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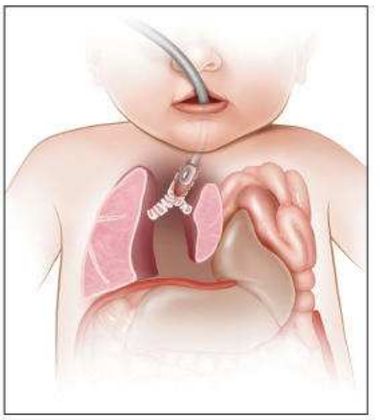

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Acquisition and Long-term Retention of Bedside Ultrasound Skills in First-Year Medical Students

Peter Steinmetz, MD, Sharon Oleskevich, PhD, John Lewis, MD

Objectives—The purpose of this study was to assess bedside ultrasound skill acquisition and retention in medical students after completion of the first year of a new undergraduate bedside ultrasound curriculum at McGill University.

Methods—Skill acquisition was assessed in first-year medical students (n = 195) on completion of their bedside ultrasound instruction. Instruction included 6 clinically based 60-minute practical teaching sessions evenly spaced throughout the academic year. Students' ability to meet course objectives was measured according to a 4-point Likert rating scale. Evaluations were performed by both instructors and the students themselves. Retention of skill acquisition was evaluated 8 months later on a year-end practical examination.

Results—The mean percentage ± SD of students assigned a rating of "strongly agree" or "agree" by instructors was 98% ± 0.4% for all 6 teaching sessions (strongly agree, 52% ± 3%; agree, 46% ± 3%). According to student self-evaluations, the mean percentage of students assigned a rating of strongly agree was significantly greater than the percentage assigned by instructors for all teaching sessions (86% ± 2% versus 52% ± 3%; $P < .0005$). Evaluation of skill retention on the year-end examination showed that 91% ± 2% of students were assigned a rating of strongly agree or agree for their ability to demonstrate skills learned 8 months previously. Ninety-five percent of students reported that bedside ultrasound improved their understanding of anatomy for all 6 teaching sessions (mean, 95% ± 0.01%).

Conclusions—These results demonstrate that first-year medical students show acquisition and long-term retention of basic ultrasound skills on completion of newly implemented bedside ultrasound instruction.

Key Words—bedside ultrasound; medical education; medical student; ultrasound education; undergraduate education

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Bedside ultrasound (point-of-care ultrasound) describes the use of a portable ultrasound device by the treating clinician. It is being increasingly integrated into clinical practice as an adjunct to the physical examination and patient history.[1] Accordingly, more emphasis is being directed to the teaching of bedside ultrasound at the undergraduate level. A substantial body of literature attests to the worldwide implementation of bedside ultrasound education at the undergraduate level, with some implementation as early as 1996.[2] To date, undergraduate bedside ultrasound education is evident in Australia,[3–6] Austria,[7] China,[8] Germany,[2,9] France,[10] the United States,[11–26] and the United Kingdom.[27–29]

Undergraduate ultrasound teaching in Canada is implemented in certain universities, including the Universities of Calgary, Ottawa, Northern Ontario School of Medicine, Sudbury, Saskatoon, and British Columbia.[30] McGill University introduced integrated bedside ultrasound instruction for medical students in October 2013, making it the first university in Canada to integrate a vertical 4-year undergraduate bedside ultrasound curriculum.

Comprehensive studies demonstrate two main benefits of undergraduate bedside ultrasound education. First, bedside ultrasound has been shown to increase the clinical accuracy of medical students, as demonstrated by the superiority of undergraduate students to estimate liver size when using bedside ultrasound compared to experienced physicians using physical examination alone.[31] Also, students using bedside ultrasound were more accurate in diagnosing cardiac disease than cardiologists using physical examination alone[32] and the same students using physical examination alone.[33] Adding ultrasound training to physical examination training enhanced basic physical examination skills,[34] competency with the femoral vascular examination,[35] and first-time pass rates on blood pressure measurements and the abdominal examination.[36] Second, bedside ultrasound has been shown to improve a student's understanding of anatomy. Two Canadian studies showed that ultrasound enhanced the understanding of living anatomy and the learning of musculoskeletal anatomy.[37,38] A randomized controlled trial showed that medical students receiving ultrasound teaching performed significantly better than an ultrasound-naïve control group on an anatomy test.[39] Overall, most medical students agree that ultrasound improves their understanding of anatomy.[2,3,28,40–43]

