Designing a multi-disciplinary undergraduate medical school ultrasonography curriculum

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ABSTRACT

Objectives: Although there is increasing demand for physicians from various specialties to be trained in ultrasonography (US), it is currently not being taught at most Canadian undergraduate medical schools in a comprehensive manner. The purpose of this study was to develop objectives to form the foundation of a comprehensive undergraduate US curriculum.

Methods: After completing an environmental assessment, which included a review of our current undergraduate objectives, a literature review was performed to identify published undergraduate US objectives. Using this information, a preliminary list of objectives was developed. The list was distributed electronically to 12 content experts from 10 disciplines and, using a two-round modified Delphi process, consensus about the inclusion of educational objectives was obtained. An a priori consensus criterion of 75% agreement was used to determine objectives that would be included in the curriculum. Objectives that met consensus in the first round of the survey were excluded from second round evaluation.

Results: Review of our undergraduate curriculum revealed that there were already 10 objectives relating to US. Combining existing objectives with those found during the literature review, an initial list of 79 objectives was produced. Sixteen of these were approved during the first Delphi round, while the remaining 63 objectives required rating during a second round. A final list of 25 objectives was produced.

Conclusions: Using a modified Delphi process, physicians from diverse backgrounds reflecting current and future use of US developed 25 multi-disciplinary objectives for a comprehensive undergraduate medical school US curriculum.

RÉSUMÉ

Objectifs: Bien qu'on demande de plus en plus que les médecins de diverses disciplines suivent une formation en échographie, cette méthode d'exploration n'est pas encore enseignée de façon exhaustive dans la plupart des programmes d'études de premier cycle des facultés de médecine canadiennes. Le but de cette étude est d'élaborer des objectifs qui serviront de fondation à la création d'un programme d'enseignement de l'échographie au premier cycle.

Méthodes: Après avoir terminé une analyse de contexte qui incluait une revue de nos objectifs d'apprentissage actuels, une revue de la littérature a été effectuée afin de faire ressortir les objectifs publiés pour l'enseignement de l'échographie au premier cycle de médecine. Avec cette information, une liste préliminaire d'objectifs a ensuite été élaborée. La liste a été envoyée électroniquement à 12 experts de contenu dans 10 disciplines différentes. Utilisant un processus de Delphi modifié en deux étapes, un consensus a été établi pour l'inclusion des objectifs d'apprentissage. Un consensus à priori de 75 % approuvant les objectifs a été utilisé pour choisir ceux qui seraient inclus dans le cursus. Les objectifs qui avaient satisfait au consensus lors de la première étape ont été exclus des évaluations lors de la deuxième étape.

Résultats: La revue de notre programme d'études de premier cycle a démontré qu'il y avait déjà dix objectifs portant sur l'échographie. En combinant les objectifs actuels et ceux qui ont été relevés lors de la revue de la littérature, une liste initiale de 79 objectifs a été produite. Seize de ces objectifs ont été approuvés lors du premier tour Delphi. Les 63 autres objectifs ont dû être évalués dans le cadre du deuxième tour. Une liste finale de 25 objectifs a été produite.

Conclusion: À l'aide d'un processus de Delphi modifié, des médecins provenant de diverses disciplines reflétant l'utilisation courante et éventuelle de l'échographie ont élaboré 25 objectifs multidisciplinaires pour offrir un programme complet de formation en échographie dans le cursus du programme de premier cycle de médecine.

INTRODUCTION

Ultrasonography (US) has been shown to be a safe and effective method for diagnosing a number of medical problems [1-2]. With increasing technology, equipment has become more portable, compact and less expensive, allowing US use to grow in many different medical specialties [1,3]. When applied appropriately, point-of-care ultrasonography (PoCUS) can provide efficient real-time diagnosis while supplementing or replacing more

advanced imaging in specific situations [1].

Studies have consistently demonstrated that undergraduate medical students are capable of learning and performing US exam skills [4-6], and that both junior and senior students find that using US can help reinforce theoretical and anatomical concepts [7-8]. Currently, the majority of US training takes place at the postgraduate level in specific residency programs (eg. Radiology, Cardiology, Obstetrics/Gynecology, and Emergency Medicine).

While several integrated US curricula at the undergraduate level do exist in the United States [9-10], based on the results of a literature review, only a few Canadian medical schools have recently attempted to introduce comprehensive undergraduate US training. At the University of Ottawa, current US teaching is mainly limited to theory presented during radiology and obstetric lectures [11]. The purpose of this study was to determine the objectives that would form a longitudinal undergraduate US curriculum..

