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POINT OF CARE ULTRASOUND: A WFUMB POSITION PAPER

Christoph F. Dietrich,[*,†] Adrian Goudie,[‡] Liliana Chiorean,[§] Xin Wu Cui,[*,†] Odd Helge Gilja,[¶] Yi Dong,[*,‖] Jacques S. Abramowicz,[#] Sudhir Vinayak,[**] Susan Campbell Westerway,[††] Christian Pállson Nolsøe,[‡‡] Yi-Hong Chou,[§§] and Michael Blaivas[¶¶]

[*] Medical Department, Caritas-Krankenhaus, Bad Mergentheim, Germany; [†] Sino-German Research Center of Ultrasound in Medicine, First Affiliated Hospital of Zhengzhou University, China; [‡] Emergency Department, Fiona Stanley Hospital, Perth, Australia; [§] Département d'imagerie médicale, Clinique des Cévennes 07100 Annonay, France; [¶] National Centre for Ultrasound in Gastroenterology, Department of Medicine, Haukeland University Hospital, and Department of Clinical Medicine, University of Bergen, Bergen, Norway; [‖] Department of Ultrasound, Zhongshan Hospital, Fudan University, Shanghai, China; [#] Section of Ultrasound, Department of Obstetrics and Gynecology, University of Chicago, Chicago, IL, USA; [**] Department of Imaging & Diagnostic Radiology, WFUMB COE, Aga Khan University Hospital, Nairobi, Kenya; [††] Charles Sturt University, New South Wales, Australia; [‡‡] Copenhagen Academy for Medical Education and Simulation (CAMES), Ultrasound Section, Department of Gastroenterology, Division of Surgery, Herlev Hospital, University of Copenhagen, Denmark; [§§] Department of Radiology, Taipei Veterans General Hospital, and School of Medicine, National Yang Ming University, Taipei, Taiwan; and [¶¶] University of South Carolina School of Medicine, Department of Emergency Medicine, St. Francis Hospital, Columbus, Georgia, USA

Abstract—Over the last decade, the use of portable ultrasound scanners has enhanced the concept of point of care ultrasound (PoC-US), namely, "ultrasound performed at the bedside and interpreted directly by the treating clinician." PoC-US is not a replacement for comprehensive ultrasound, but rather allows physicians immediate access to clinical imaging for rapid and direct solutions. PoC-US has already revolutionized everyday clinical practice, and it is believed that it will dramatically change how ultrasound is applied in daily practice. However, its use and teaching are different from continent to continent and from country to country. This World Federation for Ultrasound in Medicine and Biology position paper discusses the current status and future perspectives of PoC-US. Particular attention is given to the different uses of PoC-US and its clinical significance, including within emergency and critical care medicine, cardiology, anesthesiology, rheumatology, obstetrics, neonatology, gynecology, gastroenterology and many other applications. In the future, PoC-US will be more diverse than ever and be included in medical student training. (E-mail: Christoph.dietrich@ckbm.de)

Key Words: **Guidelines, Intervention, Neonatology, Echoscopy, Stethoscope.**

INTRODUCTION

During the World Federation for Ultrasound in Medicine and Biology (WFUMB) Congress in Orlando, Florida, March 2015, a proposal was brought forward to create a position paper by WFUMB with respect to point of care ultrasound (PoC-US) including current status and future perspectives, with particular attention given to clinical significance.

Advantages of ultrasound

The advantages of ultrasound as an imaging modality are several and include: image resolution and definition of anatomy, real-time imaging that allows immediate diagnosis and that can be precisely controlled by the operator, wide availability of ultrasound equipment and the existence of multiple simple and straightforward practical techniques covering a broad range of applications (Allan et al. 2011). All of these factors are ideal for PoC-US decision making. Ultrasound delivers no ionizing radiation and is significantly less expensive than comparable imaging modalities such as magnetic resonance imaging (MRI) and computed tomography (CT) (Nazarian 2012). Furthermore, its availability in highly compact form allows use in virtually any location where medical care could be delivered, including space travel, where weight and size restrictions are severe (Jones et al. 2009). The degree of control of the operator does, however, make ultrasound more operator dependent than some other forms of imaging, with implications for education and training (Moore and Copel 2011).