The benefits of undergraduate bedside ultrasound education hinge on successful acquisition of ultrasound skills. The aim of this study was to assess skill acquisition in a new undergraduate bedside ultrasound course at McGill University. Skill acquisition was evaluated by using both a quantitative assessment of student skill acquisition and a qualitative assessment of student perspectives. The quantitative assessment was based on instructor evaluations and student self-evaluations. The comparison of instructor evaluation to self-evaluation is of interest in the context of previous reports that self-assessments are often flawed and overconfident.[44–47]

This study also quantitatively assessed the retention of skill acquisition. Previous reports demonstrated that massed training promotes rapid acquisition of skill but not necessarily retention of skill.[45] A qualitative assessment investigates medical students' perspectives on whether ultrasound improves their understanding of anatomy. The outcomes of this study may help refine and improve future courses in undergraduate bedside ultrasound education. Some of the results have appeared previously in a preliminary form.[48]

Materials and Methods

Study Population

The study population comprised first-year medical students with no prior ultrasound experience enrolled in bedside ultrasound instruction (Clinical Methods I, Fundamentals of Medicine and Dentistry) at McGill University and their instructors in 2013. Any students or instructors not involved in first-year bedside ultrasound education were excluded from the study. All evaluation forms were anonymous and could not be traced to a particular student or instructor. Consent forms were not required, as this study was a secondary analysis of anonymously collected data. Procedures received full institutional approval (A06-E50-14A) by the Faculty of Medicine Institutional Review Board of McGill University.

Course Design

The course comprised 6 clinically based, 60-minute practical teaching sessions evenly spaced from October 2013 to June 2013 (Table 1). The sessions included approaches to: (1) dyspnea, (2) hypotension, (3) abdominal aortic aneurysm, (4) free abdominal fluid, (5) kidney injury, and (6) swollen leg. At the end of the year, the teaching sessions were followed by a review session covering all topics and a practical examination on one of the teaching sessions completed during the year.

The course was designed to include a 3-way alignment between the course textbook, course objectives, and course evaluation forms. The alignment ensured that identical topics were reinforced in all 3 components (Tables 1 and 2). Two weeks before each teaching module, selected chapters from the course textbook and the aligned course objectives were distributed to year 1 medical students (n = 195) and their instructors (n = 8). The course textbook was *Bedside Ultrasound: Level 1*[49] or its French version *Échographie Ciblée: Niveau 1*.[50] Course objectives (6–8 objectives per session) were centered on image generation and interpretation (Table 1). The course objectives were clearly identifiable and contained concepts that were repeated between chapters (Table 1). An open-access companion Web page to the textbook provided instructional videos illustrating scanning techniques and ultrasound images.

The teaching sessions took place in the Technical Skills Room at the Arnold and Blema Steinberg Medical Simulation Center, McGill University, from September 2013 to June 2014. Attendance was compulsory at all 6 teaching sessions. Instructors were senior physicians and residents with experience in bedside ultrasound. Most instructors (83%) were staff physicians with Canadian point-of-care ultrasound credentials from the Canadian Association of Emergency Physicians or the Canadian Emergency Ultrasound Society. Some instructors were residents (17%) with a minimum of 20 hours of ultrasound training and a minimum of 6 months of clinical experience using bedside ultrasound. All instructors were vetted by the course director and demonstrated excellent teaching skills as well as an understanding of the course objectives and format.