METHODS

Preliminary bank of objectives: A preliminary list of objectives was developed using a variety of sources. An environmental assessment was completed that included a comprehensive review of the current undergraduate medicine objectives at the University of Ottawa to identify any current objectives relating to US. This was accomplished through a keyword analysis and manual search of the university's published objectives. A literature review was then performed using both MESH and general search terms in PubMed and Scopus (Appendix 1) to identify any papers related to the teaching of US in undergraduate medical education. In addition to scholarly papers, publicly available online material as well as individual American and Canadian medical school websites were also searched for all existing undergraduate US curricula accessible through their respective internal search engines [10,13]. Finally, faculty members at the University of Ottawa representing 10 different specialties (Table 1) were asked to identify any objectives related to the current use of US in their respective specialties. The information gathered was collated to form a preliminary list of objectives.

Modified Delphi Method: A two-round modified Delphi process was utilized in order to achieve consensus about the educational objectives to be included in the curriculum. The Delphi technique uses multiple rounds of surveys to gain consensus amongst participants about a topic with which they are perceived to have expertise [12]. Using a purposive sample, a local group of 12 experts representing 10 different medical specialties were invited to participate in evaluating a comprehensive list of prospective objectives (Table 1). Experts from different departments were identified as those that were heads of US programs or identified as having a significant interest in US. Many different variations on the modified Delphi design have been published [12]. We chose to have two rounds of evaluation as this allowed the survey to be completed in a timely manner while still meeting the recommended range of rounds suggested by the literature [10]. The process was administered via a web-based electronic survey (SurveyMonkey Inc., Palo Alto, California, USA). In each round, a priori consensus criteria were established to determine which objectives would meet the criteria for inclusion, exclusion or for further consideration. Prior to the first round of the Delphi process, three physicians not participating in the study piloted the survey. Minor adjustments and edits were made based on their feedback.

Round One: In the first round, the 12 content experts were asked to rate each objective from the preliminary bank of objectives. An e-mail was sent to each participant providing a web link to complete the online survey. Individual participant ratings were kept anonymous from the other content experts and were only identifiable to the principal investigator and the research medical student following the completion of the survey. This allowed participants to evaluate each objective free of external influence. Reminder emails were sent to participants with outstanding surveys on a biweekly basis. The survey included a description of the process and a list of considerations to make prior to ranking the objectives (Appendix 2).

In the first round, each item was evaluated with a 7-point Likert scale, ranging from "strongly agree" to "strongly disagree", accompanied by a comment box for each item as well as a comment section for the overall survey. For an objective to meet the predefined inclusion or exclusion criteria, 75% of participants had to agree in their ratings. Objectives that were rated either 6 (Agree) or 7 (Strongly Agree) by 75% of the survey participants were considered to have met the consensus criterion for inclusion. Conversely, items that were rated 1 (Strongly Disagree) or 2 (Disagree) by 75% of participants were considered to have met the exclusion criterion. While no definite cutoff is agreed upon in the literature [10], recent studies relevant to our own have used a 75% cutoff for their own curriculum and devel-

Table 1. List of Content Experts and their specialty

Dr. Chris Johnson	Division of Cardiology
Dr Griffith Jones	Division of Obstetrics and Gynecology
Dr. Jacinthe Lamprom	Division of Surgery
Dr. David Mai	Department of Family Medicine
Dr. Mathew McInnes	Department of Radiology
Dr. Scott Millington	Division of Critical Care
Dr. Rebecca Peterson	Department of Radiology
Dr. Debra Pugh	Division of General Internal Medicine
Dr. Wael Shabana	Department of Radiology
Dr. Ron Tam	Department of Pediatrics
Dr. Calvin Thompson	Department of Anesthesiology
Dr. Michael Woo	Department of Emergency Medicine

opment of competencies [14-16].

Round Two: Only objectives that did not meet either the inclusion or exclusion criteria in the first round of the survey were reevaluated in the second round of the modified Delphi process. For the second round, the survey was adapted to a 3-point scale that included the following options: Do Not Include, For Consideration and Include. With each objective, the mean numerical score from the first round of ratings was provided to provide participants with information about the collective opinion, a technique recommended by Hasson et al. [14]. It also aided with rating some of the objectives that may not have been pertinent to the individuals' respective specialties.

The second round procedure remained the same as the first round with the exception of the 3-point Likert scale that was used instead of the 7-point Likert scale employed in the first round. Again, a priori consensus criteria were used: an objective met the inclusion or exclusion criteria if 75% of participants rated it as "Include" or "Do Not Include" respectively. Any objective that did not meet the above criteria was placed in a category "For Consideration." Objectives remaining in the "For Consideration" category would receive subsequent review by a curriculum committee regarding their inclusion at a later date.

