



A review of diagnostic accuracy and clinical impact from the focused use of perioperative ultrasound

Revue de l'exactitude diagnostique et de l'impact clinique de l'utilisation ciblée de l'échographie périopératoire

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Received: 19 July 2017 / Revised: 12 December 2017 / Accepted: 18 December 2017 / Published online: 2 February 2018
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Abstract

Purpose To perform a narrative review of the current trials examining the use of perioperative ultrasound to diagnose common issues related to the heart, lungs, stomach, and airway.

Method A review of the current literature was conducted in June 2017 on all trials involving ultrasound, including both surface and transesophageal ultrasound, in the perioperative period. The search included the terms 'ultrasonography', 'perioperative care', 'point-of-care', and 'bedside'. Trials were limited to human subjects with no language or time restrictions being applied. The results were then collected and a narrative review was completed with the available information.

Results In total 1,176 reports of original investigation or systematic reviews were collected and reviewed. Of those 1,176 reports and reviews, a total of 80 original articles met the inclusion criteria for this review. Topics were broadly defined based on common themes emerging from the literature including cardiac disease, lung pathology (pneumothorax, pleural effusion, pulmonary edema, and pulmonary consolidation), volume and contents of the

stomach, confirmation of endotracheal tube position, confirmation of lung isolation, and the application of ultrasound for guiding cricothyroidotomy. Where possible, the sensitivity and specificity of the trials are presented. Few trials reported on patient outcomes, although several discussed provider outcomes such as a change in anesthesia practice. In addition, trials reporting outcomes, although few in number, were included.

Conclusion Perioperative point-of-care ultrasound is a useful method for the diagnosis of many important perioperative conditions. The impact of this diagnostic approach on patient outcomes however remains to be determined.

Résumé

Objectif Proposer une étude narrative des essais cliniques publiés sur l'utilisation de l'échographie en période périopératoire pour le diagnostic des fréquents en rapport avec le cœur, les poumons, l'estomac et les voies respiratoires supérieures.

Méthode Une étude des publications a été menée en juin 2017 sur toutes les études impliquant l'échographie, à la fois de surface ou transœsophagienne, au cours de la période périopératoire. La recherche a inclus les termes échographie, soins périopératoires, soins au point d'intervention et au chevet des patients. Les essais ont été limités aux sujets humains sans restriction de langue ou de temps. Les résultats ont été colligés et une synthèse narrative a été effectuée à partir des renseignements disponibles.

Résultats Au total, 1 176 études systématiques ou comptes rendus d'études originales ont été rassemblés et analysés. Parmi ces 1 176 études systématiques et comptes rendus, un total de 80 articles ont satisfait les critères

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d'inclusion de cette synthèse. Les sujets étaient définis de façon large sur des thèmes fréquents provenant de la littérature, notamment maladie cardiaque, maladies pulmonaires (pneumothorax, épanchement pleural, œdème pulmonaire et consolidation pulmonaire), volume et contenu de l'estomac, confirmation de la position d'un tube endotrachéal, confirmation de l'exclusion d'un poumon, et utilisation de l'échographie pour guider une cricothyroïdectomie. La sensibilité et spécificité des études sont présentées quand cela est possible. Peu d'essais ont indiqué l'évolution des patients, bien que plusieurs aient discuté des répercussions pour le praticien, telles que les changements de pratique pour l'anesthésie. De plus, des essais indiquant des résultats, quoique peu nombreux, ont été inclus.

Conclusion *L'échographie au point d'intervention en période périopératoire est une méthode utile au diagnostic de nombreuses affections périopératoires importantes. Néanmoins, l'impact de cette démarche diagnostique sur l'évolution des patients reste à déterminer.*

The use of bedside ultrasound outside of radiology or cardiology departments began with the use of transesophageal echocardiography in the cardiac operating rooms. At roughly the same time, the benefits of portable ultrasound began to be realized in both the emergency room and critical care settings. Outside of the operating room, the use of transthoracic imaging became the predominant approach.