Emergence of PoC-US

Over the last decade it became possible to use portable scanners, namely, scanners that can be operated on battery power, yet include all conventional and Doppler ultrasound features. They even occasionally offer contrast-enhanced technology with high quality. These units range in size from hand- or arm-held to small-wheeled carts, enabling a unit to be brought to

Address correspondence to: Christoph F. Dietrich, Caritaskrankenhaus Bad Mergentheim Med. Klinik 2 Uhlandstrasse 7 Bad Mergentheim D-97980 Germany. E-mail: Christoph.dietrich@ckbm.de

the bedside. Such equipment is easily deployed in emergency settings, as it can be very quickly powered on and used at bedside. This feature is in stark contrast to many top-quality big scanners, which often require longer startup time and are less portable (Piscaglia et al. 2013). The advent of such portable ultrasound machines, which can be easily used in clinical settings such as the emergency unit or other clinical divisions, opened the way to the concept of PoC-US. It is important to note that this segment of the market is changing rapidly, and further definition as well as blurring of lines is likely.

Definitions of PoC-US

Definitions of PoC-US are somewhat diverse. All, however, incorporate some fundamental features: ultrasound performed by the clinician providing care, which is brought to the location where the patient is receiving care "at the patient's bedside," regardless of where that may be located (and even if the bed is just theoretical) (Moore and Copel 2011). Other terms used to describe PoC-US or its variants include bedside, focused, mobile, and clinician- or physician-performed ultrasound (American College of Emergency Physicians 2009; Gilja et al. 2003).

In the broad sense, PoC-US is a modality used for both procedural and diagnostic purposes, not a specific application. PoC-US examinations fundamentally differ from traditional "comprehensive" examinations. Traditional ultrasound examinations generally cover an anatomical region, often assess more than one organ, normally collect images of all examined organs and result in a full report of the examination. PoC-US examinations are focused studies used to achieve specific procedural aims (*e.g.*, direct the needle to the correct location) or answer focused questions (*e.g.*, Does my patient have ascites?). PoC-US provides answers to these questions immediately, without the delay and the potential risk of transportation to other hospital areas or another facility (Morris 2015). For diagnostic applications, PoC-US examinations may or may not replace comprehensive examinations, depending on whether the clinical question has been adequately answered. It should also be noted that comprehensive examinations can also be performed by the bedside, either by clinicians or by imaging specialists.

Direct performance of ultrasound by the clinician treating the patient allows rapid evaluation of previous and new diagnostic hypotheses and supports immediate therapeutic decisions. PoC-US is already widely used in clinical practice, but its use and teaching vary from continent to continent and from country to country. PoC-US performance is the result of combined factors, for example, basic ultrasound knowledge, clinical experience, complete integration into clinical practice and follow-up scenarios.

Common PoC-US uses

The use of these portable and pocket-sized ultrasound devices has been studied and proven in many medical specialties. It is a real-time examination, which can be performed wherever the patient may be present (Barreiros et al. 2014; Frederiksen et al. 2012). It can answer simple and focused medical questions regarding organ- or symptom-related issues. It is an excellent adjunct to the physical examination in emergency departments where patient screening and disposition are needed or in daily clinical practice where bedside imaging information may be required. Simple clinical questions may be answered by implementing rapidly performed and focused examination protocols, such as have already been documented in the fields of emergency, critical care, cardiology, anesthesiology, rheumatology, obstetrics, neonatology, gynecology, gastroenterology and many other specialties (Frederiksen et al. 2012). The following section describes some of the most common current uses of PoC-US, which have been incorporated into a number of different protocols and clinical settings. These uses often cross traditional specialty boundaries and are adapted to the specific clinical question being asked for that particular patient.