RESULTS

79 US objectives were generated through expert submission and literature review of the current University of Ottawa curriculum. Of these 79 US objectives, 10 were generated from pre-existing objectives in the current University of Ottawa curriculum. The US content experts represented a broad background in terms of education, practice type and specialty (Table 2). In the first round of the modified Delphi process, a 100% response rate was achieved. Sixteen of the 79 objectives met the consensus criterion for inclusion (Table 3). No item met the exclusion criterion; the remaining objectives were reevaluated in the second round of the modified Delphi process. In the second round of the modified Delphi process 63 objectives were reevaluated with a 100% response rate. Following the second round of evaluation, nine additional objectives met the inclusion consensus criterion, (Figure 2) while two objectives met the exclusion criterion. The remaining 52 objectives did not meet either consensus criteria and required further consideration. Following the Delphi process, these objectives were sent for review by curriculum experts to determine which objectives were reasonable and or feasible to be implemented in the curriculum.

Table 2. Ultrasound Expert Profile

Characteristic	No. (%)
Years of Practice	
Less than 5	2 (17)
5-10	3 (25)
10-15	4 (33)
More than 15	3 (25)
University Rank	
Assisstant Professor	10 (83)
Associate Professor	2 (17)
Practice center	
Academic health science center	11 (92)
Community hospital	1 (8)
Practice Type	
Almost exclusively adult	10 (83)
Almost exclusively pediatric	1 (8)
Mixture of adult and pediatrics	1 (8)
Experience with ultrasonography	
Diirector	4 (33)
Teaching	7 (58)
General use	10 (83)
Course Development	7 (58)

DISCUSSION

The modified Delphi process we successful at identifying 25 multi-disciplinary objectives to form the core of an undergraduate medicine US curriculum. Approved objectives were both theoretical and practical in nature and spanned the entire undergraduate medical curriculum at the University of Ottawa. As expected, the objectives regarding basic foundational theory were amongst the most highly agreed upon. Beyond this observation, there did not seem to be any observable trends or patterns to ratings based on individual participant or objective topic. This likely reflects the broad multidisciplinary background of our participants.

At the conclusion of the modified Delphi process, 52 of the 79 objectives were left in the category "For Consideration." Several factors likely contributed to this result. Where our study gained strength from having a multi-disciplinary group of participants, this feature likely prevented most objectives from being rated either too positively or too negatively, leaving some undecided. With the varied initial bank of objectives and the broad representation of specialties, there were instances where an objective had strong support, but only for a few individuals. Combined with the reasonably strict inclusion criterion, many objectives finished in the "For Consideration" category.

Compared to the work of Penciner et al, who approved 62 of a possible 152 (41%) emergency medicine clerkship competencies using a similar modified Delphi process [15], we were able to approve a similar proportion of curriculum objectives (32%). However, a key difference in the methods of our study was that we allowed participants three options in the final round of evaluation as opposed to requiring a dichotomous decision. Allowing for a more moderate survey choice allows raters to be indecisive when they are not certain and likely prevented objec-

Table 3. Objectives meeting positive consensus criterion for inclusion in undergraduate medical ultrasound curriculum (% agreement)

Pre-Clerkship

- Describe the risks, benefits and limitations of US as a diagnostic modality. (100%)
- Recognize the differences and limitations of point of care US (PoCUS) compared to Cardiology/Ob-Gyn/Radiology performed US. (100%)
- Explain the basic terminology used in describing US (ex: hyper/hypo/isoechoic). (75%)
- Recognize the relationship between depth, frequency and gain on an image. (75%)
- Describe the difference between in-plane (longitudinal) and out-of-plane (transverse) technique for procedures. (75%)
- Describe the difference between static (landmarking) and dynamic (real-time) use of ultrasound for procedures. (83%)
- Describe the proper sterile technique required when performing scans to assist with procedures. (75%)
- Recognize the appearance of a pleural effusion and the role of US in thoracentesis. (75%)
- Recognize the appearance of a pericardial effusion and the role of US in pericardiocentesis. (83%)
- Demonstrate and identify the appearance of the carotid artery and internal jugular vein. (83%)
- Demonstrate and identify the appearance of the femoral artery and vein. (75%)
- Demonstrate and identify the right and left ventricle and right and left atrium. (75%)
- Recognize the appearance of peritoneal fluid and the role of US in paracentesis. (92%)
- Explain the role of ultrasound examination in the diagnosis of early pregnancy. (83%)
- Recognize the role of ultrasound in abscess drainage. (75%)

