Point-of-care ultrasound: its growing application in hospital medicine

ABSTRACT

Point-of-care ultrasound is emerging as an important adjunct to the clinical examination. Ultrasonography has long been seen as a modality for experts but this is changing and it is hoped that, with appropriate training, point-of-care ultrasound will become a modern-day diagnostic necessity.

Point-of-care ultrasound is defined as the use of portable ultrasonography at a patient's bedside for diagnostic (e.g. symptom or sign-based examination) and therapeutic (e.g. image-guidance) purposes (Kendall et al, 2007). Its application has developed rapidly since the 1990s when initial case reports and series described its usefulness in emergencies. Point-of-care ultrasound has now become part of daily clinical practice across many disciplines. With improved accessibility to increasingly portable and versatile ultrasound workstations, coupled with anecdotal evidence to support novice use, basic ultrasound is no longer seen as the remit of a select few.

Clinical purists may criticize the increasing reliance on point-of-care ultrasound to make simple diagnoses. However, expert opinion suggests that ultrasound imaging in the appropriate setting can streamline the diagnostic process and expedite correct treatment. It seems a natural progression that ultrasound may become an extension of the clinical examination. This narrative review outlines the current status quo of point-of-care ultrasound within the UK. Certain educational obstacles need to be overcome and the lack of standardization of point-of-care ultrasound application remains a concern. There can be no doubt, however, that point-of-care ultrasound is here to stay.

History of point-of-care ultrasound

Ultrasound in clinical medicine is a relatively new addition to daily practice. This has followed from initial enthusiasm in the 1940s when, at the time, the pioneers of this modality had felt that ultrasound imaging was a cumbersome investigation to perform and difficult to interpret (Kendall et al, 2007). As technology improved and real time imaging became possible, case reports of the usefulness of ultrasound began to emerge during the 1970s (Goldberg et al, 1970; Asher et al, 1976). The use of bedside ultrasound investigations to guide clinical decision making was pioneered by emergency medicine as a discipline (Mayron et al, 1988). Early work from colleagues in emergency medicine led to the first point-of-care ultrasound consensus documents and position statements, resulting in widespread adoption of the focussed assessment with sonography in trauma (FAST) protocol as the prototype point-of-care ultrasound investigation (Hoffman et al, 1991; American College of Emergency Physicians, 2001).

In recent years several point-of-care ultrasound initiatives have developed which are now well established and recognized as a vital tool for all clinicians, particularly in emergency situations and the critically ill (Kendall et al, 2007). The scope for development of this field remains large and point-of-care ultrasound is likely to become a part of daily medical practice for practitioners across multiple specialties.

Dr Aidan Kingwill, Senior Clinical Fellow in Adult Intensive Care, Oxford Critical Care Ultrasound Learning and Research, Adult Intensive Care Unit, Oxford University Hospitals NHS Foundation Trust, Oxford OX2 9DU

Dr Graham Barker, Consultant Intensivist and Anaesthetist, Adult Intensive Care Unit, Oxford University Hospitals NHS Foundation Trust, Oxford

Dr Adrian Wong, Consultant Intensivist and Anaesthetist, Adult Intensive Care Unit, Oxford University Hospitals NHS Foundation Trust, Oxford

Correspondence to: Dr A Kingwill (aidankingwill@me.com)

Clinical applications of point-of-care ultrasound in hospital medicine: a multisystem paradigm

By definition, point-of-care ultrasound is a bedside tool. This mandates smaller, mobile and more robust workstations than required for more advanced ultrasound investigations, and has been made possible by rapid technological advances. Real-time image acquisition allows immediate interpretation of results and incorporation into ongoing decision making and patient care. Information can be stored for follow-up image comparison but the report is usually immediately available from the clinician or operator. In contrast to formal radiological ultrasound, point-of-care ultrasound seeks to answer very clear questions and is carried out in a focused manner. Image acquisition is rapid and interpretation simple, with the end point of guiding immediate medical care (Kendall et al, 2007). *Table 1* summarizes scenarios where point-of-care ultrasound has been shown to be useful in a clinical setting.