In the emergency departments, questions regarding the severity of blunt force trauma to the torso have been a major concern for physicians, which led to the development of focused assessment with sonography for trauma (FAST) examination, whereas in the intensive care unit, bedside ultrasound, particularly transthoracic echocardiography, was employed for assessment of hemodynamic instability. Both of these approaches recognize the use of bedside ultrasound to address clinical questions with a limited scope and then aid in both the diagnosis and treatment of the patient in real time.

The use of transthoracic echocardiography in the perioperative setting is now gaining momentum based on the experiences of cardiac anesthesiologists who were familiar with the utilization of cardiac ultrasound in the perioperative setting. Nevertheless, the focus in non-cardiac anesthesia has switched from transesophageal echocardiography to transthoracic ultrasound, using ultrasound to assess not only the heart but also the lungs, stomach (gastric volume), and airway. The use of

transthoracic echocardiography has also broadened the time periods in which ultrasound can be employed from purely using ultrasound during the intraoperative period for transesophageal to using transthoracic techniques in the pre-operative, operative, and postoperative periods (Table 1).

While consensus remains to be developed around the role ultrasound should play in the perioperative setting, as well as the questions that can be potentially addressed by its clinical use, the training of the individuals performing the examinations and the requirement for ongoing education, a growing body of evidence is developing on the utility of perioperative bedside ultrasound.

The purpose of this review is to identify the impact of perioperative bedside ultrasound on diagnosis and decision-making when used to assess the heart, lungs, gastric volume, and airway. The review will not consider ultrasound-guided procedures such as regional anesthesia or vascular access and will primarily focus on adult patients.

Search strategy

A literature search was conducted by a medical librarian at our institution (B.M.). The following electronic bibliographic databases were searched: MEDLINE (OVID and PubMed), EMBASE, The Cochrane Library [Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials (CENTRAL), Cochrane Methodology Register], Health Technology Assessment Database, CINAHL, and Web of Science (science and social science citation index).

Table 1 Time periods and possible uses for point-of-care ultrasound

Time point	Benefits of focused ultrasound
Preoperative (pre-admit clinic)	Assessment of cardiac function
Pre-induction	Assessment of cardiac function Assessment of gastric volume Assessment of cricothyroid membrane
Intraoperative	Assessment of cardiac function Assessment of lung isolation Assessment of cricothyroid membrane Assessment of tube position Assessment of lungs (consolidation, pneumothorax)
Postoperative evaluation	Assessment of cardiac function Assessment of lungs (consolidation, pneumothorax)

The search strategy included the terms ‘ultrasonography’, ‘perioperative care’, ‘point-of-care’, and ‘bedside’. The search terms were adapted for use with other bibliographic databases in combination with database-specific filters for controlled trials when available. There were no language restrictions and no time limits applied to the search strategies. The search was limited to human studies only. The initial search was conducted on 20-23 June 2017.

A hand search and related search of key articles located in the initial search were also subsequently conducted. All abstracts for all identified trials were reviewed and either discarded as not relevant or the full text version was obtained. Review of the full text version resulted in discarding further trials and retaining the rest for inclusion in this review.

Study inclusion criteria were as follows: any study design in any language, adult non-cardiac surgical patients (≥ 18 yr of age), patients undergoing perioperative ultrasound (either immediately prior to induction or intraoperatively and performed by the anesthesiologist or other designated care provider), and reported findings or diagnoses observed by ultrasound. Where few trials on perioperative studies were available, studies on intensive care patients were included to better inform the scope of potential ultrasound utilization.