Intraperitoneal free fluid. The classic peritoneal spaces that are examined for free fluid are the perihepatic space (Morrison's pouch), the perisplenic space (Koller's pouch) and the pelvis (pouch of Douglas) (Dolich et al. 2001). Simple ascites is generally anechoic, whereas blood or complex fluid contains particulate matter, septations, fluid–fluid levels and areas of echogenic clot. Examination for free fluid is used in a variety of protocols and circumstances including examining for blood, for example, in trauma (FAST and EFAST) (Blackbourne et al. 2004; Kirkpatrick et al. 2004; Scalea et al. 1999; Sisley et al. 1998) or ruptured ectopic pregnancy (Sayasneh et al. 2012), or for ascites, as in gastroenterology (Barreiros et al. 2014; Colli et al. 2015), or infectious disease (Heller et al. 2016).

In addition, ultrasound should be used by clinicians for guidance of aspiration of intraperitoneal free fluid whether by needle drainage or by catheter placement. It allows identification of the optimal puncture site taking into account amount of fluid and its antomical location, while avoiding the needle passing through structures adherent or adjacent to the parietal peritoneal lining (*e.g.*, carcinosis deposits or bowel loops) (Nolsøe et al. 2007).

Pericardial fluid. This may be examined from a subcostal, parasternal, or apical view and is used in protocols for trauma (FAST and eFAST) (Kirkpatrick et al. 2004; Scalea et al. 1999), extrapulmonary tuberculosis (Heller et al. 2016) and a multitude of differently named but similar cardiac, critical care and emergency protocols for shock and cardiac arrest (Table 1) (Labovitz et al. 2010).

Pleural fluid. Ultrasound is particularly sensitive for detecting pleural fluid and can be used both diagnostically and to guide procedures. In addition to detecting fluid, it can determine if the pleural effusion is simple or loculated. Drainage of pleural effusion and insertion of chest drains without imaging guidance have resulted in severe complications and death. Patient safety organizations and thoracic medicine societies have recommended that these procedures be performed with ultrasound guidance (Lamont et al. 2009). Thus, with the increasing availability of handheld and portable ultrasound units, this should be done as a PoC-US procedure.

Lung ultrasound. Although previously thought unsuitable for ultrasound examination, recognition that pleural changes (demonstrated by artifacts) can reflect parenchymal diseases has resulted in a rapid advance in the use and understanding of lung ultrasound. Collapse, consolidation and interstitial thickening (*e.g.*, from cardiac failure or pulmonary fibrosis) can be detected by lung ultrasound. Recent consensus statements and reviews summarize these applications (Dietrich et al. 2015a, 2015b, 2015c, 2015d; Volpicelli et al. 2012).

Pneumothorax. Pneumothorax is excluded by detecting "lung sliding" at the pleural line (Kirkpatrick et al. 2004). It is incorporated into protocols for trauma (Kirkpatrick et al. 2004), breathlessness and shock (Lichtenstein and Meziere 2008) and can be used to direct procedures and examine for post-procedural complications.

Aorta. Determining aortic diameter to exclude abdominal aortic aneurysm has been used in abdominal pain examinations, shock protocols and screening (Abbas et al. 2012; Flu et al. 2009; Lin et al. 2003; Vidakovic et al. 2006, 2007).

Liver. Hepatologists and gastroenterologists increasingly perform their own liver ultrasound not only with B-mode but often also using elastography (Bamber et al. 2013; Barr et al. 2015; Cosgrove et al. 2013; Ferraioli et al. 2015; Shiina et al. 2015). Liver biopsy and ablation treatment should always utilize ultrasound guidance, whether performed using direct or indirect image guidance (Dietrich et al. 2015a, 2015b, 2015c, 2015d; 2016a, 2016b, 2016c, 2016d; Farrell et al. 1999; Sporea et al. 2008).

