Rapid Assessment of the Neonate With Sonography (RANS) Scan

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The use of point-of-care sonography in clinical settings such as emergency medicine and intensive care units has increased, but adoption in neonatology has been slow. Unlike the focused assessment with sonography for trauma scan used in adults, a quick bedside scan to rapidly evaluate an acutely deteriorating neonate does not exist. The objective of our article is to introduce a focused bedside ultrasound scan that is easy to learn, rapidly performed, and relatively inexpensive.

Key Words—neonate; neonatal ICU; point-of-care sonogrpahy; ultrasound

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. Sonography has become a crucial adjunct to the care of neonates in the neonatal intensive care unit (NICU); however, a full appreciation for its diagnostic capabilities in the NICU is lacking.[2] Although sonography has been in medical use since the 1970s, recent technological advancements have afforded improved image quality while reducing the cost and size of ultrasound equipment.[3] As a result, the use of point-of-care sonography in clinical settings such as emergency medicine and intensive care units has increased,[4] but adoption of point-of-care sonography in neonatology has been slow.[5] Akin to the focused assessment with sonography for trauma scan[6,7] utilized in adults, a focused scan to assess an acutely deteriorating neonate is not available as yet. Such a regimen could have a significant impact on rapid diagnosis and intervention in the neonatal patient population.

Obstacles for Adoption of Bedside Sonography in Neonatology

Several impediments for the adoption of point-of-care sonography in the NICU have been identified. A recent survey of neonatal-perinatal medicine and pediatric critical care medicine fellowship programs across the United States suggested that the lack of ultrasound equipment and funding sources were significant obstacles.[8] Another major barrier identified in this study was the lack of trained ultrasound personnel to instruct fellows and faculty in ultrasound scanning techniques. Somewhat surprisingly, legal concerns over point-of-care sonography in the NICU was not a chief

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We would like to acknowledge the parents who allowed us to perform sonography on their neonates in the NICU and the nurses who assisted in positioning the neonates when we were performing the sonography on their patients.

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concern, which is consistent with a recent analysis of a noteworthy legal database in the United States that suggested point-of-care sonography use and interpretation is not a substantial source of lawsuits against neonatologists and pediatric subspecialists.[9]

Need for Point of Care Sonography in Neonatology

Despite these 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.[4,10] 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.[4,10] 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.[5] However, a formal point-of-care sonography scanning regimen for bedside sonography to rapidly diagnose acute life-threatening conditions in the neonate has not been developed. The purpose of this report is to propose a simple and effective point-of-care sonography scanning algorithm that can be used with accuracy and reproducibility by clinicians in the NICU.

Rapid Assessment of the Neonate With Sonography Scan—Collaboration, Inception, and Creation

In developing a curriculum to train clinicians in the use of bedside point-of-care sonography in the NICU, the Division of Neonatology partnered with the Center for Ultrasound Education and Department of Emergency Medicine at Augusta University, with the latter 2 departments having significant experience in bedside sonography. The goal was to develop a rapid scan for the assessment of acute life-threatening conditions in the neonate in the NICU. For the implementation of this rapid scan, the team proposed that this regimen should possess 3 essential characteristics.

First, the neonatal point-of-care sonography scanning regimen should be simple and easy to teach to personnel who have a novice level of ultrasound experience. Second, it should have the ability to be performed in a timely fashion to detect acute conditions and enhance therapeutic decision making. Third, the ultrasound equipment needed for scanning should be relatively inexpensive. For development of the scanning regimen, a pediatric abdominal probe (C 8-5 probe; Philips Healthcare, Bothell, WA) and ultrasound system (CX–50, Philips Healthcare) were utilized. Our goal in creating the rapid assessment of the neonate with sonography (RANS) scan was to balance being able to assess multiple organ systems as well as keep the number of probes necessary to a minimum. From our review of literature, one of the stated barriers to implementation of sonography in NICU was cost. More probes would translate to a higher cost and reduced chance of implementation.[8] In addition, the image quality was better with the abdominal probe compared to the sector probe. By using the curvilinear probe, we wanted to steer away from any potential of extending into functional echocardiography, which is much more complex and potentially could create conflict with pediatric cardiology. We used the abdominal preset for our images.

The next step of the process was to decide on the ultrasound components in the rapid bedside assessment of the neonate. These components included clinical conditions where prompt detection would definitively impact the outcome of critically ill neonates. The components of the regimen focus on pericardial effusion, visualization of central venous lines, presence of air or fluid in the thoracic cavity, and severe intraventricular hemorrhage. We named this ultrasound scanning regimen, the rapid assessment of the neonate with sonography (RANS) scan.

