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Original Article

Critical care Ultrasonography as a Decision Support and Therapeutic Assist Tool in the Intensive Care Unit: A Single Centre Retrospective Survey in a District General Hospital, Sri Lanka

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Abstract

Background

Despite its regular use, no literature is available regarding the use of ultrasound (US) in intensive care units (ICU) in Sri Lanka.

Objectives & Methods

This audit analysed critical care ultrasonography (CCUS) in the ICU of a District General Hospital. Data of 100 patients, from October 2019 to October 2020, were evaluated against the Society of Critical Care Medicine (SCCM) consensus guidelines of 2015. Adherence to Grade 1 recommendations (strongly recommended) was considered when assessing institutional compliance with SCCM guidelines.

Results

There were 59 males and 41 females with a mean age of 51.2 years. Indications for ICU admission included advanced monitoring (62%) and ventilatory (49%) and inotropic (41%) support for which the CCUS was employed. Fluid status was assessed in 72 patients, 67 by inferior vena cava (IVC) collapsibility / distensibility and 5 by Internal jugular vein (IJV) distensibility. Bedside cardiac US (n=74) was used for assessment of cardiac functions in 46(62.2%), pericardial effusions in 23(31.1%), pulmonary embolism in 2(2.7%) and exclusion of reversible causes of cardiac arrest in 3(4%). Lung ultrasound (n=42) was used for diagnosis of effusions in 36(83%), consolidation in 24(56%), sequential assessment of acute respiratory distress syndrome in 14(32.5%) and drainage of effusions in 3(4.6%). US-guided central venous (CV) lines were inserted in 62(95%). Of all CV catheterizations, 46(74%) were successful at the first attempt. Arterial puncture and pneumothorax were prevented at all times. In 14(82.3%), the need for central lines was avoided by US-guided peripheral cannulation. Ultrasound abdomen was used in 33(86.8%) for diagnostic and in 5(13.2%) for therapeutic purposes. Interventions and optimal management were delayed due to the unavailability of US in 80%.

Conclusion

There was 95% compliance with SCCM guidelines in following strongly recommended (Grade 1) fluid responsiveness / fluid status and central venous access. Dedicated, portable US scanners in ICUs and training of medical officers would minimize delays and improve outcomes.

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Introduction

Despite its universal use in the intensive care setting as a therapeutic and diagnostic tool, critical care ultrasonography (CCUS) is practiced largely based on anecdotal evidence in developing countries. The challenges faced by third world countries, such as the non-availability of dedicated ultrasound machines in intensive care units (ICU) and the lack of skilled sonographers and resources, demand the optimal and judicious utilization of this valuable tool. Studies in this regard are minimal in Sri Lanka.

Methods

This retrospective, cross sectional survey was conducted in the ICU, District General Hospital, Mannar. The details of all the patients admitted from August 2019 to August 2020 were collected from patient records (bed head tickets and ICU monitoring charts) into online, password protected, data extraction forms (Google® forms) which were accessible only to the investigators. A draft data extraction form was created after literature review and reviewed by a panel of experts followed by three rounds of review by the supervisor and the investigators using the Delphi method.

Data was collected under the following main sections 1) demographic details 2) utilization of ultrasound (US) for diagnostic / therapeutic procedures 3) US usage in aseptic / sterile procedures. Commonly performed diagnostic and therapeutic US guided interventions/imaging of cardiovascular, respiratory and airway, abdomen, nervous system, nerve blocks, soft tissue and skin were also assessed. All sensitive patient data were anonymized, and analysis was done using IBM SPSS 25.0 software. Categorical variables were reported as numbers and percentages. Continuous Gaussian variables were described as means with standard deviation (SD). The Society of Critical Care Medicine (SCCM) guidelines for use of US in ICU were adopted as guidance during data analysis.[1,2] Adherence to Grade 1 (strong) recommendations was used to assess institutional compliance to the guidelines. Ethics clearance was obtained from the Ethics Review Committee, Teaching Hospital, Jaffna.