Inferior vena cava. The evaluation of inferior vena cava diameter and respiratory changes has long been used to estimate central venous pressure. More recently, it has been used to try and predict fluid responsiveness in the hypotensive patient (Adler et al. 1983; Kircher et al. 1990; Simonson and Schiller 1988).

Cardiac function. A consensus paper describing the evidence for focused cardiac ultrasound in the critical care setting has recently been published (Labovitz et al. 2010). Left and right ventricle size and function are evaluated from the standard echocardiographic windows (parasternal, apical and subcostal). In critical care settings this information is used in addition to pericardial fluid and inferior vena cava evaluation in protocols for shock and cardiac arrest to suggest causes (tamponade, hypovolemia, sepsis, cardiogenic shock, pulmonary embolus, *etc.*) (Breitkreutz et al. 2010; Breitkreutz et al. 2007; Labovitz et al. 2010; Lodato et al. 2008; Moore et al. 2002; Peng et al. 2011; Pershad et al. 2004; Via et al. 2014).

PoC-US has also been used in outpatient and screening settings. Although PoC-US does not provide the same amount of information as comprehensive echocardiography, many studies have reported it can provide important clinical information and both affect patient care and provide cost savings (Badano et al. 2009; Cardim et al. 2011; Culp et al. 2010; Haji et al. 2013;

Table 1. Examples of common point of care ultrasound protocols

Acronym	Name	Includes
eFAST	Extended focused assessment with sonography in trauma	Intra-abdominal free fluid, pericardial fluid, pneumothorax
BLUE	Bedside lung ultrasound in emergency	Pleural effusion, lung parenchyma, pneumothorax
FEEL, FEER, BELS, ELS, *etc.*	Focused echocardiography in emergency life support, focused echocardiographic evaluation during resuscitation, (basic) echocardiography in life support, effusion ejection equality exit and entrance, abdominal and cardiac evaluation in shock *etc.*	Left ventricular size and function, right ventricular size and function, pericardial effusion, inferior vena cava
FATE	Focus assessed transthoracic echocardiography	B- and M-mode basic cardiac views, road map to interpret echocardiographic findings in a clinical context
RUSH	Rapid ultrasound for shock and hypotension	eFAST plus abdominal aorta plus focused cardiac

Mjolstad et al. 2013; Panoulas et al. 2013; Prinz and Voigt 2011; Roelandt 2004; Sicari et al. 2011; Skjetne et al. 2011). In these settings, POC-US has been used to evaluate valvular function, for example, as a screening test for rheumatic heart disease in resource-poor environments (Lu et al. 2015).

Vascular access. Ultrasound-guided vascular intervention examination techniques have recently been addressed by EFSUMB guidelines (Dietrich et al. 2016a, 2016b, 2016c, 2016d; Jenssen et al. 2015, 2016a). An international consensus process was held by WINFOCUS, and the results on ultrasound guidance for vascular access were published (Lamperti et al. 2012).

Hydronephrosis and nephrolithiasis. A large, multicenter, randomized trial compared the use of CT, radiology department ultrasound and PoC-US for suspected renal colic and observed no difference in adverse events, with reduced radiation exposure in the ultrasound groups. Although the calculi may not be identified with PoC-US, the presence of hydronephrosis is supportive and alternative diagnoses can be excluded (Smith-Bindman et al. 2014).

Small bowel obstruction. PoC-US can detect dilated fluid-filled loops of bowel, changes in peristalsis and collapsed distal bowel. It may also detect gastric ulcers and thickened bowel walls in Inflammatory Bowel Disease (Gilja et al. 2003). It has superior sensitivity and specificity compared with plan abdominal radiographs for bowel obstruction (Guttman et al. 2015; Jang et al. 2011; Taylor and Lalani 2013).