The Technical Skills Room contained 8 workstations, each equipped with an ultrasound machine and a ceiling-suspended monitor. Scanning was performed on normal standardized patients. The suspended monitor displayed a continuous loop of ultrasound images of common clinical conditions related to the topic being studied. The teaching sessions began with a short introduction to the clinical

Table 1. McGill University Faculty of Medicine Ultrasound Curriculum, 2013–2014

Session	Textbook	Course Objectives
1. Ultrasound basics and artifacts	Chapters 1–3	
Dyspnea	Chapter 4	Probe choice, patient position, scanning technique
	Videos 2.1–4.9	Identify lung sliding, A-lines, B-lines (if present); perform posterolateral chest examination, identify diaphragm and "curtain sign"
2. Undifferentiated hypotension	Chapter 5	Probe choice, patient position, scanning technique
	Videos 5.1–5.8	Identify the heart (subxiphoid view) with left ventricle, right ventricle, left atrium, right atrium, pericardium; understand left ventricular function, right-to-left ventricular ratio, inferior vena cava, and respiratory variability
3. Trauma	Chapter 6	Probe choice, patient position, scanning technique
	Videos 6.1–6.2	Identify Morison pouch, splenorenal space, pouch of Douglas, rectovesical space
4. Abdominal aortic aneurysm	Chapter 7	Probe choice, patient position, scanning technique
	Videos 7.1–7.2	Identify and measure true diameter of abdominal aorta in 2 planes; identify inferior vena cava, vertebral body, liver in transverse plane
5. Kidney injury	Chapter 9	Probe choice, patient position, scanning technique
	Videos 9.1–9.5	Identify right and left kidneys (renal cortices, calyces, pelvis) in 2 planes; identify bladder in 2 planes; understand obstructive causes of kidney injury (hydronephrosis)
6. Deep venous thrombosis of the lower limb	Chapter 10	Probe choice, patient position, scanning technique
	Videos 10.1–10.5	Identify and compress common femoral vein and popliteal vein; differentiate veins from arteries

Teaching sessions were aligned with the course textbook and course objectives.

Table 2. Evaluation Form Completed by Instructors for McGill University Faculty of Medicine Ultrasound Curriculum, 2013–2014

Session: Dyspnea	Rating			
Student:	Strongly Disagree	Disagree	Agree	Strongly Agree
Demonstrates correct choice of probe and indicator orientation	☐	☐	☐	☐
Demonstrates optimal patient and sonographer positioning	☐	☐	☐	☐
Identifies ribs and rib shadows on anterior chest view	☐	☐	☐	☐
Identifies the pleura and lung sliding on the anterior chest view	☐	☐	☐	☐
Identifies an A-line (if present)	☐	☐	☐	☐
Identifies a B-line (if present)	☐	☐	☐	☐
Identifies the hemidiaphragm on the posterolateral chest examination	☐	☐	☐	☐
Identifies the liver on right and spleen on left on posterolateral chest examination	☐	☐	☐	☐
Identifies the curtain sign	☐	☐	☐	☐

approach. The use of 8 ultrasound machines allowed 32 medical students to be taught per hour, with a ratio of 4 students per instructor per standardized patient.

Quantitative Assessment of Skill Acquisition

Skill acquisition was assessed by the completion of evaluation forms by instructors and students immediately after each teaching session (Table 2). The evaluation forms were aligned to the course textbook and the course objectives and were identical for instructor and student evaluations. Evaluation forms completed by instructors rated the students' ability to meet the course objectives using a 4-point Likert rating scale (strongly disagree, disagree, agree, and strongly agree). Self-assessment forms completed by students rated their skill in meeting identical objectives using an identical rating scale.

Skill retention for the dyspnea teaching session was assessed by instructors in a practical examination at the end of the academic year, 8 months after the original teaching session. Students were randomly assigned to the dyspnea module for the retention follow-up examination; thus, there was no selection bias in choosing the students who were evaluated for skill retention. All students randomly assigned to the dyspnea module had received the exact same amount of ultrasound teaching at the time of the retention follow-up examination. Only 1 component (dyspnea) was tested in the retention examination to maximize the retention period within 1 academic year. The dyspnea component provided the longest retention period, as it was taught first in the academic year, and the retention examination was performed 8 months later at the end of the academic year. Evaluation forms and rating scales were identical to those used by instructors previously in the year.