Finally, images of the RANS scan were obtained on multiple neonatal patients to assess the usefulness of the technique and to estimate the amount of time that would be needed to complete the scan. Because this project involved only the documentation of the scanning regimen and did not involve research on human subjects, it was classified as an "exempt study" by the Institutional Review Board at our university. However, we obtained a signed informed consent prior to scanning, from the parents of the neonates who were imaged and photographed for the project.

All identifiable patient information was excluded from the ultrasound images and photographs.

Components of the Rapid Assessment of the Neonate With Sonography Scan

A detailed description of (1) the utility of each view, (2) how to acquire the ultrasound images, (3) the identification of anatomic landmarks that should be included in each image, and (4) the positive/negative findings for each view are presented below. The recommended algorithm is represented in Figure 1.

Rapid Assessment of Pericardial Effusion

Although infrequent, pericardial effusion with cardiac tamponade can present acutely and can be fatal in the critical neonate if identification and intervention is delayed. These patients often present with rapid onset of bradycardia, respiratory distress, hypotension, thready pulses, and muffled heart sounds. A chest radiograph and formal echocardiogram are the current procedures for diagnosis, but obtaining them consumes valuable time and may delay treatment.

As shown in Figure 2, the heart is viewed from the subxiphoid position to document the presence or absence of a pericardial effusion. The probe is placed inferior to the xiphoid process of the sternum with the marker directed toward the patient's right and angled 30 degrees toward the patient's head (Figure 2A). On the ultrasound image, the anechoic structure closest to the liver is identified as the right ventricle (Figure 2B). The hyperechoic outline of the heart is identified as the pericardial sac, shown with a dotted line (Figure 2B). A pericardial effusion will be seen between the heart and the pericardial sac as an anechoic area. Figure 2C demonstrates a mild pericardial effusion that is denoted with an asterisk. In the case of severe/clinically relevant pericardial effusion, the previously noted anechoic area will expand significantly.

Rapid Location of Venous Catheters

The second component of the RANS scan is to image the proper placement of an umbilical venous catheter or a peripherally inserted central catheter. If the tip of the catheter is malpositioned and undetected, neonates can develop arrhythmias (ie, supraventricular tachycardia) and pericardial effusion as described previously.

To visualize the inferior vena cava (Figure 3), the probe is placed inferior to the xiphoid process of the sternum with the marker directed toward the patient's head. The probe is held at a 90-degree angle to the longitudinal axis of the patient. The probe is angled slightly toward the patient's right to visualize the

Figure 1. Recommended algorithm for RANS scan.*Abnormal vital signs include bradycardia, arrhythmias, worsening respiratory distress, hypoxia, hypotension, weak pulses.

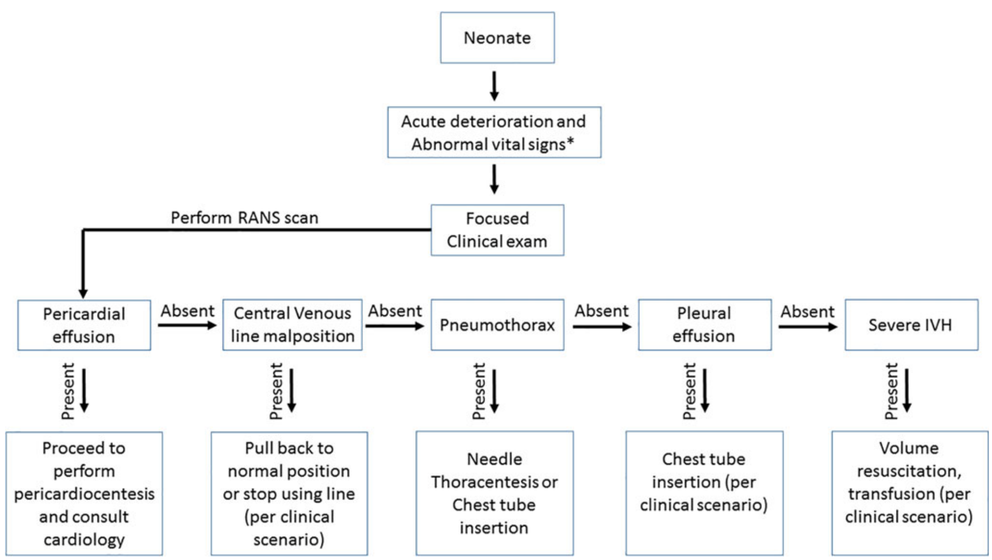


Figure 2. Rapid detection of pericardial effusion. **A**, Probe placed in the subxiphoid position with marker (star) toward the patient's right and angled 30 degrees toward the patient's head. **B**, Normal ultrasound image showing subxiphoid view of the heart with right ventricle (RV) seen closest to the liver. Dotted line represents the hyperechoic pericardial sac. **C**, Ultrasound image showing subxiphoid view of the heart with right ventricle (RV) seen closest to the liver. Mild pericardial effusion seen between the liver and RV seen as an anechoic area (*).