Bladder volume. Measurement of bladder volume is simple with ultrasound, and is often performed using automated machines. Visualization with B-mode ultrasound machines is useful when the clinical picture does not match the automated results (*e.g.*, when ovarian cysts give false-positive results) and to guide procedures (*e.g.*, prior to suprapubic aspiration in young children).

Biliary stones and obstruction. Ultrasound has high specificity and sensitivity for gallstones and is useful for evaluation of upper abdominal pain. Intrahepatic and extrahepatic duct dilation can be accurately assessed, and studies have indicated that PoC-US can improve management in both inpatient and outpatient settings and reduce further testing (Colli et al. 2015; Gilja et al. 2003).

Gynecology. Ultrasound is the imaging modality of choice for the gynecology emergency, as it can be used to identify and assess the pelvis for free intraperitoneal fluid and bleeding. Although transabdominal scanning of the pelvic region may be used for basic PoC-US, the transvaginal approach generally produces superior results. Common causes of acute lower abdominal pain in females include ovulation pain (*Mittelschmerz*), ovarian torsion, ovarian hyperstimulation, hemorrhagic functional cysts, endometriosis, pelvic inflammatory disease, pelvic abscess, ectopic pregnancy, dislocated intrauterine contraceptive device, pedunculated fibroids, as well as renal causes and appendicitis.

Obstetrics. Relatively simple obstetric findings, such as presence and location of a gestational sac, fetal viability, multiple pregnancy, adverse placental location, oligo- and polyhydramnios, can significantly affect both maternal and fetal morbidity and mortality, particularly in resource-poor settings The accuracy of small machines is comparable to that of large machines for these uses (Sayasneh et al. 2012).

PoC-US is widely accepted as an easy and accurate way to monitor the progress of the pregnant patient from 5 weeks of gestation to term. Adnexal pain in early pregnancy raises the possibility of an ectopic location, and well-performed PoC-US may detect the absence of an intrauterine gestational sac, an adnexal mass or free intraperitoneal fluid, which could be associated with tubal rupture. Although high specificity and sensitivity of PoC-US have been reported (Stein et al. 2010), it is highly user dependent. Ultrasound is used to confirm an intrauterine pregnancy, viability, number of fetuses and gestational age. Midwives and obstetricians routinely monitor the fetus in the mid and third trimesters to assess fetal lie, fetal growth and well-being, placental position, cervical length and amniotic fluid level.

Of all the areas in which PoC-US is employed, the greatest potential impact on morbidity and mortality is in the field of obstetrics. Training health workers in the use of PoC-US in underserved countries can significantly assist in decreasing fetal and maternal morbidity and mortality (Kimberly et al. 2010; Liu et al. 2016).

Rheumatological disorders. Joint effusions, synovial thickening and inflammation can be measured to monitor inflammatory activity (Kang et al. 2012).

Ocular uses. Diagnosis of ocular pathology was one of the earliest uses of ultrasound, which has been employed predominantly for vitreo-retinal disorders of the posterior segment. Subsequently, its use by non-opthalmologists has been reported to be accurate (Blaivas et al. 2002). The eye is particularly sensitive to ultrasound energy, so low-energy settings should be used when performing these examinations (WFUMB 2013).

Common PoC-US protocols. Many of the above uses are incorporated into protocols used in specific clinical settings. Examples of some of these are given in Table 1.