CNS applications

Owing to the poor transmission of sound waves through bone (in this case the skull and vertebral column), the adult CNS is the one anatomical area where the

Table 1. Current clinical scenarios where point-of-care ultrasound is regularly used

System	Applications
Central nervous system	1. Intracranial pressure monitoring: optic nerve sheath diameter 2. Cerebral blood flow: transcranial Doppler flow (this has been particularly helpful in the post subarachnoid haemorrhage population), regional blood flow post craniectomy
Cardiovascular system	1. Assessment of the shocked patient: basic echocardiography, inferior vena cava dimensions 2. Vascular access and deep venous thrombosis screening of the lower limbs
Respiratory system	1. Point-of-care assessment of the breathless patient (usually done in combination with point-of-care echocardiography) 2. Assessment of extravascular lung water: this is already being suggested as a monitor of therapeutic effectiveness in heart failure patients 3. National guidelines exist for the use of ultrasound for invasive pleural procedures
Abdomen	1. The FAST protocol in trauma: this is the mainstay in most emergency departments when deciding if shock in trauma is the result of an intra-abdominal bleed 2. Hydronephrosis or blocked urinary catheters are easily excluded by point-of-care ultrasound

application of ultrasound is limited (Liman et al, 2012). However, indirect estimates of intracranial pressure and assessment of cerebral blood flow are two attractive exceptions.

The optic nerve sheath diameter can be measured using ultrasound and is emerging as a useful surrogate for intracranial pressure monitoring (Dubourg et al, 2011). Margins of error are within the sub-millimetre range (Dubourg et al, 2011; Johnson et al, 2016). This potentially limits its role to reliably detecting extremes only, which frequently already present with associated clinical signs and symptoms.

Transcranial Doppler ultrasound is possible through the narrow window of the relatively thin temporal bone – providing valuable information that has the potential to impact on immediate management. This has already been used as real-time monitoring guiding treatment. The modality uses Doppler assessment of velocity through vessels of presumed fixed calibre, such as the middle cerebral artery. Any changes in Doppler signal strength are therefore attributed to downstream factors, e.g. intracranial pressure. This technique has been studied in the post subarachnoid haemorrhage population, but it can logically be applied to a wider spectrum of pathologies (Rigamonti et al, 2008).

Contrast-enhanced ultrasonography has been used to assess regional cerebral perfusion following ischaemic stroke. This has only been tested post-decompressive craniectomy and could be an interesting development to follow (Bilotta et al, 2016).

Cardiovascular system applications

Echocardiography has been one of the most commonly used bedside investigations since the inception of point-of-care diagnostics. This position is reinforced by endorsed guidelines from a number of international bodies (Labovitz et al, 2010; Neskovic et al, 2014; Via et al, 2014; Heiberg et al, 2016). As experience and evidence base grows, protocols are sequentially refined with a global trend towards a standardized point-of-care ultrasound echocardiography examination.

Despite multiple acronyms for focused echocardiographic assessment (FoCUS) (Via et al, 2014) all share a common thread of rapidly and systematically assessing the core circulation to complement and augment clinical examination and suggest interventions. Examples of current protocols are numerous: FEEL (focussed echocardiography in emergency life support), FATE (focussed assessed transthoracic echocardiography) and FICE (focussed intensive care echocardiography).

One of the most exciting, and indeed useful, applications of point-of-care ultrasound echocardiography has been in assessing the shocked patient. Echocardiography allows discrete objective assessment of the three core components of the circulation (pre-load, after-load and the state of inotropy). Specific variables regularly used within the point-of-care ultrasound paradigm representing these components, albeit sometimes controversial, are outlined in *Table 2*. Discussion of these variables is beyond the

Table 2. Variables depicting the core components of the cardiovascular system

Pre-load	Inferior vena cava diameter
	Inferior vena cava collapsibility or distensibility
	Visual estimation of left ventricular end diastolic volume
Contractility	Tricuspid annular plane systolic excursion
	Ejection fraction estimation
After-load	Visual estimation of left ventricular end diastolic volume – hyperdynamicity

“Using direct real time imaging of pleural collections has led to an increased success rate of pleural aspiration and a reduced incidence of iatrogenic pneumothorax and this has reinforced this change in practice.”

scope of this article. These findings are helpful both for diagnostics and to suggest therapeutic interventions. The usefulness of point-of-care ultrasound cardiac scanning in the shocked patient has led to international guidelines emphasizing the need to include echocardiographic monitoring when dealing with these patients (Cecconi et al, 2014).

