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Original Research

Neonatal Transport Clinician Performed Ultrasound Evaluation of Cardiac Function

Amelie Stritzke, MD, FRCPC, FMH(Swiss) [1,2,*],
Amuchou Soraisham, MD, DNB, MSc, FRCPC, FAAP [1,2],
Prashanth Murthy, MBBS, MD, MSc, FRCPCH(UK), FRCP(Edin) [1,3], Derek Kowal, RRT [2],
Renee Paul, RN, MN, NP-BC [2], Majeeda Kamaluddeen, MD, MRCP, FAAP [1,2],
Khorshid Mohammad, MD, MSc, FABP [1,4],
Essa Hamdan Al Awad, MD, DCH, FABP, FSBP, FRCP(Edin) [1,5],
Sumesh Thomas, MBBS, DCH, FRCP(Edin), FRCPCH(UK), FRCPC [1,2]

[1] *Department of Pediatrics, Section of Neonatology, University of Calgary, Cumming School of Medicine, Calgary, Alberta, Canada*
[2] *Foothills Medical Centre, Calgary, Alberta, Canada*
[3] *Rockyview General Hospital, Calgary, Alberta, Canada*
[4] *Alberta Children's Hospital/Research Institute, Calgary, Alberta, Canada*
[5] *Peter Lougheed Medical Centre, Calgary, Alberta, Canada*

ABSTRACT

Background: Limited point-of-care ultrasound skills for ultrasound-naïve neonatal transport clinicians could enhance clinical evaluation and decision making. Teaching Respiratory Therapists and Nurses to assess cardiac filling and contractility may be feasible.
Methods: Prospective educational study using educational materials, didactic theoretical, and hands-on practical sessions, followed by assessment of practical and theoretical skills.
Results: A total of 18 participants completed the study meeting the predefined standard, proving feasibility. Nine (50%) participants had ≤ 10 years of NICU experience. The mean time required for complete training was 8.6 ± 2.1 hours. Time was spent on average on 269 ± 104 minutes for hands-on practice, 171 ± 96 minutes on didactic training, and 76 ± 16 minutes on testing sessions. The median number of hands-on sessions per participant was 5 [Interquartile range (IQR) 5, 7]. The median number of infants required to complete training was 9 infants (IQR 7, 11). RRTs required less time than RNs. Evaluations and feedback from participants on the training program was positive.
Conclusion: Neonatal RNs and RTs can be trained to perform focused cardiac ultrasound examinations with average time of 8.6 hours. This skill could enhance clinical care on neonatal transport with appropriate interventions to manage suspected hypotension or shock.

Ultrasound as a clinical tool for emergency assessment of targeted clinical questions in the hands of nonradiology clinicians includes focused assessment with sonography in trauma, rapid ultrasound for shock and hypotension, and bedside limited echocardiography by emergency physicians.[1-3] The introduction of point-of-care ultrasound into bedside management represented a similar step to extending health care providers' access to information to support clinical decision making as was the introduction of the stethoscope to medicine 200 years ago.[4] The American Institute of Ultrasound in Medicine stated that the concept of an "ultrasound stethoscope" is moving toward reality.[5]

Several studies have shown the superiority of diagnostic bedside ultrasonography with physical examination compared with physical examination only.[6,7] Medical students receiving 18 hours of training

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* Address for correspondence: Amelie Stritzke, MD, FRCPC, FMH(Swiss), Department of Pediatrics, Section of Neonatology, University of Calgary, 780, 1403 29 St NW, Calgary, AB T2N2T9
E-mail address: amelie.stritzke@albertahealthservices.ca (A. Stritzke).