SAFETY CONSIDERATIONS

Diagnostic ultrasound has been used clinically for more than 50 years without undisputed description of harmful consequences. It is, however, a form of energy that has effects each time the waveform traverses tissues (bio-effects) (Rott 1996; Salvesen 2002; WFUMB 2013). The two major mechanisms involved are mechanical effects, resulting from the alternation of positive and negative pressures, and thermal effects, caused by heating of the tissues secondary to transformation of the acoustic energy to heat. Two real-time on-screen indices allow the end user to make assumptions regarding the potential risk: the mechanical index (MI) for the risk from mechanical effects and the thermal index (TI), which indicates the risk resulting from a rise in temperature (but does not measure an actual temperature rise) (Abbott 1999; Abramowicz et al. 2008). The TI changes depend on the type of tissue being scanned. Although few, if any, deleterious effects are generally expected in adult PoC-US, two situations require special attention: scanning the pregnant patient and scanning the eye or its vicinity in any patient. In the fetus, teratologic vulnerability is a particular concern in early gestation, and thus, special caution is recommended at that stage, specifically when using Doppler mode, because of its much higher level of energy. As a result, fetal heart rate should be measured using M-mode, not Doppler, in the first trimester (Abramowicz 2010). The eye is also particularly vulnerable to ultrasound energy, so energy outputs should be decreased for ocular scanning (Silverman et al. 2001; WFUMB 2013). In any patient, ultrasound should be used only when clinically indicated, for the shortest amount of time and with the lowest level of acoustic energy compatible with an accurate diagnosis (the "as low as reasonably achievable" [ALARA] principle) (WFUMB 2013). In general, TI (and MI) should be kept below 1. The use of ultrasound contrast agents requires further reduction in the MI because of the increased risk of cavitation (Claudon et al. 2013a, 2013b; Piscaglia et al. 2012).

INVERVENTIONAL ULTRASOUND

Interventional ultrasound has numerous outstanding applications and can be employed by medical professionals throughout a wide range of specialties (Dietrich et al. 2015a, 2015b, 2015c, 2015d; 2016a, 2016b, 2016c, 2016d; Jenssen et al. 2016b; Lorentzen et al. 2015a, 2015b; Sidhu et al. 2015). Interventional ultrasound thus renders itself as a perfect tool in the PoC-US philosophy. The real-time imaging of ultrasound is unique in enabling the user to visualize, in real time, a handheld needle passing through tissue to any target inside the body independent of needle angle or target position, as long as the target can be visualized with ultrasound. No other imaging modality can compete with ultrasound when it comes to choosing the puncture route. This feature is a genuine win–win situation. The possibility of placing the needle correctly in the target is optimized, and at the same time, the risk of complications is minimized.

As a consequence many societies now recommend that, to reduce complications, interventional procedures generally should not be performed without ultrasound (Dietrich 2015; Dietrich et al. 2015a, 2015b, 2015c, 2015d; Fusaroli et al. 2015; Jenssen et al. 2015, 2016a; Lorentzen et al. 2015a, 2015b; Sidhu et al. 2015).

The applications of interventional ultrasound can be divided into two major groups: diagnostic and therapeutic. Diagnostic interventions include biopsy of solid tissue, aspiration of fluid and instillation of diagnostic material, for example, contrast agents through a catheter. Therapeutic applications include drainage of fluid collections like ascites, pleural and pericardial effusions, lymphoceles and abscesses; catheterization of hollow organs as in intravenous catheter placement or nephrostomies, gastrostomies, cholecystostomies and suprapubic catheter placement; and also US-guided neural blockage, arthrocentesis, ovum harvesting and others, plus more complex procedures such as tissue ablation by means of heat, frost or radiation. Not all applications are likely to be used in a PoC-US setting, but, for example, US-guided nephrostomies are increasingly performed by urologists and the extent to which a US-guided intervention becomes a PoC-US procedure depends solely on the education, training and expertise of the institutions and persons in question. With the advent of US contrast agents new horizons have been reached and CEUS-guided intervention has emerged as a powerful—sometimes even indispensable—tool in areas such as radiofrequency ablation (Dietrich et al. 2015a, 2015b, 2015c, 2015d), cyst sclerosing procedures (Dietrich et al. 2016a, 2016b, 2016c, 2016d), abscess drainage and biopsy of iso-echoic or barely visible liver metastases (Nolsøe and Lorenten 2016). Interventional ultrasound at its present stage has countless applications, but the growing field of PoC-US will without doubt inspire new users to develop impressive new procedures to the benefit of patients and the medical community.