Important clinical decisions can often be made relying on simple measures, and studies comparing novice and experienced practitioners in performing basic cardiac ultrasound have consistently shown very little inter-observer variability. There is strong agreement, however, that sufficiently trained practitioners should be performing point-of-care ultrasound cardiac scans when this directs therapy (Bilotta et al, 2016). Following completion of a structured training programme practitioners should comfortably distinguish between normal and severe impairment. Many training programmes require 30–50 scans to achieve competence and are well validated within the literature. By clearly establishing training end points, the reputation of point-of-care echocardiography has steadily grown.

Vascular ultrasound is regularly used in an interventional (to guide vascular access) or diagnostic capacity (detection of deep vein thrombosis). There is overwhelmingly strong evidence supporting the use of real-time ultrasound guidance while gaining central venous access with regards to improved success and a reduction in complication rates (Dietrich et al, 2016). By identifying targets and variations in relative regional anatomy, accidental injury to adjacent structures is reduced and initial attempts are more likely to succeed compared with traditional anatomical or landmark approaches. This has been accepted as a core skill, as reflected by National Institute for Health and Care Excellence endorsement of ultrasound guidance for all vascular access procedures when feasible (Wigmore et al, 2007).

Deep vein thrombosis and pulmonary embolism are two of the commonest causes of preventable morbidity and mortality, particularly in the hospitalized population. Compression ultrasonography of the lower limb is a sensitive and specific test for rapidly confirming the diagnosis of lower limb thrombosis (Crisp et al, 2010). As treating clinicians develop the ability to perform these established procedures independently, this will both alleviate the burden on other clinical services and will also reduce the need for risky, logistically difficult transfers of patients.

Respiratory system applications

Thoracic ultrasound has emerged as a potential diagnostic tool while becoming a core component when performing invasive pleural procedures. Seminal work by Daniel Lichtenstein has firmly established the role of point-of-care lung ultrasound. The approach proposed by this single centre has formed the basis for a structured clinical examination of patients with acute respiratory pathology, using ultrasound to complement clinical examination and suggest treatments (Lichtenstein et al, 2004). A number of protocols have been described, with the BLUE protocol the most universally applied (Lichtenstein and Mezière, 2008; Lichtenstein, 2014). Other protocols include FLUID (focused lung ultrasound in dyspnoea), FALLS (fluid administration limited by lung ultrasound) and SESAME (sequential emergency sonography assessing mechanism or origin of severe shock of indistinct cause) (Chiem et al, 2015).

Lung ultrasound relies on the interpretation of various artefacts at the pleural interface caused by pathological states. In combination with echocardiography, lung ultrasound can provide valuable information in the acutely unwell patient (Lichtenstein, 2014). The usefulness of lung ultrasound has been tested in the critical care setting and there is also emerging literature from emergency medicine supporting its use. Basic lung ultrasound in patients with respiratory distress can be easily performed by relatively inexperienced practitioners after receiving appropriate training (Chiem et al, 2015). Literature out of cardiology circles has suggested the routine use of lung ultrasound in monitoring patients in cardiac failure (Picano and Pellikka, 2016), adding credence to the value of point-of-care lung ultrasound.

Pleural procedures are increasingly performed using ultrasound guidance, in accordance with current British Thoracic Society guidelines (Hooper et al, 2010). Using direct real time imaging of pleural collections has led to an increased success rate of pleural aspiration and a reduced incidence of iatrogenic pneumothorax and this has reinforced this change in practice. Lung ultrasound has a higher sensitivity than computed tomography when used to detect pleural collections (Hooper et al, 2010), and can be used in real time more conveniently than cross-sectional approaches such as computed tomography. Novel applications are continually evolving and include confirming correct placement of endotracheal tubes or assessment of diaphragmatic function. Upper airway applications of point-of-care ultrasound may become more commonplace (Latham et al, 2015).

Abdominal applications

The FAST protocol in trauma remains one of the most important applications of abdominal point-of-care ultrasound, as discussed earlier (Hoffman et al, 1991; American College of Emergency Physicians, 2001). In an early prospective trial the FAST protocol was found to be invaluable in diagnosing visceral injury among patients who had suffered blunt abdominal trauma (Hoffman et al, 1991). The FAST protocol remains very commonly used in many emergency departments. Useful point-of-care ultrasound applications beyond FAST include diagnostic (e.g. assessment of abdominal aorta and renal tract) and therapeutic aspirations. These are core skills in the Core ultrasound in Intensive Care (CUSIC) syllabus.