Quantification of skill acquisition, self-assessment, and skill retention was performed by calculating the percentage of students assigned a particular scale for each course objective in each teaching session. The percentages assigned to each course objective were then averaged to provide a percentage for all course objectives for a particular teaching session. All data remained anonymous throughout data collection and analysis.

Qualitative Assessment of Student Perceptions

Student perceptions of the ultrasound course were qualitatively assessed by collecting students' comments from a survey completed immediately after each teaching module. The survey included 4 questions: (1) Did the ultrasound course improve your understanding of the anatomy? (2) What did you enjoy most about this session at the Medical Simulation Center? (3) What did you enjoy least about this session at the Medical Simulation Center? (4) Additional comments. A quantitative assessment of student perceptions was performed on the students' reply to the survey question 1, which was a dichotomous question of whether the ultrasound course improved their understanding of the anatomy content in each clinically based teaching session.

Statistical Analysis

Statistics are quoted as mean ± standard deviation. Significant differences were determined by a 2-tailed unpaired nonparametric Mann-Whitney test for comparisons of skill acquisition (student self-assessment versus instructor assessment). All statistical analyses were performed with GraphPad Prism 6.0f software (GraphPad Software, Inc, La Jolla, CA).

Results

Students Show Significant Skill Acquisition After Each 1-Hour Clinically Based Teaching Module

The mean percentage of students assigned a rating of "strongly agree" or "agree" for their ability to successfully meet all objectives in all teaching sessions was 98% ± 0.4% (strongly agree, 52% ± 3%; agree, 46% ± 3%), according to instructor evaluations. For individual teaching sessions, the mean percentages of students with a rating of strongly agree or agree were 100% for dyspnea, 97% for hypotension, 98% for abdominal aortic aneurysm, 98% for free abdominal fluid, 98% for kidney injury, and 97% for swollen leg. Overall, the students showed the greatest skill acquisition in the dyspnea and hypotension teaching sessions. The mean percentages of students with a rating of strongly agree were 62% and 61% for all objectives in the dyspnea and hypotension teaching sessions (Figure 1). The percentages of students assigned to each of the 4 categories in the Likert rating scale are presented for each individual teaching session (Figure 1).

The overall mean percentage of students assigned a scale of "strongly disagree" or "disagree" for their ability to meet all objectives in all teaching sessions was 2% ± 0.4% (strongly disagree, 0.07% ± 0.05%; disagree, 1.8% ± 0.40%). For individual teaching sessions, the mean percentages of students with a combined rating of strongly disagree and disagree were 0% for dyspnea, 3% for hypotension, 2% for abdominal aortic aneurysm, 2% for free abdominal fluid, 2% for kidney injury, and 2% for swollen leg (Figure 1). For some objectives within the teaching sessions, the percentage of students assigned a rating of strongly disagree or disagree was greater than 5%. These objectives included generating a parasternal long-axis view of the heart (hypoten-

sion teaching session), aligning the orientation marker on the probe in the correct direction (free abdominal fluid teaching session), and visualizing the greater saphenous vein (swollen leg teaching session).

Students Significantly Overestimate Their Skill Acquisition After a 1-Hour Clinically Based Teaching Session

According to student self-evaluations for all teaching sessions combined, the mean percentage of students who self-assigned a rating of strongly agree was significantly greater than the mean percentage of students assigned a scale of strongly agree by instructors. The students self-assigned a mean percentage of 86% ± 2% for the rating of strongly agree, whereas the instructors assigned a mean percentage of 52% ± 3% ($P < .0005$, Mann-Whitney test). This overestimation was observed within individual teaching sessions, with student self-assigned mean percentages that were significantly greater than instructor-assigned mean percentages in all teaching sessions ($P < .005$, Mann-Whitney test; Figure 2). The students' self-assigned rating of strongly agree for their skill acquisition was on average 68% greater (range, 41%–100%) than the instructors' ratings across individual teaching sessions (Figure 2).