Results

Data of 100 patients, 59 males and 41 females, were collected during the study. The demographic details of the study population are illustrated in Table 1. The mean age of the sample was 51.21 years (+/- 20.68). Around 60% were medical patients while 80% were transferred from the emergency treatment unit (ETU) or from hospital wards. Mortality was 23.

Table 01: Demographics of the study population (n=100)

Demographic	Frequency
Sex	
Male	59
Female	41

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Specialty	
Gynaecology & Obstetrics	2
Medicine	59
Paediatrics	7
Surgery	32
Transferring unit	
ETU	41
Hospital ward	39
Operating theatre	16
Other hospitals	4
Indications for ICU admissions	
advanced monitoring	62
ventilator support	49
inotropic support	41
multi-organ support	30
post-operative pain relief and monitoring	19
*Patients had one or more indications for admission	

US was never indicated in 11 patients. In the 89 patients who required US at least once during the ICU stay, US was available immediately for only 9 (10.2%) while in 80 (89.8%) the US was delayed, resulting in delayed diagnosis and/ interventions. The utilization of CCUS for patient management pertaining to different indications are categorized according to the organ systems.

Cardiovascular

Echocardiography was indicated for assessment of fluid status in 28 patients while 72 patients required ultrasound assessment of fluid status, 67 for inferior vena cava (IVC) collapsibility/ distensibility and 5 for internal jugular vein (IJV) distensibility. Other uses of bedside cardiac ultrasound (n=74) included assessment of cardiac functions by bedside echocardiography in 46, assessment of pericardial effusion in 23, assessment of pulmonary embolism in 2 and exclusion of reversible causes of cardiac arrest in 3 patients. USS for vascular access included insertion of central line, indicated in 65 but used only in 62, peripheral line insertion in 17, arterial line insertion in 10 but used only in 3 patients.

Bedside echocardiography was required in 49, of whom it was not performed in three patients due to unavailability (n=2) or difficulty in obtaining echo windows (n=1). In 28 of the 46 (61%) successful USS the echo study was performed by the consultant anaesthetist, in 15 (32.60%) by the ICU medical officer under the supervision of the consultant anaesthetist and in 3 (6.4%), by the consultant cardiologist.

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Table 02: Use of ultrasound in cardiovascular assessment

Indication	Frequency (%)
US assessment of fluid status (n=72)	
Inferior vena cava (IVC) collapsibility/ distensibility	67(93.0)
Internal jugular vein (IJV) distensibility	5(7.0)
Other uses of bed-side cardiac US (n=74)	
Assessment of cardiac functions by bed side echocardiography	46(62.2)
Assessment of pericardial effusion	23(31.1)
Assessment of pulmonary embolism	2(2.7)
Exclusion of reversible causes of cardiac arrest	3(4.0)
USS for vascular access	
Central line insertion (n=65)	
US utilized	62(95.4)
US not utilized	3(4.6)
Peripheral line insertion (n=17)	
Central line insertion avoided	14(14.0)
Central line inserted later	3(17.7)
Arterial line insertion (n=10)	
US utilized	3(3.0)
US not utilized	7(7.0)

Obtaining central venous access is a key feature of advanced management modalities at present. The choice of central venous (CV) access (n=65) was as follows; internal jugular 60% (n=39), subclavian 16% (n=10), femoral 6% (n=4). Out of all the CV catheterization attempts, 74% (n=46) were successful at first attempt and the rest (26%, n= 16) took less than 5 attempts whereas none failed under direct US visualization. Advantages of direct US visualization while inserting CV lines were as follows. In all the cases arterial puncture was avoided (n=62) and in 56 (90.3%) cases pneumothorax was avoided while verifying the correct line placement. In 12 cases (19.3%) thrombus was detected prior to CV line insertion thus avoiding the affected site.

Lung ultrasound

Lung ultrasound was required in 43 patients and the indications are given in Table 03.

