (13)	2 (1–3)

(continued)

Table 4. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Important competencies (continued)					
Able to adjust focal zone	1	5 (22)	14 (61)	4 (17)	2 (1–3)
Understands difference between 2-dimensional B-mode and M-mode	1	13 (57)	7 (30)	3 (13)	3 (1–3)
Able to select different Doppler modes (color, pulsed, continuous wave, power)	1	9 (39)	12 (52)	2 (9)	2 (1–3)
Able to archive images or cine clips	1	6 (26)	14 (61)	3 (13)	2 (1–3)
Knowledge and understanding of:					
Reverberation artifact	1	13 (57)	10 (43)	0	3 (2–3)
Ring down artifact	1	16 (69)	5 (22)	2 (9)	3 (1–3)
Beam width artifact	1	9 (39)	10 (43)	4 (17)	2 (1–3)
Side-lobe artifact	1	9 (39)	11 (48)	3 (13)	2 (1–3)
Mirror image artifact	1	14 (61)	7 (30)	2 (9)	3 (1–3)
Speed displacement artifact	1	5 (22)	15 (65)	3 (13)	2 (1–3)
Shadowing	1	15 (65)	7 (30)	1 (4)	3 (1–3)
Posterior acoustic enhancement	1	11 (48)	10 (43)	2 (9)	2 (1–3)
Performs initial nonsterile scan at lower quadrant	1	17 (77)	4 (18)	1 (5)	3 (1–3)
Performs semiquantitative assessment of fluid volume	1	11 (48)	9 (39)	3 (13)	2 (1–3)
Able to identify presence of strands/debris/septations	1	15 (65)	7 (30)	1 (4)	3 (1–3)
Able to characterize fluid as homogeneous or heterogeneous	1	18 (78)	4 (17)	1 (4)	3 (1–3)
Able to identify location of inferior epigastric artery	1	12 (52)	8 (35)	3 (13)	3 (1–3)
Able to image fluid in at least 2 views	1	16 (70)	6 (26)	1 (4)	3 (1–3)
Able to use direct real-time ultrasound guidance	1	9 (39)	10 (43)	4 (17)	2 (1–3)
Able to hold ultrasound probe in nondominant hand during active needle guidance	1	18 (78)	3 (13)	2 (9)	3 (1–3)
Able to direct needle tip to fluid using ultrasound	1	18 (78)	2 (9)	3 (13)	3 (1–3)
Able to maintain direct visualization of full path of needle tip from point of entry into fluid pocket	1	14 (61)	5 (22)	4 (17)	3 (1–3)
Able to perform procedure in both longitudinal and transverse approaches	1	7 (30)	12 (52)	4 (17)	2 (1–3)
Able to perform procedure in at least longitudinal approach	1	11 (48)	11 (48)	1 (4)	2 (1–3)
Able to perform procedure in at least transverse approach	1	14 (61)	6 (26)	3 (13)	3 (1–3)
Color flow					
Able to apply appropriate angle of insonation (as parallel as possible)	1	15 (65)	7 (30)	1 (4)	3 (1–3)
Able to determine direction of blood flow	1	15 (65)	6 (26)	2 (9)	3 (1–3)
Able to identify presence of aliasing	1	8 (35)	11 (48)	4 (17)	2 (1–3)
Able to adjust color gain when using color Doppler	2	11 (48)	7 (30)	5 (22)	3 (1–3)
M-mode					
Able to select M-mode	2	9 (39)	9 (39)	5 (22)	2 (1–3)
Able to use M-mode	2	8 (38)	8 (38)	5 (24)	2 (1–3)
Able to adjust scan line to area of interest when using M-mode	2	8 (38)	7 (33)	6 (29)	2 (1–3)
Marginal competencies					
Adheres to ALARA principle (exposing patient to lowest ultrasound energy possible)	2	7 (30)	7 (30)	9 (39)	2 (1–3)
Checks that mechanical or thermal index is within acceptable limits	2	3 (13)	8 (35)	12 (52)	1 (1–3)
Able to articulate benefit of setting focus in improving lateral resolution	2	5 (22)	12 (52)	6 (26)	2 (1–3)
Able to use multiple focal zones	2	3 (13)	10 (43)	10 (43)	2 (1–3)
Able to articulate that use of multiple focal zones will reduce frame rate	2	2 (9)	7 (30)	14 (61)	1 (1–3)
Able to adjust frequency within range of selected transducer	2	4 (17)	10 (43)	9 (39)	2 (1–3)
Able to articulate effect of adjusting dynamic range on image	2	3 (13)	9 (39)	11 (48)	2 (1–3)
Able to adjust dynamic range to optimize image	2	4 (17)	8 (35)	11 (48)	2 (1–3)
Able to adjust sample volume when using pulsed wave Doppler	2	7 (32)	5 (23)	10 (45)	2 (1–3)
Able to control Doppler mirror image artifact when using pulsed waved Doppler	2	3 (14)	9 (41)	10 (45)	2 (1–3)

(continued)

Table 4. (continued)

Proposed Competency	Round in Which Consensus[a] Was Reached	Experts Who Indicated Competency Is Essential in Round 1, n (%)	Experts Who Indicated Competency Is Important in Round 1, n (%)	Experts Who Indicated Competency is Marginal in Round 1, n (%)	Median Responses in Round 1, (Range)[b]
Items without consensus					
Able to adjust color flow region size when using color Doppler		7 (30)	11 (48)	5 (22)	2 (1–3)
Able to steer color flow region box when using color Doppler		10 (43)	8 (35)	5 (22)	2 (1–3)
Able to control aliasing when using color flow Doppler		5 (22)	11 (48)	7 (30)	2 (1–3)
Able to adjust pulse repetition frequency when using color flow Doppler		7 (30)	7 (30)	9 (40)	2 (1–3)
Understands when to use power Doppler vs color Doppler		3 (13)	10 (43)	10 (43)	2 (1–3)
Understands difference between color Doppler and pulsed wave/ continuous wave Doppler		7 (32)	9 (41)	6 (27)	2 (1–3)
Aware that power Doppler does not offer velocity or direction information		3 (13)	11 (48)	9 (39)	2 (1–3)
Able to differentiate between arterial and venous waveforms from spectral waveforms		7 (32)	9 (41)	6 (27)	2 (1–3)
Confirms needle position within abdominal cavity with ultrasound after flashback is seen		10 (43)	7 (30)	6 (26)	2 (1–3)

[a]Consensus for each item was defined as agreement by at least 80% of the experts.
[b]1 = marginal; 3 = essential.

Future studies should evaluate the importance of these higher-level skills.

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