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Review Article

Neonatal & Paediatric Point of Care Ultrasound (Pocus): A Novel Standard Practice

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Abstract:

An ever expanding branch of applications have been developed for ultrasound, including its goal directed use at the bedside, often called point-of-care ultrasound (POCUS). Although neonatologist-performed functional echocardiography has been at the frontline of the worldwide growth of POCUS, a rapidly growing body of evidence has also demonstrated the importance of non-cardiac applications, including guidance of placement of central catheterisation and lumbar puncture, endotracheal tube localisation as well as rapid estimation of the brain, lungs, bladder and bowel. Ultrasonography has become a pivotal adjunct to the care of neonates in the neonatal intensive care unit (NICU); but a full appreciation for its diagnostic capabilities in the NICU is lacking. Ultrasonography (USG) is no longer the exclusive domain of radiologists and cardiologists. With appropriate training, clinician performed ultrasound (CPU) is now practised widely in obstetrics, emergency medicine and adult intensive care .In many developed countries, it is standard practice in neonatology. In this review, we will discuss neonatal & paediatric point of care ultrasound (POCUS) as a novel standard practice & its clinical application for assessment of the head, heart, lung, gut and bladder for vascular line localization & for endotracheal tube placement. As new applications and adoption of point-of-care ultrasound continues to gain acceptance in paediatric and neonatal medicine throughout the world, a rapidly growing body of evidence suggests that the result will be faster, safer and more successful diagnosis and treatment of our patients.

Key Words: Neonatal intensive care unit, Ultrasound in Neonate, Point of care ultrasound (POCUS)

Introduction:

Point-of-care ultrasound (POCUS) is the ever expanding branch of ultrasound which have been used at bedside in developed countries. In many developed countries like New Zealand, the United Kingdom, and many other European and Asian countries, neonatologist routinely performed, targeted POCUS in neonatal intensive care units (NICUs). Although neonatologist-performed functional echocardiography has been at the frontline of the global growth of POCUS, it also has many non-cardiac applications, including guidance of central catheter placement, endotracheal tube localisation, lumbar puncture and rapid estimation of the brain, lungs, bladder and bowel. Point-of-care ultrasound (POCUS) is a new imaging modality of ultrasound that continues to gain acceptance in paediatric and neonatal medicine. Initially it is served as a clinical tool with the consultation of radiology and cardiology practitioner. In neonatology throughout many areas of the world, functional echocardiography performed by neonatologists has been at the forefront in the growth of POCUS compared to non-cardiac POCUS. Image quality and mobility improve due to technology advancement, decreasing cost and size of devices increasing the availability of ultrasound as a point-of-care bedside tool in several areas such as emergency medicine, obstetrics, and intensive care. Despite the early adoption in obstetrics and maternal-fetal medicine, the actual bedside implementation in neonatology has unfortunately been much slower in India.

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ISSN No. *: (p) 2348-523X, (o) 2454-1982*

DOI: 10.46858/vimshsj.8308

Date of Published : *25th September 2021*

Since 1960, the field of neonatology has undergone extensive development and growth in the care of the youngest of patients.[1] New and ever improving technology is enhancing the effectiveness and efficiency of neonatal care. Ultrasonography has become a pivotal adjunct to the care of neonates in the neonatal intensive care unit (NICU).[2]

Ultrasonography (USG) is no longer the exclusive domain of radiologists and cardiologists. With appropriate training, clinician performed ultrasound (CPU) is now practised widely in obstetrics, emergency medicine and adult intensive care, and is the standard practice in neonatology in many developed countries.[3] Cardiologists and radiologists undoubtedly have crucial role to play in clinical care, it is practically not possible to have 24 hour speciality coverage even in resource rich setting as neonatal care is dynamic process and requires frequent evaluation.[4]

Despite the obstacles and slow adoption of point of care sonography in neonatology, there has been some advancement in establishing point-of-care sonography as the standard of care.[5, 6] Areas of point-of-care sonography investigation in neonatology include vascular access, detection of pneumothorax and pleural effusions, and a targeted evaluation of the neonatal heart. [5, 6] A recent editorial calling for a formal point-of-care sonography curriculum to include training requirements and proficiency standards for widespread implementation in the practice of neonatal-perinatal medicine drew considerable attention.[7]

In this review, we will discuss neonatal & paediatric point of care ultrasound (POCUS) as a novel standard practice & its clinical application for imaging the head, heart, lung, gut, bladder, for vascular line localization & for endotracheal tube placement.