EDUCATION

As with any other medical training, the use of ultrasound devices requires dedicated education and practical training. Educational programs need to be designed to facilitate the general medical practitioner learning at any level of experience, starting at the medical student level and continuing with more focus on specialty-related issues (Frederiksen et al. 2012; Royse et al.

2012). The ultimate goal is to incorporate PoC-US into daily clinical practice, making ultrasound examination available to every physician. This will subsequently improve diagnostic efficiency and possibly patient management (Royse et al. 2012).

Some educators have expressed concern that teaching medical students to use ultrasound will strain an already full curriculum and lead to degradation of time-honored physical examination skills. However, PoC-US cannot supplant all aspects of the physical examination. As with any investigation that is used appropriately, it provides further information that supplements the physical examination, allowing more rapid and accurate assessments, and is particularly valuable where physical examination is known to be either difficult or inaccurate (Morris 2015).

A number of medical schools now incorporate ultrasound training into their curriculum, ranging from a teaching adjunct for basic sciences (Patten 2015) to full integration into the course as a clinical tool (Hoppmann et al. 2015), and some schools supply handheld machines for students to learn with. Some authors predict that increasing numbers of clinicians and students will have such "echoscopes" in their white coats, instead of, or in addition to, a "stethoscope" (Solomon and Saldana 2014). Teaching material for such students is widely available (Dietrich 2016; Gilja et al. 2016; Society of Ultrasound in Medical Education [SUSME] 2016). Despite a high level of enthusiasm for using ultrasound to help students learn anatomy, it has not been found to improve anatomical knowledge (Sweetman et al. 2013).

Ultrasound is a complex skill to learn, requiring the skill to obtain images, the knowledge to interpret the images and the overall clinical judgment to use the findings appropriately to manage the patient's problem (Bowra et al. 2015). The procedural component requires complex visual perception and psychomotor skills, and as for all procedural skills, "hands on" training, and phantoms and virtual reality equipment can assist in the process (Grantcharov and Reznick 2008; Nicholls et al. 2014). Theoretical knowledge and cognitive skills can be taught using newer teaching techniques, such as Web-based and case presentation-based curricula that have been reported (Hempel et al. 2015; Kang et al. 2015) to be as effective as traditional classroom-based teaching. Distance learning, using the Internet, holds further promise for reaching practitioners who may not have access to traditional learning pathways (Bowra et al. 2015).

COMPETENCY ASSESSMENT AND ONGOING QUALITY ASSURANCE

To be confident that providers are using PoC-US appropriately, standards for assessment that encompasses both examination performance and interpretation should be developed. However, both competence and ongoing quality assessment are hampered by the fact that unlike chest radiographs and CT scans, which have standard protocols that can be interpreted widely by providers who did not perform the examination themselves (Morris 2015), PoC-US is by its nature individualized and brief. A system of quality assurance is crucial to ensure that providers are performing high-quality examinations, obtaining high-quality images and interpreting them appropriately (Labovitz et al. 2010). For physicians in practice, several national and international organizations offer training and certification in various aspects of PoC-US.

POC-US IN A THIRD WORLD SETTING

In a Third World setting, PoC-US takes on a different perspective. Patients may have to travel long distances to access medical care. Many cannot afford the cost of transportation to a medical facility. Ultrasound is cheap, easy to perform and easy to teach, and machines are robust, making it easy to take them to a rural setting where they are most needed. The role of PoC-US would be to identify high-risk patients who can be referred to regional hospitals for further management. It tends to simulate a triage service that identifies patients requiring further treatment. A key feature of PoC-US is that it is not a replacement for comprehensive ultrasound practice, but a focused ultrasound examination often performed under suboptimal conditions and with time limitations.