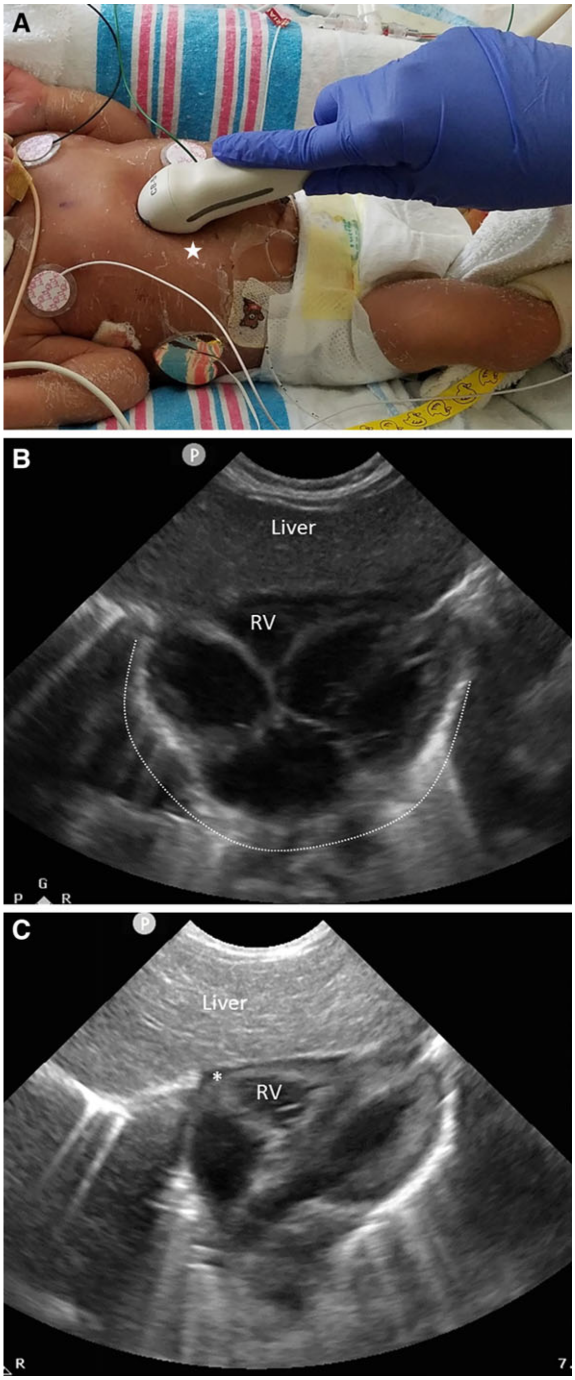
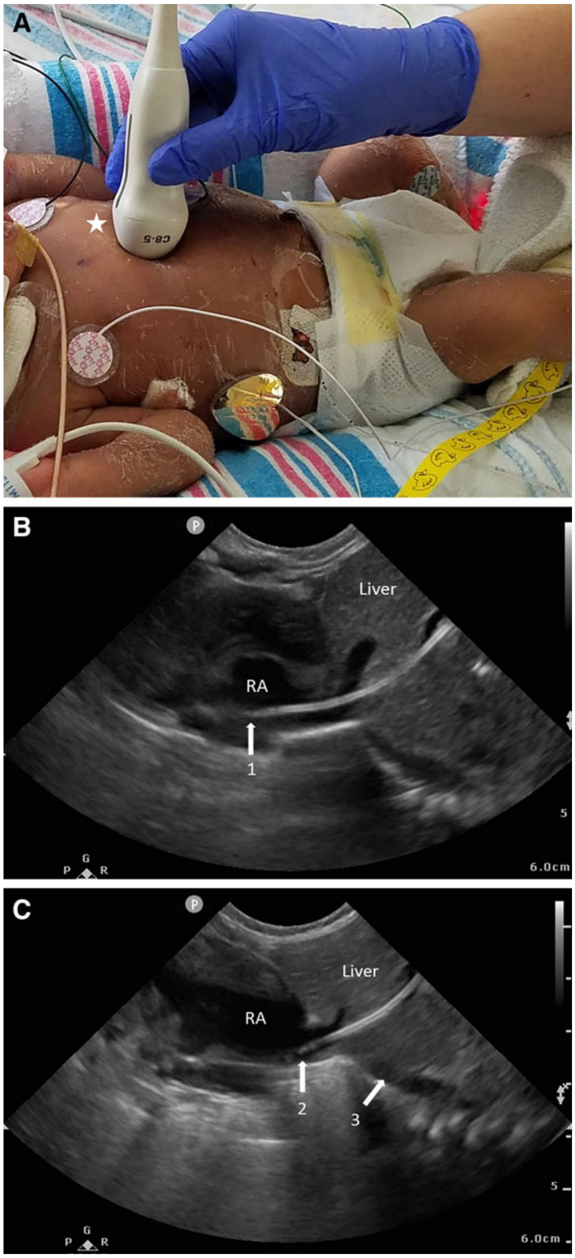