Training needs in point-of-care ultrasound and current educational perspectives

There is good evidence to suggest that the components required to perform point-of-care ultrasound effectively are achievable within set time frames compatible with modern medical training schemes. By clearly defining educational criteria prospectively, novices are consistently able to distinguish between normal and severe abnormalities. Multiple educational articles have validated the approach using a certain number of logged scans, usually in the range of 30–50 scans, to achieve competence, in combination with a parallel educational programme (tutorials, mentorship, courses, seminars and e-learning). Does this imply that minimal training is required, or indeed acceptable? All would agree that a certain level of training should be mandatory. International consensus guiding training is lacking.

Lack of adequate training remains an important obstacle to practitioners wishing to use point-of-care ultrasound (Mengel-Jorgensen and Jensen, 2016). Early exposure to ultrasound has demonstrable effects in scanning proficiency among undergraduate students and there is growing enthusiasm for the integration of ultrasound within this stage of medical training (Dinh et al, 2015, 2016). By learning in a structured manner earlier in training, it is feasible that both a higher quality of learning and confidence in image integration into clinical decision making could be achieved. However, while the majority of front-line clinicians do not yet possess this skill set, it is likely to remain an additional skill reserved for the enthusiast and not readily taught to undergraduates in the clinical setting. A thorough discussion of the educational methods and end-points for point-of-care ultrasound training at the undergraduate level is beyond the scope of this article and has been covered elsewhere (Dinh et al, 2016).

Importantly, any training in point-of-care ultrasound should aim to stay firmly within this realm, and not attempt to replace formal ultrasound. By implication, the level of investigations performed by both radiographers and radiologists requires a far more advanced understanding of ultrasound as a modality and a greater depth of training is required. An important starting point would therefore be to define the essential skills required, with training in these areas being prioritized. An interesting survey from the USA has found that trainees in emergency medicine consider point-of-care ultrasound essential and lists modalities they felt most useful (Stolz et al, 2015).

“Early exposure to ultrasound has demonstrable effects in scanning proficiency among undergraduate students and there is growing enthusiasm for the integration of ultrasound within this stage of medical training.”

Training frameworks currently available are varied, but many point-of-care ultrasound curricula use similar approaches, as outlined above. Some centres use testing before and after training to gauge theoretical knowledge, although most do not. Across the board, there is little uniformity in the approach to training novices and there is concern over the absence of a revalidation process.

Future developments in point-of-care ultrasound

As technological advances bring more sophisticated ultrasound workstations to the fore it can be expected that these devices will become far more easily accessible and affordable. The cost of training practitioners to perform point-of-care ultrasound scans as well as the cost of the ultrasound machines still appear to be major hurdles to the widespread roll-out of skills (Schnobrich et al, 2013), and this is particularly true for developing countries, where the positive impact of point-of-care ultrasound may in fact be greater than in developed countries. This challenge remains something that we can address in partnership with the trade sector. There is a drive to deliver point-of-care medical technology to the patient's bedside and ultrasound has to be recognized as part of this. Affordable, more durable and user-friendly workstations may make all the difference.

Conclusions

Point-of-care ultrasound has a huge impact on diagnosis and treatment of patients in certain settings (Schnobrich et al, 2013). It is likely that the application of point-of-care ultrasound will continue to develop. However, it is important to stay true to the philosophy of what this useful modality aims to achieve. Point-of-care ultrasound should always be applied at the bedside, aim to answer very specific questions and direct therapy or guide diagnostic or invasive procedures. These scans do not represent comprehensive imaging studies and should never replace studies performed by specialist colleagues, such as radiologists, radiographers or cardiologists. The multi-system applications described here are testament to the diagnostic strength of point-of-care ultrasound, as well as its value in guiding interventional or therapeutic procedures (Zieleskiewicz et al, 2015). Education, accreditation and revalidation remain open to standardization, and conversations about the value of adding point-of-care ultrasound into undergraduate medical training in the UK need to happen. **BJHM**

Conflict of interest: none.

KEY POINTS

- Point-of-care ultrasound is defined as the use of portable ultrasonography at a patient's bedside for diagnostic and therapeutic purposes.
- Point-of-care ultrasound is particularly helpful in many emergency situations and is now seen as vital for aiding correct diagnosis in many scenarios.
- Various national guidelines mandate point-of-care ultrasound when performing certain procedures.
- Point-of-care ultrasound should never replace more comprehensive diagnostic studies performed by specialist colleagues.
- Educational perspectives on point-of-care ultrasound need standardization for training to be sustainable.