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Table 03: Use of ultrasound in respiratory system assessment

Indication	Frequency (%) n=43
Diagnostic	
pleural effusion	36(83.7)
lung consolidation	24(55.8)
sequential assessment of acute respiratory distress syndrome (ARDS)	14(32.5)
pulmonary oedema	3(6.9)
pneumothorax	2(4.6)
Therapeutic	
drainage of pleural collections	2(4.6)

Ultrasound abdomen

Bedside abdominal USS was performed in 38 patients (38%) for the reasons listed in Table 04.

Table 04. Indications for ultrasound abdomen

Indication	Frequency (%)
Diagnostic (n=33)	
Screening for an abdominal focus in sepsis	14(36.8)
Follow up after acute kidney injury	8(21.1)
Bladder volume assessment in oliguria	5(13.2)
Focused assessment of sonography in trauma	3(7.9)
Post-operative ileus	3(7.9)
Therapeutic (n=5)	
Paracentesis	3(7.9)
Aspiration of? pancreatic pseudo-cyst	1(2,6)
Urinary catheter bulb rupture	1(2.6)

Relatively infrequent uses of US are shown in Table 05.

Table 05: Uncommon uses of US in ICU

Indication	Frequency (%)
Airway assessment (n=5)	
Detection of altered anatomy prior to elective tracheostomy	4(80.0)
Cricothyroid membrane identification prior to difficult intubations in ICU	1(20.0)
Neurological assessment (n=10)	
Assessment of papilloedema	10(100.0)
Assessment of deep vein thrombosis (n=17)	
Detected	1(5.9)
Not detected	16(94.1)
Assessment of skin and soft tissue (n=11)	
Detection of abscess	6(54.5)
Assessment of compartment syndrome	4(36.4)
Aspiration of collections	1
Regional nerve blocks for analgesia (n=6)	6(100.0)
Assessment of nutritional status	0(0)

The following practices with regard to cleaning and maintenance of the US probe were noticed. For sterile procedures, US probe was covered with sterile drapes in all the patients. At all instances probe was cleaned with normal saline and an antiseptic solution before and after use.

Discussion

Critical care ultrasonography (CCUS) comprised of both ultrasonography and echocardiography, has gained wide acceptance as an integral part of critical care management. Non-invasiveness and freedom from radiation and dye have contributed to improved patient satisfaction [3], safety and efficacy. Thus, point of care ultrasonography (POCUS) is currently regarded as an extension to physical examination [4].

We conducted this study with the aim of identifying the usage patterns of CCUS in a resource poor setting and the results were intriguing. The main indications for ICU admission were advanced monitoring (62%) and ventilatory (49%) and inotropic (41%) support, for which CCUS is employable.

Cardiovascular ultrasonography

The assessment of fluid status is an integral part of the mangement of critically ill patients as both hypovolaemia and hypervolaemia are a hindrance to achieve homeostasis. The

role of ultrasound in the assessment of fluid status and identifying volume responders is well established. SCCM provides a Grade 1B recommendation (strong) for ultrasonic assesment of preload responsiveness in ventilated patients [1]. Instead of the former static indices of volume status such as central venous pressure and pulmonary capillary wedge pressure, inferior vena cava (IVC) size and its variability (IVC collapsibility/ distensibility) with respiration and obliteration of the left ventricular (LV) cavity in systole at the level of the papillary muscle (PLAX view- kissing sign) are found to be more sensitive in identifying hypovolaemia and fluid responders [5]. The SCCM guidelines recommend IVC collapsibility or distensibility and LV systolic and diastolic function for assessment of fluid status with a cut-off of 15% change in diameter in the IVC between inspiratory and expiratory phases, although accuracy is more in positive-pressure ventilated patients without abdominal hypertension and less in spontaneously breathing patients [5].

Bedside cardiac ultrasonography (BCU) has an array of applications including assessment of ventricular function, pulmonary embolism and pericardial effusions, to name a few. Jensen et al. were able to obtain echocardiographic windows and haemodynamic parameters in 97% of critically ill patients by focus assessed transthoracic echo [6]. In our study, nearly half of the patients underwent BCU, among which a one third was to exclude pericardial effusion. The relatively infrequent uses of BCU were to exclude pulmonary embolism and reversible causes of cardiac arrest in peri-arrest patients. The American Heart Association recommends the use of ultrasound during cardiopulmonary resuscitation. However prognostication is discouraged [7]. Similarly, POCUS in cardiac arrest is recommended in the most recent European Resuscitation Council guidelines [8].