Figure 3. Rapid location of venous catheters. **A**, Probe placed in the subxiphoid position with marker (star) toward the patient's head and held at a 90-degree angle to patient's longitudinal axis. The probe is angled slightly toward the patient's right to visualize the inferior vena cava (IVC). **B**, Ultrasound image demonstrating the liver and right atrium (RA) with the umbilical venous catheter whose tip is deep in the RA (1). **C**, Ultrasound image demonstrating the liver and RA with the umbilical venous catheter whose tip has been pulled to be at the cavoatrial junction (2). Also seen is the IVC (3).



normal anatomic position of the inferior vena cava to the right of the aorta (Figure 3A). On the ultrasound image, the umbilical venous catheter is seen as a linear, hyperechoic structure with its tip deep in the right atrium (Figure 3B). In the subsequent image, the umbilical venous catheter has been retracted so that the tip is seen at the junction of the inferior vena cava and right atrium (Figure 3C).

Rapid Detection of Air in Pleural Space

The next segment of the RANS scan examines the thorax for the presence of air in the pleural space. Pneumothorax often presents with respiratory distress, hypoxia, irregularities of vital signs, and reduced breath sounds on the affected side. In the setting of a tension pneumothorax, hemodynamic compromise and rapid deterioration in the critically ill neonate may occur. Transillumination is unreliable in extremely premature neonates. A chest radiograph, which is the cornerstone in detection of pneumothorax, may not be obtained in a timely fashion and involves radiation. To detect air in the pleural space (Figure 4), begin with the probe placed in the midclavicular line on the side of interest with the marker directed toward the patient's head (Figure 4A). Because most neonates are positioned supine in the incubator, air rises to the surface. To image the lung-pleura interface, a shallow ultrasound beam depth is required because this interface is very superficial. By moving the probe along the midclavicular line, the normal findings of the lung-pleura interface can be visualized to include A-lines and the presence of the sliding lung sign. A-lines are horizontal, regularly spaced, hyperechoic lines that represent reverberations of the pleura (Figure 4B). The sonographic appearance of the sliding lung sign represents the sliding between the visceral and parietal layers of pleura, which is a normal finding. On sonography, the sliding lung sign is seen as a shimmering effect as the lung expansion creates a sliding movement between the layers of pleura (Figure 4C). In the chest, the presence of the sliding lung sign rules out a pneumothorax. In the left chest, the inability to visualize the beating heart beneath the pleural surface should raise concern for a pneumothorax.

Rapid Detection of Fluid in Pleural Space

Similar to the identification of air in the pleural space, the RANS scan can also be used to detect fluid in the pleural space. Similar to a pneumothorax, pleural effusions can present with respiratory distress, hypoxia, and reduced breath sounds on the affected side. To image free fluid in the pleural space, it is important to note that fluid is heavier than air and it sinks to the dependent areas of the chest. Therefore, in this view (Figure 5), the probe will be placed in the midaxillary line at the level of the diaphragm with the marker directed toward the patient's head either on the right side of the patient (to image the liver-diaphragm interface) or left side of the patient (to image the spleen-diaphragm interface) (Figure 5A). Under normal circumstances, the lung, diaphragm, liver (or spleen on the left side), and kidney will be visualized (Figure 5B). The diaphragm can be seen as an echogenic, curvilinear line between the lung and liver or spleen. In the absence of fluid in the pleural space, the vertebral processes are visualized in the abdomen but disappear at the level of diaphragm. In the presence of free fluid in the pleural space, which transmits the ultrasound beam, the spine will be visualized superior to the diaphragm as well, which is called the spine sign (Figure 5C).