Nomenclature

The use of transthoracic and transesophageal echocardiography in the lexicon became commonplace as a method of describing cardiac examination, but provided an ultrasound approach with the organ being examined (the heart) inferred. Even here, the transesophageal examination has frequently been used to assess for pleural effusions and diseases involving the aorta, so strictly speaking it has never been cardiac specific. Ultrasound examination of other organs or body regions typically follows an anatomical approach with abdominal ultrasound, carotid ultrasound, or Doppler ultrasound of the legs being examples. Many terms have been used for ultrasound performed by the treating physician or designate, such as point-of-care ultrasound (POCUS), bedside ultrasound, and perioperative ultrasound. The “perioperative period” is also becoming quite indistinct with some anesthesiology departments using ultrasound machines in the pre-admission clinic, thus separating the treating anesthesiologist from the one performing the examination. Many acronyms have been developed to describe the use of point-of-care approaches to certain medical situations such as the FAST examination to rule out free peritoneal fluid, or the FOCUS examination to

assess hemodynamic instability. In addition, both transesophageal and transthoracic techniques may be used at the point of care and both probes may be used for lung and other POCUS examinations. In the same way that the anatomical approach for cardiac examinations may affect the diagnostic accuracy, so the probe selection (i.e., linear vs curved, high frequency vs low frequency) for POCUS may have an impact on the diagnosis of various conditions. For the remainder of this review, we will use the term POCUS to refer to ultrasound performed by the anesthesiologist or treating physician performed in close temporal relationship to the procedure or condition being diagnosed. We have used the approach of referring anatomically to the structure being examined and make no assumption about the approach or probe used unless specifically stated.

Results

A total of 1,176 original articles were identified during the search. Following an extensive review of the abstracts, a total of 221 articles were selected for further review, after which 80 reviews in total were identified as relevant for inclusion in to our study (Figure). Of the 80 trials selected for inclusion, seven were reviews or meta-analyses.

Heart

Historically, cardiac ultrasound has played the largest role in POCUS in the operating room environment. As a clinical tool, it has been used specifically to identify potential causes of hypotension, low cardiac output, or heart failure. Point-of-care ultrasound is available in the cardiac operating rooms in the form of transesophageal echocardiography; however, this review will not deal with that specific use.

The widespread adoption of transesophageal echocardiography in cardiac surgery has led to adoption of transesophageal echocardiography in the non-cardiac operating rooms. While early studies of perioperative cardiac ultrasound used transesophageal echocardiography, a mixture of both transthoracic and transesophageal modalities have more recently been employed.

The patient populations examined fell into two broad groups. The first are patients who are at high risk prior to their operation and the ultrasound examination is used as a screening tool prior to induction of anesthesia. This information is used to alter hemodynamic monitoring and management to prevent hypotension or hemodynamic collapse. The second group consists of patients who are suffering unexplained hypotension or cardiac collapse in the perioperative setting, and ultrasound is used after the

event to help diagnosis the cause of the hemodynamic instability.^{1,2}

A recent review by Jasudavicius *et al.* looked at the use of either screening or rescue ultrasound with the intent of identifying common diagnoses to better inform teaching paradigms.³ The Jasudavicius review identified 14 studies (nine transesophageal, four transthoracic, and one combined) that reported common findings in both the screening and rescue settings. Specifically, a low ejection fraction, aortic valve disease, and mitral valve disease were the top three preoperative diagnoses, while hypovolemia, low ejection fraction, and right ventricular failure were the top three specific intraoperative diagnoses.

Transesophageal echocardiography was utilized in a number of studies examining the impact of ultrasound on planned surgical procedures. Hofer *et al.* suggested the rate of management change was 47% on intraoperative transesophageal echocardiography examinations performed in non-cardiac surgical patients at risk of hemodynamic instability or myocardial ischemia.⁴ This was similar to results found by Schulmeyer but higher than a study by Suriani, which had a rate of change in the anesthesia plan of 15%.^{5,6}

Several trials also examined the use of transthoracic ultrasound; for example, Canty *et al.* showed that peri- and intraoperative POCUS had an impact in 75% of emergency cases and 43% of elective cases.⁷ In two separate studies by Cowie, the author showed an 80-85% change in care associated with the use of a point-of-care cardiac examination in patients with a clinical indication for a scan.^{8,9} The primary reason for ultrasound examination in Cowie's studies was an undifferentiated systolic murmur, present in roughly 50% of patients.