The novel practice of ultrasound guided central line insertion rendered the traditional method of landmark guided insertion obsolete due to its superiority in success rate of correct placement, reduced number of attempts, decreased time to insertion, improved cost-effectiveness and possibly, decreased risk of catheter-related sepsis [9]. In addition, a Cochrane review has shown an overall reduction of procedure related complications by 71% and inadvertent arterial cannulation by 72% [10]. SCCM recommends the same (Grade I A, strong recommendation), where short-axis, single person, conventional B-mode is preferred over longitudinal-axis, two person, Doppler aided line insertions and post-procedure US studies to exclude complications such as pneumothorax instead of chest X-ray [1]. In our study, US was used in 95% of patients for CV cannulations, majority using IJV with 75% success at first attempt with no intra-arterial or pleural entries. Although US guided subclavian access is not recommended by SCCM, claiming difficulty in visualization, our study revealed a 100% success rate and no life-threatening complications of this practice.

Venous thromboembolic phenomena are important concerns in the critically ill and could be assessed by POCUS with higher degree of accuracy by intensivists. Out of the 17 venous duplex studies performed, one patient was found to have venous thrombosis up to the common iliac veins, later attributed to a femoral venous line, and received systemic anticoagulation followed by complete recovery.

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Ultrasound guided arterial line insertions were relatively less (n=3) as operators were competent in blind radial arterial cannulations. SCCM provides a B grade (2B) recommendation with preference given to the traditional method of palpation for arterial cannulation. The same recommendation is provided for US assisted peripheral venous line insertion, however reduced number of attempts and time for venous access were reported in several prospective studies [11]. In our study, 17 patients required US guided peripheral cannulation due to oedema, distal venous thrombosis, burns or obesity. The commonest site of entry was the basilic vein in the arm and the cephalic vein in the arm and near the clavipectoral fascia. Interestingly, we were able to avoid further central line insertions and related complications in 14(82.3%) of these patients.

Thoracic and airway ultrasonography

Thoracic ultrasonography has been proven to be superior to radiography in the diagnosis of pneumothorax in the ICU, with a sensitivity and specificity of more than 90% [12]. Although computed tomography (CT) has diagnostic superiority, it leads to delays, requires transportation of potentially unstable patients out of the ICU, entails exposure to radiation and incurs increased costs. Moreover, thoracic ultrasound can be used for the diagnosis of acute respiratory distress syndrome (ARDS), consolidations, pleural effusion and assessment of progression of ARDS and resolution of pneumonia. Lichtenstein et al. record a sensitivity of 90% and a specificity of 98% for the diagnosis of consolidation by ultrasound [13]. Ultrasound has also been used to diagnose and quantify pleural effusions. Furthermore, real time ultrasound guidance facilitates safer pleural fluid aspiration compared to a land mark guided technique [14]. The role of US in COVID-19 has been evaluated and the results are promising, with findings of pulmonary changes at the different stages of COVID-19 correlating with CT [15] and it has been suggested as a screening tool early in the disease when typical CT changes may not be detectable [16]. The repeatability, non-invasiveness and, most importantly, feasibility of lung US in the prone position are advantages in an ICU setup. In our study, out of the patients who underwent thoracic US, above 80% had varying degrees of pleural effusions, around 50% had lung consolidations and one-third were followed up with serial US for underlying ARDS. Two patients were diagnosed with pneumothorax following trauma, which helped in prompt management with good outcomes, and two underwent aspiration of pleural collections. In a center where CT facilities were not available, US proved to be advantageous in terms of reduced transfers and associated costs.