American College of Emergency Physicians (2001) ACEP emergency ultrasound guidelines–2001. *Ann Emerg Med* **38**: 470–481. https://doi.org/10.1016/S0196-0644(01)70030-3

Asher WM, Parvin S, Virgillo RW et al (1976) Echographic evaluation of splenic injury after blunt trauma. *Radiology* **118**: 411–415. https://doi.org/10.1148/118.2.411

Bilotta F, Robba C, Santoro A, Delfini R, Rossa G, Agati L (2016) Contrast-enhanced imaging in detection of changes in cerebral perfusion. *Ultrasound Med Biol* **42**(11): 2708–2716. https://doi.org/10.1016/j.ultrasmedbio.2016.06.007

Cecconi M, De Backer D, Antonelli M et al (2014) Consensus of circulatory shock and hemodynamic monitoring. Task force of the European Society of Intensive Care Medicine. *Intensive Care Med* **40**(12): 1795–1815. https://doi.org/10.1007/s00134-014-3525-z

Chiem AT, Chan CH, Ander DS, Kobylivker AN, Manson WC (2015) Comparison of expert and novice sonographers' performance in Focused Lung Ultrasonography in Dyspnea (FLUID) to diagnose patients with acute heart failure syndrome. *Acad Emerg Med* **22**(5): 564–573. https://doi.org/10.1111/acem.12651

Crisp JG, Lavato LM, Jang TB (2010) Compression ultrasonography of the lower extremity with portable vascular ultrasonography can accurately detect deep venous thrombosis in the emergency department. *Ann Emerg Med* **56**(6): 601–610. https://doi.org/10.1016/j.annemergmed.2010.07.010

Dietrich CF, Horn R, Morf S et al (2016) Ultrasound-guided central vascular interventions, comments on the European Federation of Societies for Ultrasound in Medicine and Biology guidelines on interventional ultrasound. *J Thorac Dis* **8**(9): E851–E868. https://doi.org/10.21037/jtd.2016.08.49

Dinh VA, Dukes WS, Prigge J, Avila M (2015) Ultrasound integration in undergraduate medical education: Comparison of ultrasound proficiency between trained and untrained medical students. *J Ultrasound Med* **34**(10): 1819–1824. https://doi.org/10.7863/ultra.14.12045

Dinh VA, Lakoff D, Hess J et al (2016) Medical student core clinical ultrasound milestones: a consensus amongst directors in the United States. *J Ultrasound Med* **35**(2): 421–434. https://doi.org/10.7863/ultra.15.07080

Dubourg J, Javouhey E, Geeraerts T et al (2011) Ultrasonography of optic nerve sheath diameter for detection of raised intracranial pressure: a systematic review and meta-analysis. *Intensive Care Med* **37**: 1059–1068. https://doi.org/10.1007/s00134-011-2224-2

Goldberg BB, Goodman GA, Clearfield HR (1970) Evaluation of ascites by ultrasound. *Radiology* **96**(1): 15–22. https://doi.org/10.1148/96.1.15

Heiberg J, El-Ansary D, Royse CF, Royse AG, Alsaddique AA, Canty DJ (2016) Transthoracic and transoesophageal echocardiography: a systematic review of feasibility and impact on diagnosis, management and outcome after cardiac surgery. *Anaesthesia* **71**(10): 1210–1221. https://doi.org/10.1111/anae.13545

Hoffman R, Nerlich M, Muggia-Sullam M et al (1991) Blunt abdominal trauma in cases of multiple trauma evaluated by ultrasonography: A prospective analysis of 291 patients. *J Trauma* **32**: 452–458.

Hooper C, Lee YC, Maskell N ; BTS Pleural Guideline Group. (2010) Investigation of unilateral pleural effusion in adults: British Thoracic Society pleural disease guideline 2010. *Thorax* **65** (Suppl2): ii4–ii17. https://doi.org/10.1136/thx.2010.136978

Johnson GGRJ, Zeiler FA, Unger B, Hansen G, Karakitsos D, Gillman LM (2016) Estimating the accuracy of optic nerve sheath diameter measurement using a pocket-sized, handheld ultrasound on a simulation model. *Crit Ultrasound J* **2016**: 1–5. https://doi.org/10.1186/s13089-016-0053-9