Rapid Recognition of Severe Intraventricular Hemorrhage

The last component of the RANS scan assesses the neonatal brain for severe intraventricular hemorrhage (IVH). Severe IVH (Grade III and Grade IV bleeds) can be the source of excessive blood loss and metabolic acidosis, especially in extremely low-birth-weight infants. Detection of severe IVH as an etiology aids in the management of critically ill neonates by enabling care providers to enact appropriate medical therapies for this condition in a timely fashion.

For this view (Figure 6), the probe is placed on the anterior fontanel of the neonate with the marker pointing toward the patient's right side or right ear (Figure 6A). The probe is angled anteriorly toward the patient's nose to visualize the frontal horns of the lateral ventricles (Figure 6B) in a coronal section. Once the frontal horns of the lateral ventricles are visualized, the probe is fanned posteriorly toward the back of the head to completely image the remaining portion of the ventricles. We have termed this view the *butterfly view*. In the subsequent image, we see a coronal section of the neonatal brain showing a Grade IV bleed on the right side and Grade III bleed on the left side (Figure 6C).

Lessons Learned—Need for Formal Curriculum, Credentialing Guidelines, and Collaboration

Point-of-care sonography at the bedside represents a valuable yet underutilized diagnostic tool for

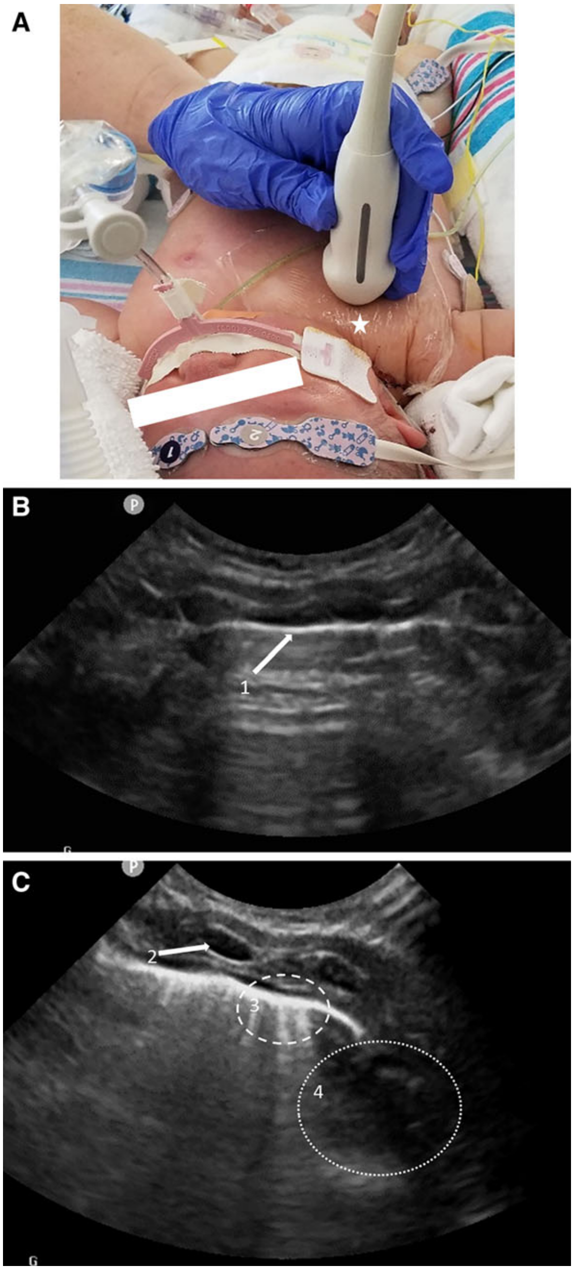
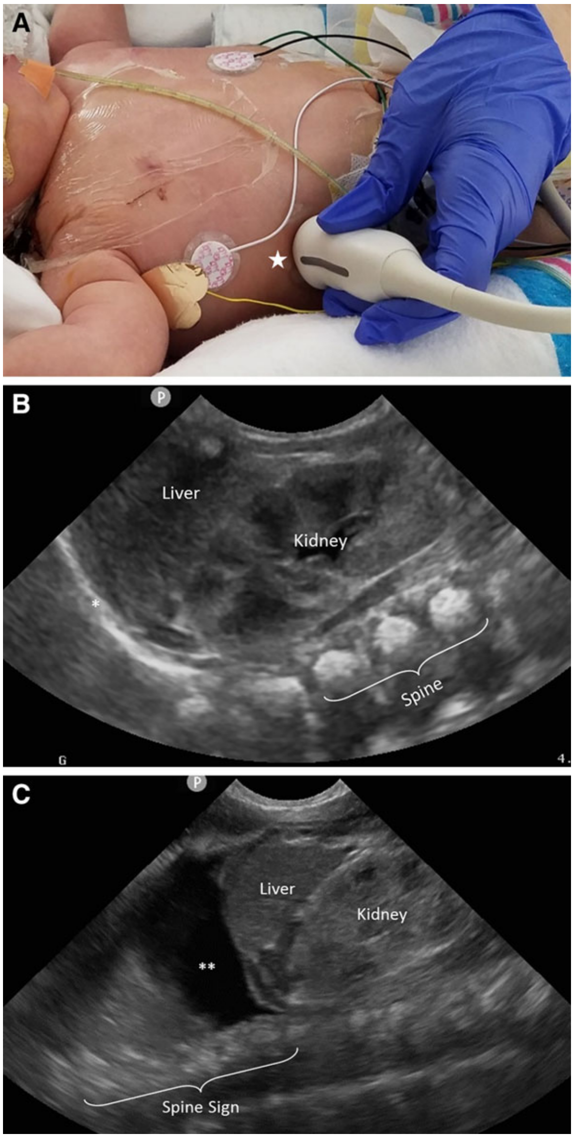