Canty *et al.* performed an audit of patients undergoing hip fracture surgery and compared those patients who received bedside echocardiography before surgery with those who did not, and the comparison showed a significant reduction in mortality at 12 months after surgery.¹⁰ The highest level of evidence to date is from a recent study by Canty *et al.*,¹¹ who reported a randomized pilot study of 100 participants undergoing surgery from hip fracture who then received bedside transthoracic echocardiography prior to surgery and a control group who did not receive preoperative transthoracic echocardiography assessment. The incidence of a combined primary outcome of any death, acute kidney injury, non-fatal myocardial infarction, cerebrovascular accident, pulmonary embolism, or cardiopulmonary arrest within 30 days of surgery was 14% in the bedside echocardiography group and 24% in the control group. In the transthoracic echocardiography group, there was a change in diagnosis in 26 (53%) and a change in management in 17 (35%); in nine cases, imaging identified significant unexpected pathology prompting

stepped-up treatment, and in eight cases, echocardiography excluded significant suspected pathology, prompting stepped-down treatment. Unsuspected cardiac pathology led to increased use of invasive monitoring, use of vasopressor or inotrope infusions, reduced fluid infusions, and disposition after surgery to a high dependency unit or intensive care unit (ICU). Absence of suspected cardiac pathology led to a reduction in planned invasive monitoring, vasoactive medicine, or ICU admissions and increased fluid use if hypovolemia was diagnosed in an otherwise normal heart. Studies in patients requiring intraoperative echocardiography for hemodynamic collapse all suggested that this approach provided useful information to help guide the care of the patient.^{1,2,12,13}

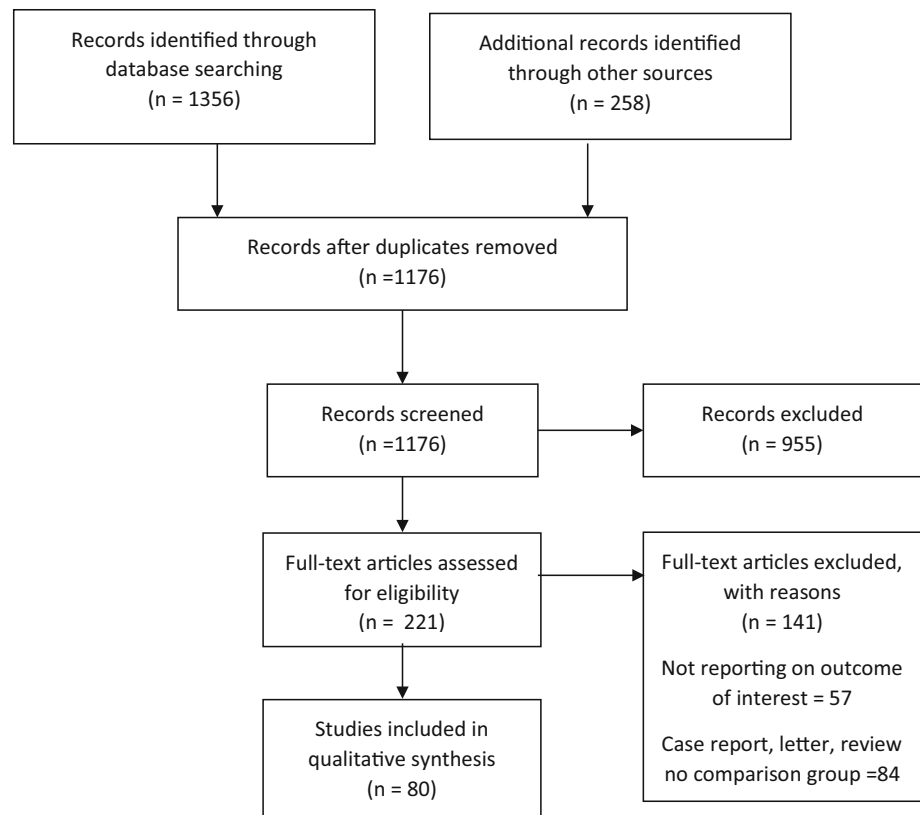
Cardiac echocardiography in patients who clinically warrant an examination appears to have an important impact on patient care, although it is important to acknowledge that there are no large pragmatic trials to evaluate whether the change in management leads to improved outcomes and which patient populations may benefit the most. As skill levels increase, there is likely to be an increase in the use of ultrasound by non-cardiac anesthesiologists to either assess patients at high-risk of intraoperative events or to help guide the therapy of patients who have suffered either severe hemodynamic disturbances or cardiac arrest. A definitive pragmatic randomized trial is recommended.