CCUS can be used for airway management in instances like anatomical assessment prior to intubation, direct visualization of the endotracheal tube, indirect visualization of respiratory mechanics and bedside tracheostomy. Ultrasonography assisted front of neck access in difficult intubations may minimize complications. Four patients had US of neck prior to elective tracheostomies due to anatomical alterations such as goitres, previous surgery to the neck with predicted difficulty, and no procedure related complications were reported under US visualization.

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Abdominal ultrasonography

Focused assessment sonography of trauma (FAST) is commonly performed to diagnose any solid organ damage and identify haemoperitoneum in trauma. Abdominal US is also used to identify infective foci, diagnose intestinal obstruction, aortic dissection, aortic aneurysms and to assess the progression of diseases like dengue haemorrhagic fever [17]. Moore and Edwards reported a reduction in the incidence of nosocomial urinary tract infections with the use of a portable bladder-scanning device. Bedside ultrasonography assessment of urinary bladder volume can also be helpful in the evaluation of oligo-anuric patients in whom an obstructive etiology is suspected. Ultrasound guidance during procedures such as paracentesis, percutaneous cholecystostomy, nephrostomy and drainage of collections improves the success rate and reduces the complications. One-third of our study population required US abdomen where an abdominal focus of infection was sought in nearly 40%. Other uses were sequential assessment following acute kidney injury, assessment of bladder volume, following ileus to assess peristalsis and FAST scans in polytrauma. US was deployed for therapeutic interventions such as paracentesis in decompensated chronic liver disease, drainage of pancreatic pseudo-cyst and rupturing the bulb of a urinary catheter following failed conventional deflation. Apart from the drainage of the pancreatic pseudo-cyst (for bacteriological analysis), the rest were performed by the intensive care team without any significant procedure related complications.

Nervous system ultrasonography

Transcranial Doppler ultrasonography (TCD) in the ICU can be used to assess cerebral perfusion pressure and intracranial hypertension, to detect subarachnoid hemorrhage associated vasospasm (especially in traumatic brain injury) and for screening for brain death [18]. Ultrasound is utilized in the assessment of papilloedema in patients where fundoscopy is practically difficult (cataract, injuries to the globe). Ten patients required assessment of papilloedema with the use of US (by measuring optic nerve diameter), due to cataract and two (20%) were found to have papilloedema and managed accordingly.

Soft tissue ultrasonography

Ultrasonography can be used to screen for skin and soft tissue infections and for the drainage of abscesses. Ultrasound guided nerve blocks are well established for acute and chronic pain relief. Body composition measurement is a novel tool to evaluate nutritional status in the ICU. Objective skeletal muscle measurements has been shown to be a reliable and accurate tool in assessing change in muscle mass secondary to catabolic effects of trauma, surgery or critical illness [19]. Due to the lack of experience in this area, nutritional assessment was not carried out in this ICU.

The main drawbacks to the universal practice of ultrasonography in critical care are unavailability/ inaccessibility to ultrasound devices and inadequate training of the ICU team on ultrasonography. Furthermore, there are concerns among physicians regarding losing the ability to perform landmark guided interventions and the ultrasound probe as a source of pathogens [20]. It is recommended to clean and disinfect the US probe or use a sterile sheath during US guided interventions and maintain a 'cleaning registry' (FUSIC

Accreditation- Intensive Care Society, UK). Our study revealed that all sterile procedures were conducted with sterile draping covering the probe (mainly sterile gloves even though this is discouraged by current guidelines due to the risk of structural breakage) and probes were cleaned before and after use conforming to current guideline recommendations.

Annual health statistics show that Sri Lanka had 99 ICUs by 2017. The data on dedicated CCUS facilities were not shown. However, immediate access to bedside ultrasound and echocardiography is highly recommended by local authorities on critical care as proposed in the SLMA newsletter on critical care in Sri Lanka by Pinto et al in 2019.

Recommendations

We propose that immediate access to bedside ultrasound and echocardiography should be made available in all ICUs in Sri Lanka and sonography skills among ICU medical officers should be fostered so as to enhance the standard of care.

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Confidentiality

No data were collected which could lead to identification of the patients.

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