Clerkship

- Demonstrate proper documentation of scan results in a patient's chart. (92%)
- Recognize areas of uncertainty and personal limitations in performing scans and understand when to seek the appropriate help and additional imaging. (100%)
- Describe the proper disclosure and documentation of critical incidents. (82%)
- Demonstrate efficient communication of critical findings to an attending physician. (75%)
- Recognize the role of US in the evaluation of hepatosplenomegaly in pediatrics. (75%)
- Recognize the role of US in evaluation of patients of different age groups presenting with acute scrotal pain. (75%)
- List the advantages and limitations for US-guided central line insertion. (75%)
- List the advantages and disadvantages of US-guided peripheral IV insertion. (75%)
- Recognize the role of ultrasound in assisting with the placement of an arterial line. (75%)
- Recognize the role of US as part of ACLS to rule out pneumothorax and pericardial effusion in pulseless electric activity (PEA) arrest. (83%)

tives from meeting inclusion and exclusion criteria [17].

Other explanations as for why some objectives did not meet either consensus criteria speak to the limitations of our study. Our group of participants was limited in size to 12. Similar studies using the Delphi process at a regional or national level have been able to secure larger participant numbers [18-19]. While we aimed to create a curriculum that could be generalizable across Canada, as well as schools beyond Canada, our survey's participants were limited to the University of Ottawa. The number of local US experts was limiting to our sample size. Within this sample, our recruitment criteria resulted in increased radiologist representation that may have added an additional source of bias to the results. In addition, despite pre-survey instructions (Appendix 2), it was evident from some of the additional comments that participants were still concerned with the feasibility of a minority of the resource intensive objectives while rating them. Our goal in asking participants to ignore resource considerations while evaluating objectives was to identify the ideal content for the curriculum through the Delphi process. Further committees would deal with the practical aspects of implementing the curriculum at a later date. Inability to look past feasibility concerns likely led to several objectives not meeting the positive consensus criterion that would have otherwise.

While the survey process was designed to promote curriculum development free of external pressure, it should be noted that the process was not completely blinded. While this incomplete blinding was a likely a source of bias, the anonymous nature of the responses during the survey process may have minimized the extent of this bias. As seen in similar studies, an external review could have been completed to evaluate the validity of the results and extent of bias within our methodology [15]. This step was omitted, as our results required further external review locally prior to being implemented into a curriculum..

CONCLUSION

The modified Delphi process was able to systematically achieve consensus with 25 core objectives to form an undergraduate medical US curriculum. The process was successful at obtaining multidisciplinary input representing the current and future landscape of US use in medicine. We were also able to attain this information in a manner that minimized external pressure or influence and promoted participant opinion. Although the majority of curriculum objectives will require further consideration, our study was not intended to be a final step. Further consideration and analysis of our results is needed to determine which of the undecided objectives are required to ensure the final curriculum is comprehensive and consistent. Next steps will include the development of educational strategies to implement and deliver the proposed curriculum. Following implementation, further efforts will be taken to evaluate its efficacy and make any required modifications. Ultimately, we were able to achieve consensus with 25 curriculum objectives amongst a diverse group of experts

Table 4. Objectives needing further consideration for inclusion in undergraduate medical ultrasound curriculum

Pre-Clerkship
- List and explain the characteristics of an ideal ultrasound machine.
- Recognize the following artifacts on an image: low and high attenuation, refraction, reverberation and mirror image.
- Recognize the proper care required to maintain ultrasound equipment.
- Describe the most appropriate transducer and machine settings to identify the appropriate structure.
- Demonstrate and identify the appearance of a bone, muscle, tendon and nerve.
- Demonstrate and identify the appearance of a joint space for the elbow, hip, knee, and ankle in adults and children.
- Recognize the role of ultrasound in arthrocentesis.
- Describe the standard 2-D echocardiographic views.
- Explain the principles of cardiac ultrasound with emphasis on the assessment of left ventricular function.
- Identify intima-media thickness of the carotid artery on an image with colour Doppler.
- Recognize the appearance of a deep venous thrombosis.
- Demonstrate the parasternal long, parasternal short, subxiphoid and apical views of the heart.
- Demonstrate and identify the mitral, tricuspid and aortic valves.
- Identify the height of the jugular venous pressure (JVP).
- Demonstrate and identify the appearance of the abdominal aorta and inferior vena cava.
- Demonstrate and identify the appearance of the ribs, lungs, pleura and diaphragm.
- Interpret global left ventricular function (normal/mildly depressed/severely depressed/hyperdynamic) using ultrasound.
- Recognize the appearance of hydronephrosis.
- Recognize the appearance and describe the limitations of obtaining images of the gall bladder, kidneys and intestines.
- Recognize the appearance of a fetal heartbeat.
- Recognize the appearance of the uterus and bladder.
- Assess the post-void residual volume of a patient using ultrasound.
- Demonstrate and identify the appearance of the liver, gall bladder, spleen and pancreas in both and adult and pediatric population.
- Demonstrate and identify the appearance of the kidneys and bladder in both an adult and pediatric population and recognize the role of ultrasound in suprapubic aspiration of urine.
- Demonstrate and identify the appearance of the intestine.
- Demonstrate and identify the appearance of the normal uterus.
- Demonstrate, identify and measure the abdominal aorta using ultrasound.
- Describe the sonographic features of cholecystitis.
- Describe the advantages, disadvantages and limitations of ultrasound as a method of locating nerves.
- Recognize the differences between cervical lymphadenitis, cellulitis, and abscess in adults and children.
- Demonstrate and identify the appearance of skin abscesses and cellulitis.