1) Cranial Ultrasound (CUS):

The new-born brain is readily accessible for sonographic imaging by the open soft tissue windows of the anterior fontanelle and the open sutures found between the unfused cranial bones. Neonatologists are quite familiar with viewing and interpreting cranial ultrasound images as these are routinely reviewed daily on clinical rounds. The primary views are coronal (front to back), sagittal (left to right) and axial views for posterior fossa. POCUS can provide excellent views of the general architecture of the brain especially the two ventricles, evaluation of haemorrhage or calcifications and early evidence of ischemic changes. The use of POCUS for brain imaging is particularly useful when suspect haemorrhage may be responsible for deterioration or hemodynamic instability, at times when sonographic support is not readily available. The detection of increased pressure, cerebral edema or stroke is not sensitive with HUS and other imaging modalities such as CT or MRI are recommended. It is important to remember that these evaluations are limited in evaluating this triangulated view of the brain and can miss events or lesions outside of this window in the parietal regions. Head ultrasound is one of the easier techniques to learn for neonatologists since the views are already very familiar to them. The imaging techniques hinge upon establishing stable upright views of the two hemispheres and axial views of the posterior fossa structures. Neonatal providers have ample experience in reviewing and interpreting head ultrasounds for common pathology such as periventricular leukomalacia, intraventricular and intracranial haemorrhages and so most of the skills are focused on imaging.[8]

Intraventricular Haemorrhage:

GMH-IVH is one of the most common ultrasound findings in NICU. Studies performed in the 1980s suggested that >90% IVH cases in very low birth weight (VLBW) infants occurred within postnatal days 4 to 5.[9] Premature infants are relatively resistant to haemorrhage after this period, irrespective of the gestational age (GA) because of the shutdown in angiogenesis, making the vessels resistant to rupture despite fluctuation in the cerebral blood flow.[10]

A recently published review[11], which included studies from the antenatal steroid and surfactant era, concluded that 48% of cases of IVH occurred in the first 6 hours of life in VLBW infants, and suggested that early cranial USG may have prognostic, preventive and medicolegal implications. A small percentage of GMH-IVH may occur up to third week of life.

Once the diagnosis of GMH-IVH is made, we should look for cerebellar bleeding, as the external layer of the cerebellum is also a germinal zone. Bleeding in and around the cerebellum may lead to poor future neurodevelopmental outcome. Early detection with the help of cranial USG through the mastoid foramen is important for prognostication and appropriate counselling of the family. Though small punctate cerebellar haemorrhages may not be seen well with cranial USG as compared to MRI, it remains a useful bedside tool.[12]

Periventricular Leukomalacia

PVL, which occurs as a consequence of preterm brain ischemia and/or inflammation, is of great diagnostic importance because of its association with cerebral palsy and abnormal development. PVL usually occurs in preterm infants <32 weeks gestation as they have poorly vascularized white matter, which contains oligodendro-cyte progenitors sensitive to ischemia and inflammation.[13] MRI has been reported to be a better modality than ultrasound in detecting white matter injury particularly in the diagnosis of punctate white matter lesion (PWML) and diffuse excessive high signal intensity.[14] However, serial USG has a definite role in evaluation of cystic PVL, a more severe form of white matter injury. The more extensive cysts tend to develop within 2-3 weeks following an insult, while the more localized cystic lesions may take as long as 3-6 weeks to develop.[15] Therefore, PVL diagnosed in the first week of life indicates an antenatal insult rather than a perinatal insult. Echogenicity in the brain equal to or greater than echogenicity in the choroid plexus, when persisting for more than 10-14 days, should alert the clinician about possible early PVL.

Table 1: Proposed Cranial Ultrasonography Scanning Protocol for Preterm Infants

< 28 weeks or birth weight <1000g or 28-31+6 weeks and/or birth weight <1500 gm on life support.	28-31+6 weeks or birth weight 1000-1500g without life support	32-34 weeks with risk factors: Monochorionic twins, head circumference <3rd centile, ventilation and/or surfactant need, fetal distress, acidosis, 5 minute APGAR score of <6, or hypotension
6 hours of age	Day 3 to 1 week	Day 5 to 1 week and then as indicated
Day 3 to 1 week	4 weeks	
4 weeks	TAE or discharge	
Term age equivalent (TAE) or discharge whichever occurs first		

2) Echocardiography:

Echocardiography is the investigation of choice to diagnose congenital heart defects, and historically it has been performed by pediatric cardiologists. It is non-invasive, readily available, performed at the bedside, and provides information in real time, making it an ideal tool to evaluate hemodynamics and to acquire physiological and anatomical information in critically-ill patients.[16-18] This practice is well established in adults and pediatric cardiac intensive care units. Anecdotally, echocardio-graphy is being used by the neonatologists in many neonatal intensive care units (NICU) across the world. A recent survey of clinical practice in the United Kingdom showed that it was being performed by neonatologists in most tertiary neonatal intensive care units. However, there remains a significant variation in the clinical practice of the neonatologists performing echocardiography.[19]