Lung

The intensive care physicians have taken a strong lead in the use of POCUS for the diagnosis of lung pathology, thereby potentially reducing the cost, inconvenience, and radiation exposure associated with chest x-rays and computed tomographic scans. Ultrasound of the lung can be used to diagnose interstitial edema, atelectasis, consolidation, pleural effusion, and pneumothorax, as shown in Table 2.¹⁴⁻¹⁶ It is also possible to image the diaphragm to look at the innervation and strength of contraction, which is an approach used in the intensive care unit for ventilator weaning.¹⁷

Data for the use of lung ultrasound in the perioperative setting are lacking as current studies have focused primarily on the intensive care setting. Studies specifically from intensive care perspectives have examined the role of lung ultrasound to diagnose common conditions that previously would have required a chest x-ray or a computed tomographic scan.¹⁴⁻¹⁶ Thus, the main goal of these studies has been to show diagnostic sensitivity and specificity.

Most individual studies suggest diagnostic accuracies > 90% for pleural effusions, 70-90% for consolidation, 60-

Figure Flow diagram of included trials

90% for pulmonary edema, and 90-98% for pneumothorax (Table 2).¹⁴⁻¹⁶ Ford *et al.* examined point-of-care lung ultrasound in the perioperative period and compared this method with chest *x-ray* and clinical assessment to diagnose lung pathology.¹⁸ Ultrasound assessment was considered the reference method and was superior to the use of either chest *x-ray* or clinical assessment alone or combined for the diagnosis of lung disease. In comparison with ultrasound use, sensitivity of the different pathologies ranged from 7-69% for chest *x-ray*, 7-76% for clinical assessment, and 14-94% when the two methods were combined. Many of the reasons for differences in the sensitivity and specificity of lung ultrasound may lie in the methods used to diagnose a given pathology. For example, the diagnosis of pneumothorax may involve the absence of lung sliding, the A line sign (abolition of lung sliding and exclusive A lines on lung ultrasound), and/or the lung point.¹⁹

A recent consensus statement about the use of lung ultrasound in the intensive care unit made strong recommendations for the use of lung ultrasound for ruling in pleural effusion and ruling in pneumothorax, whereas conditional recommendations were given for interstitial and parenchymal lung diseases.²⁰

Lung isolation

Several studies²¹⁻²⁴ have assessed the utility of ultrasound to determine lung isolation during procedures requiring one lung anesthesia or in the assessment for endobronchial intubation when tracheal intubation is desired, and a summary of findings is shown in Table 3.

The identification of lung isolation utilizes lung sliding as the finding to indicate that the lung is being ventilated. Saporito *et al.*²¹ compared ultrasound with bronchoscopy and found the two methods equivalent and obtained identical results in all cases except one, in which the patient had no suitable rib window for ultrasound assessment. Alvarez compared clinical assessment (sensitivity 85%, specificity 41%) with ultrasound plus clinical assessment (sensitivity 99%, specificity 53%) and found ultrasound to be superior.²² Ramsingh *et al.* placed single-lumen endotracheal tubes into the trachea, the right main stem, or the left main stem under flexible bronchoscopic guidance and then had blinded assessors determine the tube position,²³ showing that ultrasound was superior to auscultation in determining endobronchial intubation with a sensitivity and specificity for ultrasound of 93% and 96% vs auscultation of 66% and 59%. In

addition, Sustic *et al.* compared ultrasound alone vs clinical assessment alone²⁴ and showed that while both methods had a sensitivity of 100%, the specificity was only 22% for clinical assessment, and increased to 50% for ultrasound.