Clerkship
- Demonstrate proper archiving of scanned images.
- Demonstrate proper logging of all ultrasound-guided procedures.
- Recognize the role of ultrasound in evaluation of anatomy and pathology of the eye.
- Recognize the role of ultrasound in evaluation of sinusitis.
- Recognize the role of ultrasound in evaluation of a peritonsillar abscess.
- Demonstrate the use of M-mode to assess the fetal heartbeat.
- Identify appearance of pneumonia using point of care ultrasound (PoCUS) in a pediatric population.
- Recognize the role of ultrasound in the evaluation of abdominal symptoms in a young child including gastroenteritis, intussusception, pyloric stenosis and appendicitis.
- Recognize the role of ultrasound in the evaluation of neonates for intraventricular bleeds.
- Recognize the appearance of acute thoracic aortic dissection.
- Recognize the appearance of gallstones.
- Demonstrate proper technique for ultrasound-guided peripheral IV insertion.
- Recognize the role of ultrasound in performing regional nerve blocks.
- Recognize the role of ultrasound in performing a lumbar puncture.
- Perform an extended focused assessment with sonography for trauma (eFAST – Checking for free fluid in the abdomen and a pneumothorax).
- Demonstrate the use of M-mode to assess a pneumothorax.
- Confirm the placement of an endotracheal tube using ultrasound.
- Describe the algorithmic approach using ultrasound to assist in undifferentiated shock (R.U.S.H. exam, Rapid Ultrasound for Shock and Hypotension – Heart, IVC, Morison's Pouch/FAST, Aorta, Pneumothorax).
- Determine and identify superficial foreign bodies and help with their removal using ultrasound.
- Recognize the ultrasound appearance of cardiac standstill.
- Recognize the appearance of pulmonary edema on ultrasound

using a modified Delphi process to form the core of an undergraduate US curriculum.

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Table 5. Objectives meeting negative consensus for exclusion from undergraduate medical ultrasound curriculum

• Recognize normal appearance of the thyroid gland. • Demonstrate and identify the appearance of a normal thyroid gland

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Keywords: Ultrasound, Ultrasonography, PoCUS, Point-of-care-ultrasound, Curriculum, Delphi, Undergraduate, Multi-disciplinary, Medical Education

APPENDIX 1 : Literature Search Strategies

- PubMed - ultrasound AND medical school curriculum – 320 results
- PubMed - undergraduate medical education AND ultrasound – 67 results
- PubMed - MeSH (Ultrasonography) + MeSH (Undergraduate Medical Education) – 34 results
- PubMed - ultrasound curriculum + MeSH (Undergraduate Medical Education) – 53 results
- Scopus – undergraduate AND ultrasound curriculum – 26 results
- Scopus – ultrasound AND undergraduate curriculum – 29 results

APPENDIX 2 : Survey instructions for content experts

When rating the following objectives please consider the following:

1. The following objectives are intended for undergraduate medical students both in pre-clerkship and clerkship.
2. Ratings should reflect the knowledge and skills that every medical student should have upon graduation regardless of chosen specialty or career path.
3. Objectives can be obtained through a variety of education modalities (eg. clinical, workshops, simulation, online learning).
4. The purpose is to determine the objectives and not how they will be delivered. The objectives will be further refined with curriculum experts after the Delphi process to determine how and where each objective will be taught. With this in mind, please try to rank objectives on content rather than how and where they are currently written.