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were able to identify 75% of major cardiac pathologies compared with 49% identified on physical examination by a cardiologist.[5] Ventricular function assessment by emergency room physicians using bedside limited echocardiography was comparable with pediatric cardiology ($r = 0.78$).[3] The most basic yet pivotal assessment by point-of-care ultrasound in a pediatric emergency setting is for pericardial tamponade, cardiac function and filling, and differentiation of pulseless electrical activity from asystole. Furthermore, ultrasonographic evaluation in hypotension before fluid resuscitation helped ascertain individuals with an increased need for volume.[3]

The neonate is ideally suited for the use of diagnostic ultrasound because of a small body size, cartilaginous bones, and high water content. The structures to be examined are rarely more than a few centimeters deep. Bedside ultrasound in the neonatal intensive care unit (NICU) is routinely used to help guide management of patent ductus arteriosus, pulmonary hypertension, arterial hypotension, fluid therapy in resuscitation and shock, and line placement.[8-10] These applications are part of the sonographic clinical assessment in the neonate curriculum in Calgary.[11]

Education in point-of-care ultrasound has been developed as a competency-based skill for adult learners, not only physicians but also allied health personnel, such as paramedics and critical care providers. Ultrasound training has been incorporated into pediatric curricula, with the Royal College of Physician and Surgeons of Canada expected to incorporate this skill in their new competency by design curriculum.[1,12] A skill, defined as an ability or proficiency to perform a task, may be acquired and developed through learning experiences or training.[13] Courses have didactic and technical components with demonstration and hands-on training with individualized interactive case analysis and discussion.

The Southern Alberta Neonatal Transport Service based at the Foothills Medical Centre in Calgary, Canada, provides transport for approximately 500 neonates annually. The transport team consists of transport clinicians who are either registered transport nurses (RTNs) or registered respiratory therapists (RRTs) with specialist training and experience in neonatal care working under medical directives of a neonatologist on call. The function of the team includes attending high-risk deliveries in centers without neonatal care facilities, stabilization, and retrieval of sick neonates requiring higher levels of care than locally available.

The availability of handheld, portable ultrasound devices offers ideal clinical applicability for neonatal transport clinicians. This could enhance the care of sick neonates by targeted interventions and the avoidance of potentially detrimental interventions (eg, the use of fluid boluses in the presence of poor myocardial contractility or, conversely, the early use of inotropes in an underfilled circulatory system in clinical hypotension).

Our approach commenced from the following pertinent clinical question: In the setting of neonatal hypotension or poor perfusion where the clinician might be conventionally inclined to give volume, what is the cardiac contractility and filling? The aim of this study was to evaluate the feasibility and duration of training required for neonatal transport clinicians to rapidly and reliably acquire images and identify poor cardiac function and filling in a neonate with presumed normal cardiac anatomy. We hypothesized that a structured training module would be sufficient for a specialist group of health care providers who did not have any previous exposure to ultrasound to acquire the practical and cognitive skills to assess cardiac contractility and filling in neonatal patients.

Methods

The 39-bed level III NICU at the Foothills Medical Centre in Calgary admits 1,100 infants between 22 weeks to term annually. There is an established point-of-care ultrasound program with 7 neonatologists trained in bedside ultrasound (sonographic clinical assessment in the neonate). After the identification and signed consent of transport clinician volunteers, a curriculum (Table 1) with proposed timelines was disseminated. With an emphasis on self-directed learning, a mix of learning methods was used, including an offer of self-directed reading materials and online resources, didactic local theoretical sessions, and individualized hands-on training sessions. All sessions occurred at the NICU on a flexibility basis at natural clinical downtimes; no dedicated paid extra time was given. All participants were provided didactic hands-on training sessions using stable neonates in the NICU after parental consent.

We adopted our approach to teach health care professionals based on sound learning principles that have been previously described.[14] The target skill was simplified to a single view (the cardiac 4-chamber view) with learning of typical signs of underfilling or poor contractility such as “kissing of the ventricles”; presence of pericardial effusion, which might impair filling; and successive assessment of different ventricular areas’ contractility by covering other areas.[15] We focused initially on cognitive learning with a reversed classroom approach followed by psychomotor learning with a combination of these 2 components thereafter, which resulted in participants acquiring the ability to perform a skill along with interpretive skills.[16] Participants were provided with targeted learning material that primed them to effectively benefit from a didactic teaching encounter. Then, they were provided with a period of “deliberative practice” with targeted feedback, which has been shown to enhance motor learning.[17] This allowed participants to transition from being uncertain in acquiring and interpreting images to becoming more assured.[18] Repetitive practice and experience trigger multiple central nervous processes that constitute learning, finally resulting in motor memory formation. Participants were also encouraged to interpret images under supervision, thereby developing an internalized 3-dimensional map of the anatomy of the heart. Table 1 outlines the structured didactic modules that were used.