Therefore, PoC-US training and practice need to reflect the nuances of the particular region covered (Dietrich et al. 2015a, 2015b, 2015c, 2015d; Richter et al. 2016). The specific applications and training methodology should be chosen to suit the local environment. Different pathologies in different parts of the world mean that certain applications may be irrelevant; for example, the FASH (focused assessment with sonography in HIV/AIDS) scan is useful only in under-developed nations that see many cases of HIV/AIDs and tuberculosis (Barreiros et al. 2008). In addition, the impact of the disease on the local population is important and may necessitate its inclusion into a curriculum despite not being common (van Hoving et al. 2013).

Certain components of PoC-US curricula should share common structures and principles and should adopt best practices where possible. The basic components common to all curricula, regardless of region, are an understanding of the physics/operation of the ultrasound machine and good governance in PoC-US practice.

The methodology of curriculum delivery centers on the various steps in training and demonstration and maintenance of competency and may vary according to local conditions. There is evidence to indicate that competency can be assumed after a relatively small number of ultrasound examinations have been undertaken. Our own experience has revealed that for obstetric scanning, a training period of 1 month is sufficient to trigger a competency assessment.

One area of medicine in which PoC-US is strongly applicable is antenatal care. Very few women in sub-Saharan Africa have access to antenatal care, and the maternal death rate is unacceptably high. Pilot projects in Kenya have found that midwives can be trained to perform basic ultrasound with a view to identifying high-risk pregnancies. The training period is 1 month, and the midwives' accuracy in identifying high-risk pregnancies is very high. Using portable machines that run on batteries, midwives can scan patients in their homes and villages. The images and provisional reports can be transmitted to a specialist using mobile phone technology and simple modems. Image transmission times are low, and the image quality is lossless. As there is a shortage of specialists, this type of tele-radiology is extremely useful. All high-risk pregnancies can be referred to specialist centers, thereby reducing the chance of unfavorable outcomes.

OPEN QUESTIONS

A current unresolved issue is the recording and storage of images. Best practice requires storing images or videos from prior studies so they are available for review and future comparison.

Tension will always exist as to the exact boundaries of non-specialists performing focused exams and specialists performing comprehensive exams. These issues are mirrored in all aspects of medical practice and are best viewed more as issues of training, credentialing and quality assurance rather than definitions of specialties or practice.

FUTURE PERSPECTIVES

As new specialties and practitioners take up ultrasound in their daily clinical practice, we may see a radical change in the content of the physical examination. Given the inadequacy of the physical examination in the hands of most clinicians for many disorders and the superiority of PoC-US, the typical examination in most clinical settings is likely to be a combination of traditional skills and focused ultrasound for evaluation of any questionable findings or areas of specific interest. For patients this will mean increased accuracy and more rapid diagnosis and hence treatment. For clinicians, the benefits will include greater efficiency, but also increased satisfaction in their diagnostic and procedural capabilities. Several additional evolutionary steps are likely to be forthcoming in PoC-US. These will be welcome additions that will lead to even greater expansion of diagnostic and procedural PoC-US capabilities. Live 3-D or volumetric ultrasound transducers have the capability to capture large volumes of data in real time and not only allow clinicians a new way to look at anatomy and pathology but also enable greater automation by the ultrasound machine. For example, it may become possible to only have to obtain an adequate apical cardiac window and have the machine make multiple hemodynamic calculations of cardiac function.

To further improve the use of PoC-US, the very nature of imaging data delivery to the user may have to change to enable more efficient procedure performance and also more convenient diagnostic scanning. Optimized adjuncts such as goggle or monocle displays, projections onto walls and other wireless image transmission will make ultrasound less cumbersome in critical and cramped situations.

It is crucial that imaging specialists (radiology, obstetrics, cardiology) and PoC-US users work together to recognize its potential and its limitations, to teach current and future care providers how to use ultrasound responsibly and to create an infrastructure that maximizes quality of care while minimizing patient risk.

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