Figure 4. Rapid detection of air in pleural space. **A**, Probe placed in the midclavicular line on the side of interest with marker (star) directed to patient's head. **B**, Normal ultrasound appearance of A-lines (1), which appear as horizontal, regularly spaced, hyperechoic lines due to reverberations of the pleura. **C**, Sonography of the left lung showing the sliding lung sign with a shimmering effect (3). Also seen are the ribs (2) and the heart (4). On the right chest, the presence of the sliding lung sign rules out a pneumothorax, but on the left chest, the absence of the heart raises suspicion for pneumothorax.

clinicians and care teams in the NICU. There is growing evidence of the utility of point-of-care sonography to reduce procedure time, and to diagnose and begin intervention in acute processes in pediatric emergency medicine (PEM), pediatric critical care medicine, and neonatal-perinatal medicine.[4,11–15] The

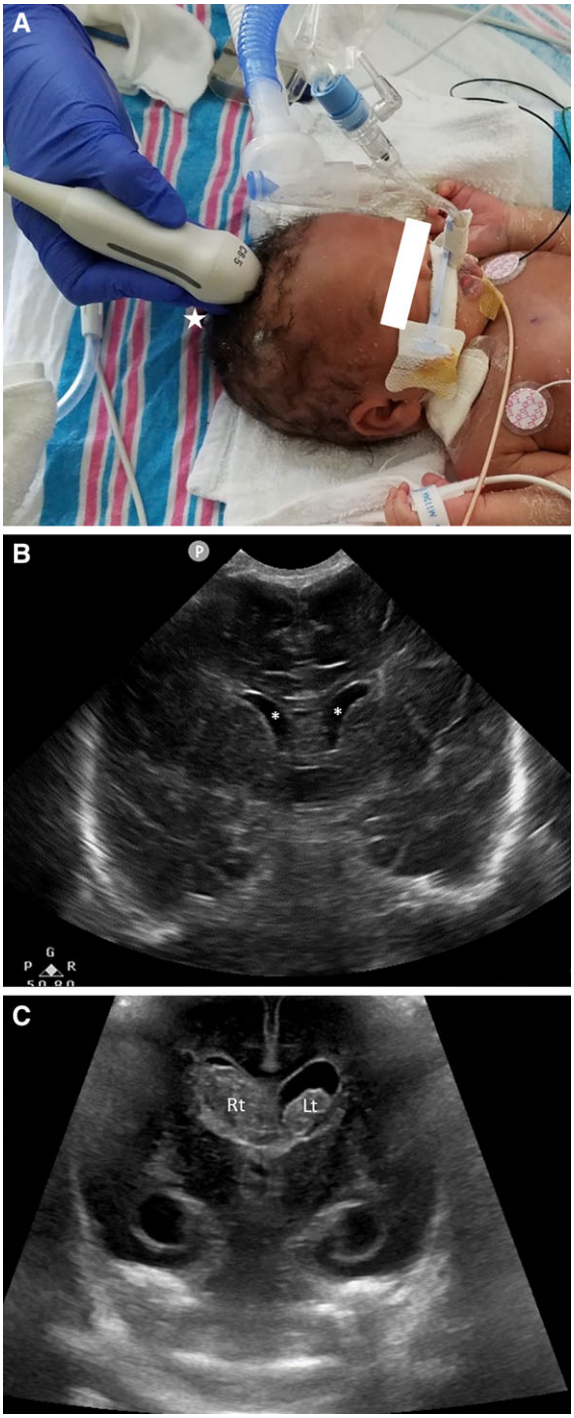
Figure 5. Rapid detection of fluid in the pleural space. A, Probe placed in the midaxillary line with marker (star) directed toward patient's head. **B**, Normal patient with no fluid in pleural space. Diaphragm (*), liver, kidney, and spine are seen. Note that we cannot visualize the spine proximal to the diaphragm. **C**, Ultrasound revealing free fluid in pleural space as indicated by the anechoic area (**) above the diaphragm. In addition, the vertebral processes are visualized proximal to the diaphragm, which is called the spine sign.