Assessment of Pulmonary Hypertension

Acute pulmonary hypertension in newborn, often referred as Persistent pulmonary hypertension of newborn (PPHN), continues to have high mortality in NICUs despite advances in neonatal care. Infants with acute pulmonary hypertension are often very sick and they need time-sensitive interventions to optimize cardiorespiratory support. The clinical presentation may mimic as critical cyanotic congenital heart defect. In clinical practice, a bedside point-of-care echocardio-graphy plays an important role to rule out underlying major congenital heart defect (CHD), diagnose pulmonary hypertension, assess its severity and target specific therapy.[20-23]

Early diagnosis of pulmonary hypertension on Point of care echocardiography may help in initiation of pulmonary vasodilator (such as inhaled nitric oxide) without any delay, and serial assessments may help in monitoring the response to treatment. In addition, early detection of cardiac dysfunction may help in rationalizing the choice of appropriate inotropic or vasopressor support based upon underlying pathophysiology.[21,22,24]

Patent Ductus Arteriosus

Persistent PDA has been suggested as an independent risk factor for increased risk of intraventricular hemorrhage (IVH), necrotizing enterocolitis (NEC), bronchopulmonary dysplasia (BPD), acute pulmonary hemorrhage, and a 4-8 fold increase in mortality.[25] However, studies on PDA treatment have failed to demonstrate any benefit on the long-term outcomes.[26] Certainly there is a clear trend towards treating less number of infants with PDA.[27] The signs and symptoms of PDA depend not only on the size of ductus arteriosus, but also on the magnitude of the shunt and ability of premature myocardium to adapt to this excessive shunt.[28]

Point of care functional echocardiography can help in assessing the impact of transductal shunt on hemodynamic status – pulmonary hyperperfusion and systemic hypoperfusion. It can also help to diagnose PDA in record time & will help neonatologist to take proper action.

3) Lung Ultrasonography (LUS):

The use of ultrasound to evaluate the paediatric patient's lungs is relatively new and a potentially revolutionary approach. Over the past 2 decades there have been accumulating data, which allow radiologists and bedside providers to understand the value and the limitations of this imaging modality. Lung ultrasound (LUS) signs (e.g, A-lines, B-lines, lung-sliding, etc) are the same among neonatal, paediatric, and adult patients. Among neonates, changes in the presence and absence of these signs occur rapidly after birth. It is only recently that these changes have been systematically documented in a large healthy cohort of term and late-preterm infants.[29]

There are many neonatal disorders in which bedside LUS may have use. The typical ultrasound appearance of pneumothorax and pleural effusions are well established and are essentially the same across age groups.[29-32] The diagnostic characteristics of LUS for neonatal diseases, such as transient tachypnea of the newborn, respiratory distress syndrome, meconium aspiration syndrome, and pneumonia, have been described.[33-35]

Thus point of care LUS will help in diagnosing respiratory diseases in much quicker way & appropriate action can be taken at right time.

4) Bowel Ultrasound (BUS):

The potential for use of bowel ultrasonography (BUS) in the evaluation of paediatric diseased bowel states has been well recognised. Whilst plain abdominal radiography is the gold standard modality for diagnosis, monitoring and guiding management of suspected diseased bowel state in neonates, there is a growing interest in the utility of BUS. The use of BUS in the diagnosis of necrotising enterocolitis (NEC) has steadily increased worldwide over the last 12 years, particularly in the hands of the radiologists.[36] There is compelling evidence demonstrating diagnostic ultrasound findings in NEC correlating with clinical presentation and pathological bowel findings intraoperatively.[37, 38]

Whilst assessment of functional changes in cardiac state, intracranial structural injuries such as intraventricular haemorrhage using point-of-care ultrasound is well established, knowledge of point of-care BUS is a growing area of interest amongst neonatologist.

Identifying gastrointestinal obstruction or perforation presents as critical, time-sensitive scenarios for neonatal clinicians. Also, a common scenario faced by neonatologists is the occurrence of abdominal distension, feed intolerance in preterm infants on respiratory support with continuous positive airway pressure (CPAP) ventilation.