Saporito *et al.* also examined the costs of the use of ultrasound compared with flexible bronchoscopy. While there were reported cost savings in personnel (i.e., a nurse performed the ultrasound scan while an anesthesiologist was required to perform the bronchoscopy), there were also added costs related to the reprocessing of the bronchoscope.²¹ Thus, at their clinical institution, Saporito *et al.* estimated a cost savings of 37 euros per case. The ultrasound examination was also quicker to perform than bronchoscopy.

Ultrasound diagnosis of lung isolation is both rapid and practical in the operating room and may be the technique of choice to confirm lung isolation, but is unlikely to replace the flexible bronchoscope, which can provide visual confirmation of tube position and aid in trouble shooting inadequate lung isolation. Familiarization with ultrasound diagnosis of lung isolation may also aid the anesthesiologist in the diagnosis of main stem intubation with a single-lumen tube in cases where hypoxemia occurs.

Gastric

Gastric volume

Determination of a patient's fasting status has frequently been done based on history of the last meal/*npo* status. Nevertheless, gastric emptying may be delayed when there is pain, concomitant opioids, or intra-abdominal pathology. Therefore, the use of ultrasound to assess gastric volume may play an important role in identifying those at increased risk of aspiration.

A systematic review completed in 2014 identified nine papers that correlated ultrasound scanning to gastric volume with correlation coefficients ranging from 0.72-0.91.²⁵ A summary of trials is shown in Table 4. The gold standard method to compare with ultrasound has usually been nasogastric suction; however, gastroscopy and magnetic resonance imaging have also been used. Several of the studies also derived mathematical formulas to convert the antral area into a gastric volume. The cut-off value used by the authors of low vs high risk for aspiration was usually 1.5 mL·kg⁻¹.^{25,26} In addition to the volume of gastric contents, ultrasound also has the ability to determine whether the stomach contains liquids or particulate matter and thereby allows for additional quantification of the risk from aspiration.^{25,27,28}

It appears that the relationship between the antral area and volume is now generally accepted as most recent literature has turned to evaluation of emptying times of various per os intake materials.²⁹ Work remains to be done as currently several different formulas are used to derive gastric volume based on antral area and there are few data validating aspiration risk against gastric volume.

The study by Bouvet *et al.* is one of a handful that examined the prevalence of an empty stomach as determined by gastric ultrasound among patients arriving for surgery. Bouvet *et al.* found a full stomach, defined as the presence of gastric content in the right lateral decubitus and semi-recumbent positions, in 5% of elective patients and 56% of emergent patients.³⁰ A second retrospective study among elective patients found the incidence of full stomach, defined as a calculated stomach volume greater than 1.5 mL·kg⁻¹, was 6.2%, while the incidence of solid content in the stomach was 1.7%.²⁶

Finally, one study examined the impact of gastric ultrasound on the timing of surgery in patients who had

Table 2 Reviews of critical care trials examining US for lung diagnosis

Diagnosis	Review trial	Included trials (n)	Sensitivity range (%)	Specificity range (%)
Pleural effusion	Ashton Cleary ¹⁴	7	83-100	67-100
	Lichtenstein ¹⁵	1	94	97
Alveolar consolidation	Ashton Cleary ¹⁴	5	89-100	78-100
	Lichtenstein ¹⁵	1	90	98
Pulmonary edema	Ashton Cleary ¹⁴	8	80-100	67-90
	Al Deeb ¹⁶	7	94	92
Pneumothorax	Ashton Cleary ¹⁴	7	75-100	90-100
	Lichtenstein ¹⁵	3	80-100	94-100