Data collection included details about the number of years of clinical NICU experience of participants before undertaking training, clinical background training (ie, RTN/RRT), and number of supervised examinations per trainee. The total time spent in didactic sessions, self-study, hand-on training sessions, and testing was collected. Course evaluations were taken on a Likert scale from 1 (positive) to 5 (negative) immediately after completion of the assessment.

Throughout training, emphasis was given that this skill should only be applied to the presumed heart of normal cardiac anatomy in the absence of symptoms of congenital heart disease such as murmur or cyanosis. Participants were instructed that if images looked anatomically abnormal, the imaging attempt should be aborted, no clinical decision should be made based on the obtained images, and troubleshooting and proper cardiac assessment should occur.

Sample Size

This was a pilot feasibility study. A convenience sample of 10 was planned, but because of high interest, all members of the Southern Alberta Neonatal Transport Service at the inception time, which was 19, volunteered to be included in this study.

Statistical Analysis

Descriptive statistical analyses were used. The mean, standard deviations, or median with interquartile range (IQR) were used for continuous variables where appropriate.

Confidentiality and Ethics

Participation was voluntary. All information collected was anonymized. NICU patients selected for training were stable neonates with limited other stressful events or deterioration that day. Bedside nurses were employed to help identify suitable candidates. Patient

Table 1
Didactic Modules, Sessions, and Timeline

Phases	Name	Number of Sessions	Timeline
Phase 1	Self-directed learning module: online access to: • Learning resources about basic ultrasound principles, cardiac function assessment, background information about point-of-care ultrasound use, YouTube video link about circulation and normal cardiac anatomy[16,18] • Basic cardiac anatomy and spatial orientation in the chest (PowerPoint [Microsoft, Redmond, WA] presentation) • Resources on how to obtain a cardiac 4-chamber view on ultrasound with orientation to ultrasound probes and machine	Continuous	April 27, 2017-May 15, 2018 (~12 months)
Phase 2	Small group didactic session (1-3 people at a time) • Teaching session on the basics of ultrasound and cardiac anatomy with a heart model • Demonstration of cardiac function on a 4-chamber view • Familiarization with equipment (GE [Boston, MA] Vivid I with 12-MHz vector array transducer) • Question and answer sessions	10	May 29, 2017- July 24, 2017 (~2 months)
Phase 3	Hands-on small group sessions (1-4 people at a time) • Under supervision, candidates obtained images on stable neonates in the NICU • Anatomy was reviewed and direct observation, reproducibility, and interpretation discussed	40	June 6, 2017-April 25, 2018 (~11 months)
Phase 4	Didactic session on pathologic images • Dissemination of select normal and abnormal cine-clip images of cardiac 4-chamber views with solutions. After individual review, discussion and review of findings with preceptor • Differentiation of normal from abnormal	18	July 1, 2017-April 25, 2018 (~10months)
Phase 5	Assessment a. Practical: candidates must be able to obtain acceptable 4-chamber views on 3 babies in the NICU. The examination of each patient was expected to be completed within 2 minutes. • 2 neonatologists trained in ultrasound independently agree on the adequacy of images obtained for interpretation b. Theoretical: candidates must be able to correctly identify 10 study ultrasound clips of cardiac 4-chamber cine loops either as having adequate cardiac function or not (binary). • A candidate should be able to correctly interpret 80% of the clips to be deemed to have achieved the expected cognitive ability.	18	July 4, 2017- May 15, 2018 (~11 months)
End of study	Evaluation of study content by participants Analysis and dissemination of study findings		Staggered July 3, 2017, until May 16, 2018 (~10 months)

NICU = neonatal intensive care unit.

contact was always supervised by a neonatologist after verbal consent was taken from parents to obtain practice images within a maximum of 15 minutes of scanning.