Students Retain Practical Bedside Ultrasound Skills During the Academic Year

According to instructor evaluations after an initial dyspnea teaching session (at time = 0 months), the percentages of students who successfully met all objectives with ratings of strongly agree and agree were 62% ± 2%, and 38% ± 2%, respectively (Figure 3A). The combined mean percentage of students assigned a rating of strongly agree or agree was 100%.

Eight months later, 65 students completed a practical examination on dyspnea to evaluate their skill retention. According to instructor evaluations completed after this examination (time = 8 months), the percentages of students who successfully met all objectives with ratings of strongly

Figure 1. Students show significant bedside ultrasound skill acquisition. Percentages of students able to meet course objectives in 6 teaching sessions according to instructor evaluations using a 4-point Likert rating scale. AAA indicates abdominal aortic aneurysm; and Abdo, abdominal.

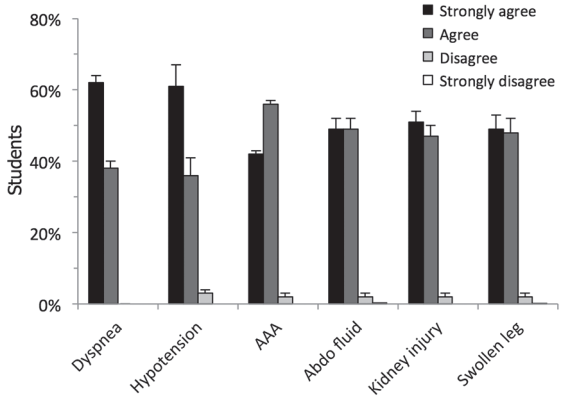


Figure 2. Students significantly overestimate their bedside ultrasound skill acquisition. Percentages of students able to meet course objectives with a rating of strongly agree in 6 teaching sessions according to student self-evaluations using a 4-point Likert rating scale. The self-assigned rating of strongly agree was on average 68% greater (range, 41%–100%) than the instructors' ratings across teaching sessions. *$P < .005$. Abbreviations are as in Figure 1.

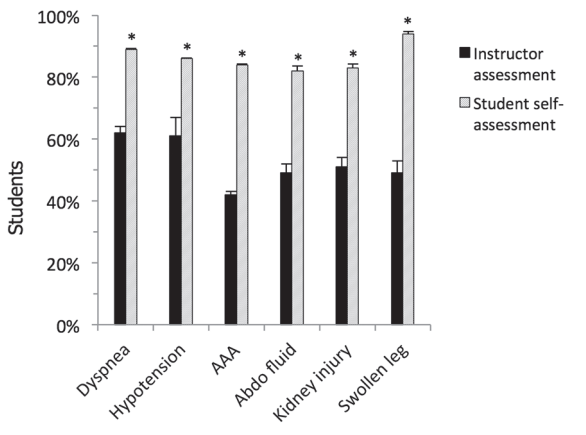
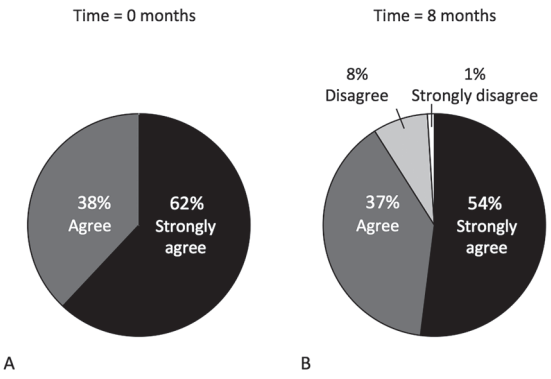


Figure 3. Students retain practical bedside ultrasound skills. **A**, Percentages of students able to meet course objectives in an initial teaching session according to instructor evaluations using a 4-point Likert rating scale (time = 0 months). **B**, Percentages of students able to meet course objectives in a teaching session 8 months later (time = 8 months) according to instructor evaluations using a 4-point Likert rating scale (time = 0 months). There were no significant differences between the mean percentages of students at the two time points.



agree and agree were 54% ± 4% and 37% ± 3%, respectively (Figure 3B). The combined mean percentage of students assigned a rating of strongly agree or agree was 91%.