This benign gaseous abdominal distension is called CPAP belly syndrome and often necessities differentiation from life-threatening bowel conditions such as NEC. The use of point-of-care abdominal ultrasound can be a very valuable clinical tool in these scenarios. BUS can enhance diagnostic accuracy of diseased neonatal bowel states in conjunction with clinical assessment and findings from plain abdominal radiography.

5) Central Catheters Ultrasonography:

Central vascular catheters such as umbilical arterial catheters (UAC), umbilical venous catheters (UVC), and peripherally inserted central catheters (PICC) are the most common central catheters placed in the sick neonate. Any neonate born at less than 32 weeks gestation will have at least a UVC and/or a PICC during their admission for nutrition and/or medications. In most units all of these lines are placed blind and confirmed with a single radiograph. UVC tip localization by standard radiography is imprecise. In one study approximately 30% of the radiographs were read as normal but actually had the UVC tip in the right atrium when checked with US. Radiographic localization of UVC on anterior–posterior (AP) is difficult to place in ideal position because of the doming of the diaphragm. The lateral chest radiograph is better than the AP view of the chest but this view is not as convenient with the infant typically secured down for the procedure.

Ultrasound more accurately confirms the position of the catheter tip than radiographs and reduces the exposure of ionizing radiation. Ultrasound guidance results in faster placement and fewer manipulations and radiographs for both umbilical catheters and PICC as compared with conventional placement. POCUS can be very useful in localizing the tip of central catheters either during placement or after a catheter has been placed to follow any migration. Umbilical catheters can frequently migrate after placement in the first few days after insertion. This may be due to drying and shrinkage of a longer umbilical cord. POCUS allows for the direct visualization of the umbilical and PICC catheters and their tips and indirect visualization of the UVC in the hepatic portion of the catheter pathway where it is localized by the shadow cast by the catheter.[4] Ultrasound may be able to help guide the catheter and thereby reduce complications during UVC, UAC, or PICC insertion. Doppler ultrasound is also useful to examine the aorta and renal vessels when placing or evaluating a UAC.[8]

6) Bladder ultrasonography:

Bladder aspiration through suprapubic urine collection is ideal to perform under ultrasound guidance over landmark techniques. Ultrasound of the bladder can help determine the size and location of the bladder and the volume of urine in the bladder. Portable ultrasound can significantly improve the diagnostic yield; a minimum volume on ultrasound of 10 mL is associated with a 90% successful bladder aspiration. If the cephalocaudal diameter of the bladder (sagittal view) is >20 mm and the anteroposterior diameter is >15 mm, the success rate approaches 100%.

7) Endotracheal tube localization:

Endotracheal intubation is a common procedure in neonatal intensive care unit (NICU) and in delivery room. Correct placement in trachea and correct level of endotracheal tube (ET) tip is of paramount importance in emergency as well as elective conditions. Clinical methods, end-tidal carbon-di-oxide (ETCO2) monitor and chest radiography has been used to identify correct intubation.[39] Clinical findings such as direct visualisation of passage of tube through glottis, rising heart rate, improving oxygen saturation and improvement in colour suggest tracheal intubation but are prone to errors.[40-43] ETCO2 measurement in preterm and term neonates has been recommended to confirm tracheal intubation. However, ETCO2 measurement does not inform the healthcare personnel about the depth of ET insertion. Chest radiograph is considered as a gold standard investigation for determining level of the ET tip but has radiation hazard, involves handling of the neonate, and has high turnaround time.

There is evidence in adult literature about the use of ultrasonography (US) for confirming ET tip but it has not been studied adequately in neonatal and paediatric population.

There are few studies of ET localization in newborn and paediatric population. Slovis, et al.[44] used 5-8 MHz probe in neonates and encountered no difficulty in identifying ET tip and related anatomical structures. They also correlated the distance from ET tip to aortic arch and concluded that the ET tip more than 1 cm above aortic arch was optimum. Lingle[45] also used arch of aorta as a landmark during US with 5 MHz probe and ET tip was considered in low position if the tip was located below the superior margin of arch of aorta and high position if the tip is located above the superior border of manubrium sternum assessed by shadow from the tin foil.

Conclusion:

Existing and emerging POCUS applications are numerous and promising but more validation for clinical value is required in addition to larger scale training of individuals to learn and become competent in these techniques. Emphasis should be on training all incoming and existing fellows to learn POCUS. Ultrasound-literate clinicians should be able to do this novel standard practice as point of care USG in an acute clinical setting, document it and do appropriate intervention in absence of specialist. As new applications and adoption of point-of-care ultrasound continues to gain acceptance in paediatric and neonatal medicine throughout the world, a rapidly growing body of evidence suggests that the result will be faster, safer and more successful diagnosis and treatment of our patients.

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