Scans were only performed with agreement with the patients' most responsible physician, in keeping with existing clinical guidelines, Infection Prevention Committee policies, and developmental care recommendations. Institutional Conjoint Health Research Ethics Board approval was granted (REB16-0939). Images obtained during training were never used to direct clinical care; however, significant incidental findings, if any, were shared with the responsible physician. None of the authors declared any conflict of interests.

Results

Nineteen ultrasound-naive neonatal transport clinicians volunteered to participate in this study, 10 RTNs and 9 RRTs. One participant (RRT) failed to complete training because of relocation of employment. Therefore, 18 data sets were available for analysis. Nine participants had $\leq$ 10 years of NICU experience. Participants were identified in March 2017 and given the curriculum (Table 1). Online modules were made and kept available starting April 27, 2017, and the educational interventions took place between May 2017 and May 2018 (12-month period).

Eighteen participants completed the study and met predefined criteria in being able to obtain and interpret images obtained in a focused limited cardiac examination of neonates, proving the feasibility of teaching ultrasound-naive transport clinicians this new skill.

The average time a transport clinician invested in learning this new skill was 516 $\pm$ 131 minutes (equals 8 hours 36 minutes, Fig. 1). This time was broken down on average to 269 $\pm$ 104 minutes for hands-on practice, 171 $\pm$ 96 minutes of didactic training, and 76 $\pm$ 16 minutes of testing sessions (Fig. 2). The didactic sessions were further broken down into initial didactic theory (phase 2) with a mean of 56.4 $\pm$ 11 minutes, self-study with a median of 48 minutes (phase 1, IQR = 10–120), and pathologic clip review with a mean of

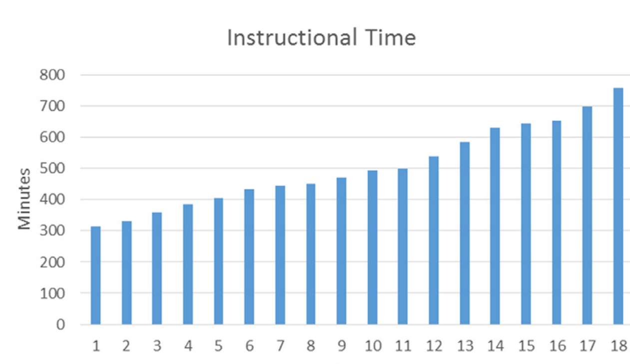

Figure 1. The range of instructional time per trainee.

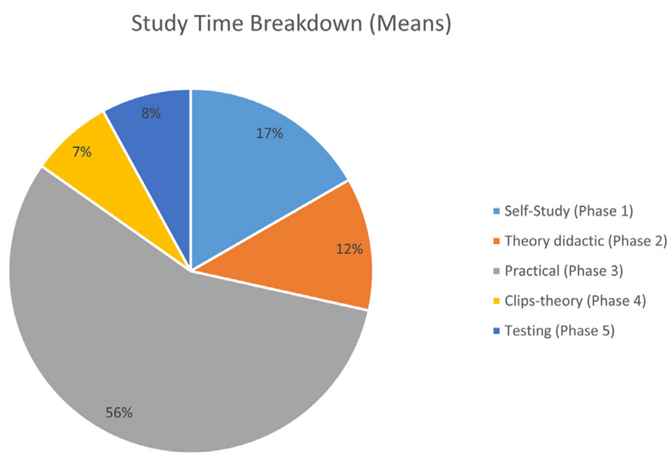

Figure 2. The breakdown of instructional time per designation (averages).

35 ± 10 minutes (phase 4, Fig. 2). The median number of hands-on practical sessions per participant was 5 (IQR = 5–7) with a median of 9 “practice” infants (IQR = 7–11).

From an instructor perspective, the time commitment was different because up to 4 participants attended a session at a time. Excluding the time for preparation and obtaining parental consent, for the main instructor (A.I.S.), the pure instructional time accumulated for theory sessions (phase 2) was 9.25 hours, for hands-on practical sessions (phase 3) it was 32.2 hours, theory in pathologic images (phase 4) was 8.75 hours, and testing was 15.1 hours (phase 5).