A comparison of ratings at the initial versus later time point suggests that skills were retained until the end of the academic year. There was no significant difference between the mean percentages for students assigned a rating of strongly agree at the initial time point versus the later time point (62% ± 2% versus 54% ± 4%; $P = .052$, Mann-Whitney test). There was also no significant difference between the mean percentages for students assigned a rating of agree at the initial versus later time point (38% ± 2% versus 37% ± 3%; $P = .4$, Mann-Whitney test).

Students Perceive That Bedside Ultrasound Improves Their Understanding of Anatomy

Student perceptions of the bedside ultrasound course were qualitatively assessed from a 4-question survey completed immediately after each teaching session (Table 3). The students' comments to the survey indicated that an overall mean of 95% ± 0.01% of students (n = 116–175) believed that bedside ultrasound improved their understanding of anatomy for all teaching sessions (question 1; Figure 4). The mean percentages of students who believed that bedside ultrasound improved their understanding of anatomy for individual teaching sessions were similarly high (91%–97%; Figure 4). Comments also included numerous positive

Table 3. Students' Perceptions of the McGill University Faculty of Medicine Ultrasound Curriculum, 2013–2014

Question	Answer
1. Did the bedside ultrasound course improve your understanding of anatomy?	Overall comments showed that 95% of students believed that bedside ultrasound improved their understanding of anatomy for all teaching sessions. Great experience for actually visualizing the anatomy. Seeing the image, really understanding the anatomy, and the explanations of the physician/teacher. The website (with instructional videos) is also very good. Being able to see the anatomy in a unique way on a live patient. The hands-on nature helps solidify the anatomy and normal function. Having the hands-on approach early on in the curriculum in a "normal" patient, which really helped with my understanding of anatomy and ultrasound.
2. What did you enjoy most about the bedside ultrasound course?	Very practical, instructor very experienced and helpful. Extremely well organized, clear objectives, concise readings, helpful professors. Thank you. Hands-on, super complement to readings, answered many questions I had. Very stimulating experience. Excellent hands-on experience, super awesome instructor: clear, knowledgeable, and patient. It was very hands-on and clinically relevant. The teacher was wonderful. Able to have time to practice and being in small groups so we can ask questions. How practical the application is and how closely it emphasized the reading materials; right amount of material to understand the material well by the end of the session. It was both practical and really informative. The instructor gave good feedback and was really pedagogical. It was also really well tailored to our level of understanding and encouraged participation and safe learning.
3. What did you enjoy least about the bedside ultrasound course?	Nothing (×13). Too short (×2). Time was tight. I was concerned about our lack of knowledge, but it ended up not being a problem. A little tricky to see everything but had enough time to practice. Not enough time to practice. Time constraints: it went by way too fast.
4. Additional comments?	We were 3 at our ultrasound machine, and I found it was the perfect number of people to practice enough and be able to ask our questions. Learned a lot and am excited to continue in this course. Good to do the test right after. The instructor was very helpful. Hope we will have more courses like that.

remarks regarding course format and logistics (questions 2 and 4) and some negative comments relating to insufficient time to practice (question 3). Overall, the students perceived the course to be practical, feasible, informative, and interesting.

Discussion

This study provides both quantitative and qualitative assessments of the skill acquisition of first-year medical students enrolled in a new undergraduate bedside ultrasound curriculum. The quantitative assessment demonstrated that students show significant skill acquisition after each of 6 1-hour clinically based teaching sessions. According to instructors' evaluations, the percentage of students who met course objectives with a rating of strongly agree or agree varied between 97% and 100% for the 6 teaching sessions. The results suggest that course objectives were set at an achievable level for the teaching time allotted. The results also suggest that a teaching method comprising alignment of a course textbook, objectives, and evaluation allows substantial bedside ultrasound skill acquisition for first-year medical students.