utilization rate and creation of a definitive curriculum, however, has been more pronounced in PEM. The American Academy of Pediatrics acknowledged point-of-care sonography use and training in PEM and recently published the first guidelines for point-of-care sonography implementation by PEM physicians in July 2015.[16,17] While comprehensive expertise in the use of point-of-care sonography requires dedicated training often spanning months, recent studies have demonstrated that the use of an objective-driven ultrasound curriculum can be used to effectively train clinicians in clinically relevant point-of-care sonography in a relatively short time.[18–21]

Currently, published guidelines on accreditation of the neonatologist for targeted neonatal echocardiogram exist,[22,23] but these guidelines are cumbersome

Figure 6. Rapid detection of severe intraventricular hemorrhage. A, Probe placed in the anterior fontanel with marker (star) to the patient's right or right ear. **B**, Normal ultrasound image of coronal section of neonatal brain demonstrating the lateral ventricles (*) or butterfly view. **C**, Ultrasound image of coronal section of neonatal brain demonstrating intraventricular bleed filling the entire lateral ventricle and invading parenchyma on right side (Rt) (Grade 4 IVH) and filling almost 50% of ventricle with dilation on left side (Lt) (Grade 3 IVH).



and challenging to attain for the general neonatal clinician. Unfortunately, no accreditation guidelines exist for point-of-care sonography implementation and training in neonatology. We believe that the applications of point-of-care sonography are many and that there are multiple opportunities to improve neonatal care through the use of point-of-care sonography. Building upon the RANS scan, accreditation guidelines can be created through valuable collaborations with other specialties such as emergency medicine, radiology, and cardiology, which can provide guidance and quality assurance.

Conclusion

Point-of-care sonography is increasingly present in graduate medical school curriculums, and the adoption of bedside sonography in other pediatric subspecialties has proven effective.[24] The RANS scan represents the first formal point-of-care sonography scanning algorithm for rapid assessment of pericardial effusion, visualization of central venous lines, presence of air or fluid in the thoracic cavity, and severe intraventricular hemorrhage in the critical neonate.

The RANS scan is intended only to complement the clinical assessment; it is not a substitute for clinical examination or formal evaluation of a neonate by radiologists or cardiologists. Instead, we present an approach and outline a protocol that may be implemented by neonatal providers to enable the use of bedside sonography for the rapid detection of life-threatening conditions, which may improve time to intervention and outcomes for this population. Detecting these conditions in a timely manner, avoiding exposure to radiation, and overall improvement of quality of care are some of the advantages compared to radiographs.

We believe that point-of-care sonography training for the neonatal provider should be a tiered approach. The RANS scan represents a basic approach that we have labeled as tier 1 training. We acknowledge that the RANS scan in the current form is a road map for addressing an acutely deteriorating neonate. Further studies are needed to validate our approach, including reproducibility, diagnostic accuracy, improvement of skill acquisition, and development of criteria for credentialing. Current efforts at our institution are focused on formalized training for neonatal faculty, fellows, and nurse practitioners in the use and implementation of the RANS scan. Future directions include development of expertise in using sonography for complex procedures such as placement of central lines, peripheral arterial catheter, endotracheal tube position, and assessment of fluid status in the critical neonate.