Table 3 Trials comparing ultrasound with determine lung isolation

Lung isolation	Comparison	Year	n Patients	Ultrasound		Clinical	
				Sensitivity	Specificity	Sensitivity	Specificity
Sustic ²⁴	Clinical vs Clinical + US	2010	50	100%	50%	100%	22%
Piccolo ⁴⁷	FB	2014	51				
Alvarez-Diaz ²²	Clinical	2015	105	98%	53%	85%	41%
Ramsingh ²³	Clinical	2016	42	93%	96%	66%	59%

FB = flexible bronchoscopy; US = ultrasound
 Trials listed in chronological order by year of publication

Table 4 Quantitative studies on gastric volume

Gastric volume	Year	n	Population	Standard measure	CC	Formula to derive volume from antral area
Fujigaki ⁴⁸	1993	39	Adults	NG suction	NR	N/A
Ricci ⁴⁹	1993	15	Adults	NG suction	NR	N/A
Hveem ⁵⁰	1994	35	Adults	Gastroscopy	0.91	N/A
Tomomasa ⁵¹	1996	32	Newborns	NG suction	0.83	N/A
Gilja ⁵²	1997	14	Adults	Ingested volume	0.99	
Perlas ²⁸	2009	90	Adults	Ingested volume	0.82	GV (mL) = -372.54 + 282.49 × log (right-lat CSA) - 1.68 × weight
Bouvet ⁵³	2009	22	Adults	Ingested volume	NR	N/A
Bouvet ⁵⁴	2011	183	Adults	NG suction	0.72	GV (mL) = - 215 + 57 log CSA (mm2) - 0.78 age (yr) - 0.16 height (cm) - 0.25 weight (kg)- 0.80 ASA + 16 mL (in the case of emergency)
Schmitz ⁵⁵	2012	16	Children	MRI	0.79	Volume = 0.0093 * CSA [mm 2] 1.36
Perlas ⁵⁶	2013	110	Adults	Gastroscopy	0.86	GV (mL) = 27.0 + 14.6 × right-lat CSA-1.28 × age
Hamada ⁵⁷	2014	55	Critical care	CT	0.97	
Spencer ⁵⁸	2015	100	Children	Gastroscopy	Supine 0.63 RLD 0.67	Volume = -7.8 = (3.5 × RLD CSA) + (0.127) × age (months)
Schmitz ⁵⁹	2016	18	Children	MRI	RLD 0.76 SUBE 0.57	Volume = 0.0093 * CSA [mm 2] 0.96
	2016	40	Obstetric	Ingested volume	Supine 0.59 RLD 0.64	
Kruisselbrink ⁶⁰	2017	38	Adults (BMI > 35)	Gastroscopy	0.82	

ASA = American Society of Anesthesiologists; BMI = body mass index; CC = correlation coefficient; CSA = cross-sectional area antrum of stomach; CT = computed tomography; GV = gastric volume; MRI = magnetic resonance imaging; NG = nasogastric; NR = not reported; RLD = right lateral decubitus; SUBE = supine with upper body elevation

Trials listed in chronological order by year of publication

Table 5 Meta-analyses of trials of ultrasound to detect endotracheal intubation

	Year	Trials included	Intubation attempts (n)	Sensitivity (95% CI)	Specificity (95% CI)
Das ³¹	2015	11	969	0.98 (0.97 to 0.99)	0.98 (0.95 to 0.99)
Chou ³²	2015	12	1656	0.93 (0.86 to 0.96)	0.97 (0.95 to 0.98)

95% CI = 95% confidence interval

Table 6 Comparative trials involving ultrasound for cricothyroidotomy

Trial	Year	n	Population	Treatment	Control	Outcome	
						Ultrasound	Control
Suctic ⁴⁶	2000	26	Cadavers	Real-time ultrasound	Landmark	Cranial misplacement in 36%	Cranial misplacement in 43%
Rudas ⁴⁴	2014	50	Patients	Ultrasound	Landmark	Deviation from midline 15°	Deviation from midline 35°
Yavuz ⁴⁵	2014	341	Patients	Ultrasound	Landmark	Complications 7.8%, multiple attempts 3.9%	Complications 15%, multiple attempts 13.6%
Dinh ⁴²	2014	23	Patients	Ultrasound	Palpation	Midline 72.7%, attempts 1.4	Midline 8.3%, attempts 2.9
Gobatto ⁴¹	2015	60	Patients	Ultrasound	Bronchoscopy	Procedure length 12 min	Procedure length 15 min
Rajajee ⁴⁰	2015	200	Patients	Ultrasound + bronchoscopy	Bronchoscopy	Complications 0.9%	Complications 9.7%
Siddiqui ⁴³	2015	47	Cadavers	Ultrasound	Palpation	Laryngeal injury 6/24	Laryngeal injury 17/23