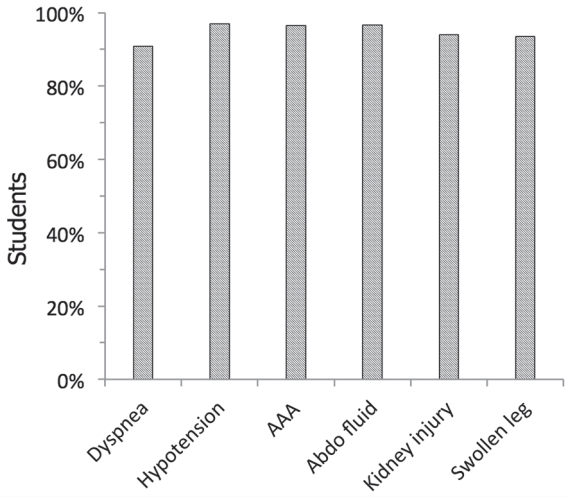
The results demonstrate that students significantly overestimate their skill acquisition in each clinically based teaching module. The student self-evaluations were on average 68% greater than the instructors' evaluations for the same skill. The overestimation of skill acquisition is concurrent with previous reports of overconfidence in self-assessments.[44–47] The observation of student over-estimation of skill acquisition has resulted in a refinement to the course curriculum through addition of theoretical precourse and postcourse tests to each teaching session. The precourse and postcourse tests are identical and will be completed before and immediately after each teaching session. Instantaneous scoring of the postcourse test will provide students with an accurate and quantitative determination of their knowledge base and will address the commonly observed overconfidence in self-assessments.

A comparison of student skill acquisition for the dyspnea module at the beginning versus the end of the academic year reveals that students show long-term retention of their bedside ultrasound skills over an 8-month period. There was a small increase in the percentage of students assigned a rating of disagree or strongly disagree for their ability to meet course objectives at the later time point. The results indicate that a minority of ultrasound skills was lost, yet most skills were retained after 8 months. Few studies have reported such long periods of retention of ultrasound skills in medical students. Some studies demonstrated shorter retention of ultrasound skills in medical students[51] and residents[52,53] and longer periods of retention for ultrasound-guided procedures in residents.[54]

A qualitative assessment of students' perceptions revealed that the students were highly enthusiastic about the inclusion of bedside ultrasound education in their medical school curriculum. Most of the students (95%) reported an improved understanding of basic anatomy after completion of bedside ultrasound instruction. This finding was consistent with studies showing that 96% of students agreed that ultrasound-based teaching increased students' knowledge of anatomy acquired through traditional teaching methods[40] and that 76% of students (score of 3.82 of 5) reported that ultrasound education had enhanced their understanding of human anatomy.[23] Other studies reported that ultrasound considerably or generally improved a medical student's anatomic knowledge.[2,28,42]

Certain ultrasound skills were difficult to master, as evidenced by a small percentage of students (5%–8%) assigned a rating of strongly disagree or disagree for their ability to meet the course objective. Some difficulty was encountered when generating a parasternal long-axis view of the heart. This difficulty could be explained by the limited amount of ultrasound teaching (1 hour) before the completion of this task and the fact that more emphasis was placed on teaching the subxiphoid view of the heart. Choosing the correct orientation of the probe to visualize

Figure 4. Bedside ultrasound improves a student's understanding of anatomy. Percentages of students who reported that bedside ultrasound education improved their understanding of anatomy. The overall mean percentage was 95.0% ± 0.01% (range, 91%–97%). Abbreviations are as in Figure 1.



free abdominal free fluid also proved difficult, suggesting that some students require considerable hands-on practice to fully understand probe and image orientation. Some students were unable to locate the greater saphenous vein at its junction with the common femoral vein. This difficulty can partly be explained by this junction's position in the far cephalad region of the groin and the student's discomfort with scanning in this region. The discomfort provided the instructors with an opportunity to discuss and demonstrate professionalism when examining sensitive areas.

In summary, the results support the feasibility of introducing bedside ultrasound instruction into the undergraduate curriculum of a large Canadian medical school. First-year medical students acquired and retained considerable basic ultrasound skills on completion of the newly implemented bedside ultrasound instruction. The outcomes of this study may help refine and improve future courses in undergraduate bedside ultrasound education.

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