Kendall JL, Hoffenberg SR, Smith RS (2007) History of emergency and critical care ultrasound: the evolution of a new imaging paradigm. *Crit Care Med* **35**(5 Suppl): S126–S130. https://doi.org/10.1097/01.CCM.0000260623.38982.83

Labovitz AJ, Noble VE, Bierig M et al (2010) Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr* **23**: 1225–1230. https://doi.org/10.1016/j.echo.2010.10.005

Latham S, Baydoun J, Bailey J et al (2015) A prospective evaluation of real-time, transverse tracheal ultrasound in the evaluation of emergent intubation by minimally trained practitioners. *Ultrasound Med Biol* **41**(14): Suppl 1(S35).

Lichtenstein D (2014) Lung ultrasound in the critically ill. *Ann Intensive Care* **4**: 1–12. https://doi.org/10.1186/2110-5820-4-1

Lichtenstein D, Mezière G (2008) Relevance of lung ultrasound in the diagnosis of acute respiratory failure. The BLUE protocol. *Chest* **134**: 117–125. https://doi.org/10.1378/chest.07-2800

Lichtenstein D, Goldstein L, Mourgeon E, Cluzel P, Grenier P, Rouby JJ (2004) Comparative performance of auscultation, chest radiography and lung ultrasonography in ARDS. *Anesthesiology* **100**: 9–15.

Liman J, Bähr M, Kermer P (2012) Transcranial ultrasound in adults and children with movement disorders. *Perspectives in Medicine* **1**(1): 349–352. https://doi.org/10.1016/j.permed.2012.02.003

Mayron R, Gaidop PE, Plummer D et al (1988) Echocardiography performed by emergency physicians: Impact on diagnosis and therapy. *Ann Emerg Med* **17**: 150–151.

Mengel-Jorgensen T, Jensen MB (2016) Variation in the use of point-of-care ultrasound in general practice in various European countries. Results of a survey amongst experts. *Eur J Gen Pract* **22**(4): 274–277. https://doi.org/10.1080/13814788.2016.1211105

Neskovic AN, Edvardsen T, Galderisi M et al (2014) Focus cardiac ultrasound: the European Association of Cardiovascular Imaging viewpoint. *Eur Heart J Cardiovasc Imaging* **15**: 956–960. https://doi.org/10.1093/ehjci/jeu081

Picano E, Pellikka PA (2016) Ultrasound for extravascular lung water: a new standard for pulmonary congestion. *Eur Heart J* **37**: 2097–2104. https://doi.org/10.1093/eurheartj/ehw164

Rigamonti A, Ackery A, Baker AJ (2008) Transcranial Doppler monitoring in subarachnoid hemorrhage: A critical tool in critical care. *Can J Anaesth* **55**(2): 112–123. https://doi.org/10.1007/BF03016323

Schnobrich DJ, Gladding S, Olsen APJ, Duran-Nelson A (2013) Point of care ultrasound in internal medicine: A national survey of educational leadership. *J Grad Med Educ* **5**(3): 498–502. https://doi.org/10.4300/JGME-D-12-00215.1

Stolz L, Fiorello AB, Adhikari S (2015) Emergency medicine ultrasound milestones: Resident opinion and perceptions of the guidelines. *Ann Emerg Med* **66**(4): Suppl 1 (S43).

Via G, Hussain A, Wells M et al; International Liaison Committee on Focused Cardiac UltraSound (ILC-FoCUS); International Conference on Focused Cardiac UltraSound (IC-FoCUS) (2014) International evidence-based recommendations for focused cardiac ultrasound. *J Am Soc Echocardiogr* **27**(7): 683–685. https://doi.org/10.1016/j.echo.2014.05.001

Wigmore TJ, Smythe JF, Hacking MB, Raobaikady R, MacCallum NS (2007) Effect of the implementation of NICE guidelines for ultrasound guidance on the complication rates associated with central venous catheter placement in patients presenting for routine surgery in a tertiary referral centre. *Br J Anaesth* **99**(5): 662–665. https://doi.org/10.1093/bja/aem262

Zieleskiewicz L, Muller L, Lakhal K et al ; CAR'Echo and AzuRea Collaborative Networks. (2015) Point of care ultrasound in intensive care units: assessment of 1073 procedures in a multicentric, prospective, observational study. *Intensive Care Med* **41**(9): 1638–1647. https://doi.org/10.1007/s00134-015-3952-5