Trials listed in chronological order by year of publication

consumed solid food or full fluids in a shorter than routine fasting time or in patients who were suspected of having a full stomach following a standard fast. Twenty-seven out of 38 patients had a change in their anesthetic plan as a result of these findings, with 15 patients proceeding with surgery instead of delaying it and 12 patients further delaying surgery.²⁷ This emphasizes the role of perioperative ultrasound as an adjunct to clinical evaluation to better inform the physician.

Airway

Endotracheal placement

Multiple studies have examined the role of ultrasound to identify correct placement of an endotracheal tube; the majority of these studies were performed outside the operating room, usually in the emergency department. To date, two meta-analyses have examined the relative specificity and sensitivity of this approach.^{31,32} Typically in these studies, the ultrasound probe is placed slightly above the suprasternal notch and evidence for tracheal intubation inferred from a single air-mucosa interface and esophageal intubation inferred by a double air-mucosa interface.³¹ The results of the findings are presented in Table 5. The primary difference between the inclusion criteria was that Das *et al.*³¹ used only clinical trials, while Chou *et al.*³² included cadaveric studies. Several studies suggest that endotracheal tube depth can be ascertained in pediatric patients, and such an approach may be useful in the future for adults; however, exhaled CO₂ remains the gold standard for detection of tracheal intubation as it is both ubiquitous and reliable.

Cricothyroidotomy

Ultrasound may play a useful role in the identification of the puncture site for performing cricothyroidotomy^{33,34} in that it is able to identify the relevant thyroid, cricoid, and cricothyroid cartilage by also identifying the appropriate centre of the trachea (medial to lateral). The traditional approach employs palpation to identify structures, which may be inaccurate especially with swelling or trauma to the neck.

There have been several trials and one review looking at the feasibility of ultrasound to guide percutaneous tracheostomy.³⁵⁻³⁹ Several of these studies have examined the benefits of using ultrasound for percutaneous tracheostomy, and a summary is shown in Table 6.⁴⁰⁻⁴⁶ Most of the trials were performed on patients requiring elective tracheostomy by either intensivists or otolaryngologists. Ultrasound was used in conjunction with bronchoscopy to help identify the midline instead of palpation and bronchoscopy, though in one study, the ultrasound was used instead of the bronchoscope.⁴¹

In general, the aforementioned studies suggest that ultrasound improved the placement accuracy of the guide wire without specifically identifying a reduction in complication rates,^{41,42} although a few trials did identify reductions in complications.^{40,43,45} Overall, ultrasound-guided tracheostomy appears to improve the site of tracheal puncture and may improve outcomes.

Conclusion

Perioperative ultrasound involves multiple applications of ultrasound to provide better diagnostic fidelity, which in

turn influences clinical management, or to more accurately guide procedures such as vascular access and nerve blocks. The use of perioperative ultrasound has become increasingly popular as more ultrasound machines become available along with an increase in training opportunities for anesthesiologists. The level of training and on-going maintenance of certification within the field of POCUS needs to be more clearly elucidated. The scanning protocols, time points when scanning should occur, and type of patients who benefit need to be explored in more detail. Further large-scale trials are required to determine if the change in diagnosis and management leads to improved patient outcomes.

Conflicts of interest None declared.

Editorial responsibility This submission was handled by Dr. Gregory L. Bryson, Deputy Editor-in-Chief, *Canadian Journal of Anesthesia*.

Funding None.

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