References

1. Philip AGS. The evolution of neonatology. *Pediatr Res* 2005; 58: 799–815.
2. Allan WC, Roveto CA, Sawyer LR, Courtney SE. Sector scan ultrasound imaging through the anterior fontanelle: its use in diagnosing neonatal periventricular/intraventricular hemorrhage. *Am J Dis Child* 1980; 134:1028–1031.
3. Evans N, Gournay V, Cabanas F et al. Point-of-care ultrasound in the neonatal intensive care unit: international perspectives. *Semin Fetal Neonatal Med* 2011; 16:61–68.
4. Srinivasan S, Cornell TT. Bedside ultrasound in pediatric critical care: a review. *Pediatr Crit Care Med* 2011; 12:667–674.
5. Nguyen J. Call for point-of-care ultrasound training regimens in neonatal-perinatal medicine. *J Pediatr* 2017;185:254.
6. Rozycki GS, Ochsner MG, Jaffin JH, Champion HR. Prospective evaluation of surgeons' use of ultrasound in the evaluation of trauma patients. *J Trauma* 1993; 24:516–527.
7. Rozycki GS, Ochsner MG, Schmidt JA et al. A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. *J Trauma* 1995; 39:492–500.
8. Nguyen J, Amirnovin R, Ramanathan R, Noori S. The state of point-of-care ultrasonography use and training in neonatal-perinatal medicine and pediatric critical care medicine fellowship programs. *J Perinatol* 2016; 36:972–976.
9. Nguyen J, Cascione M, Noori S. Analysis of lawsuits related to point-of-care ultrasonography in neonatology and pediatric subspecialties. *J Perinatol* 2016; 36:784–786.
10. Lambert RL, Boker JR, Maffei FA. National survey of bedside ultrasound use in pediatric critical care. *Pediatr Crit Care Med* 2011; 12:655–659.
11. McLario DJ, Sivitz AB. Point-of-care ultrasound in pediatric clinical care. *JAMA Pediatr* 2015; 169:594–597.
12. Nguyen J. Ultrasonography for central catheter placement in the neonatal intensive care unit—a review of utility and practicality. *Am J Perinatol* 2016; 33:525–530.
13. Levy JA, Noble VE. Bedside ultrasound in pediatric emergency medicine. *Pediatrics* 2008; 121:e1404–e1412.

14. El-Khuffash AF, McNamara PJ. Neonatologist-performed functional echocardiography in the neonatal intensive care unit. *Semin Fetal Neonatal Med* 2011; 16:50–60.
15. Wyllie J. Neonatal echocardiography. *Semin Fetal Neonatal Med* 2015; 20:173–180.
16. Marin JR, Lewiss RE. American Academy of Pediatrics, Committee on Pediatric Emergency Medicine, Society for Academic Emergency Medicine, Academy of Emergency Ultrasound, American College of Emergency Physicians, Pediatric Emergency Medicine Committee, World Interactive Network Focused on Critical Ultrasound. Point-of-care ultrasonography by pediatric emergency medicine physicians. *Pediatrics* 2015; 135:e1113–e1122.
17. Marin JR, Abo AM, Doniger SJ, et al. Point-of-care ultrasonography by pediatric emergency physicians. *Ann Emerg Med* 2015; 65: 472–478.
18. Pershad J, Myers S, Plouman C et al. Bedside limited echocardiography by the emergency physician is accurate during evaluation of the critically ill patient. *Pediatrics* 2004; 114:e667–e671.
19. Longjohn M, Pershad J. Point-of-care echocardiography by pediatric emergency physicians. *Clin Pediatr Emerg Med* 2011; 12:37–42.
20. Spurney CF, Sable CA, Berger JT, Martin GR. Use of a hand-carried ultrasound device by critical care physicians for the diagnosis of pericardial effusions, decreased cardiac function, and left ventricular enlargement in pediatric patients. *J Am Soc Echocardiogr* 2005; 18:313–319.
21. Dinh VA, Chrissian AA, Giri PC et al. Impact of a 2-day critical care ultrasound course during fellowship training: a pilot study. *Crit Care Res Pract* 2015; 2015:1–8.
22. Mertens L, Seri I, Marek J et al. Targeted neonatal echocardiography in the neonatal intensive care unit: practice guidelines and recommendations for training: writing group of the American Society of Echocardiography (ASE) in collaboration with the European Association of Echocardiography (EAE) and the Association for European Pediatric Cardiologists (AEPC). *Eur J Echocardiogr* 2011; 12:715–736.
23. Singh Y, Gupta S, Groves AM et al. Expert consensus statement "Neonatologist-performed Echocardiography (NoPE)"—training and accreditation in UK. *Eur J Pediatr* 2015; 175:281–287.
24. Hoppmann RA, Rao VV, Bell, F. The evolution of an integrated ultrasound curriculum (iUSC) for medical students: 9-year experience. *Crit Ultrasound J* 2015; 7:18.