We also analyzed the total time of training based on the profession (ie, registered nurse [RN] vs. RRT). The RRTs took a shorter time to complete the course compared with nurses (447 ± 89 vs. 571 ± 126 minutes, $P = .043$). There was no correlation between previous years of NICU experience with the total time needed to complete the training. Clinicians with ≤ 10 years of NICU experience took 481 ± 136 minutes compared with those with > 10 years who took 551 ± 126 minutes ($P = .27$).

The majority of the participants (16/18, 89%) felt that they either strongly agreed or agreed that the course met their expectations and that they would recommend the course to their colleagues. The main positive themes from the participants were thankfulness for opportunity to learn a new skill, hands-on practical sessions, and overcoming with relative ease the apprehension in learning a perceived “difficult skill.” Some participants expressed concerns about retention decay, protracted practice period, and limitations associated with availability and consent to practice the skill on suitable neonates still receiving intensive care treatment.

Discussion

To our knowledge, this is the first study of its kind teaching clinicians without medical school background basics an ultrasound-guided approach to a single important clinical question. We showed it is feasible to train ultrasound-naive neonatal transport clinicians (RNs and RRTs) a targeted sonographic skill in 8.6 hours.

The answer to our clinical question in neonatal hypotension, whether it is a cardiac contractility or filling problem, requires a focused and relevant sonographic skill. After this, our group designed and implemented a systematic and structured training pathway to successfully teach this skill to nonphysician health professionals. By adopting this approach, we were able to show that a complex skill like sonography can be broken down into smaller “bite-size” skills that can be easily adopted, taught, and learned effectively. A complex skill like sonography was “demystified” to an extent.

The curriculum met its intended goal because the adult learner theory shows that better engagement results from training questions relevant to their practice.[19] Basic cognitive skills were learned outside a classroom environment. The self-directed learning phase was self-paced and nonthreatening, which is evidenced by learners’ comments such as “Not overwhelming, as broken down” and “Daunting at first.” Participants acquired competence in their targeted sonographic skill at different time points. There was an unintended positive effect wherein some members acquiring competence sooner became more confident and acted as trainers for some of their counterparts. Additionally, the emphasis on self-directed learning minimized trainer time. Subsequently, the practice time was spent expanding motor skills, creating muscle memory, and consolidating targeted cognitive questions thought through beforehand.

We were surprised to see RRTs needing less time to acquire this new skill than RNs. We can only speculate that RRTs may be more familiar with radiograph image interpretation because they frequently look at chest radiographs and may therefore be more comfortable with an already established systematic interpretation approach. It was interesting to note that the time to acquire the skill was not related to clinical experience. Our study participants constituted a mix of individuals with varying levels of NICU experience (between 5 and 32 years).

Studies have consistently shown that specialized transport teams, irrespective of composition, have improved overall outcomes for neonates requiring transportation.[2] Despite advances in neonatal care, neonates who require transportation after birth have poorer outcomes.[20] Fluid boluses are commonly administered for presumed or suspected hypovolemia and hypotension during the stabilization and transport of newborns. The use of fluid boluses during the first few days of life has been shown to be associated with an increased incidence of bronchopulmonary dysplasia, intraventricular hemorrhages in preterm infants, and adverse neurologic outcome.[21-23]

The initial approach by most clinicians to presumed hypotension in the preterm infant in the absence of echocardiographic evidence to guide therapy is the use of volume replacement.[24] There is no physiologic rationale for this approach and no reliable evidence to support it; most newborn infants who are hypotensive have normal circulating blood volumes in the absence of a clear history of blood loss. In this setting, ultrasound of the heart would allow rapid, real-time, and serial visual assessment of the filling and contractility of the heart by observation of ventricular wall movement and emptying of the cavity, looking for “kissing” of the ventricular walls at end systole.[15] It is anticipated that with acquisition of this skill, neonatal transport clinicians can augment conventional decision-making algorithms to determine the need for appropriate intervention with inotropic support or fluid boluses for neonatal hypotension. This is likely to enhance the care of sick neonates by targeted interventions and avoidance of potentially detrimental interventions.

Successful transfer of learning from a simulated setting to a real clinical setting is the gold standard for successful learning. We aim to study the clinical applicability of this skill in neonatal transport in a clinical setting in a subsequent trial. In planning the next steps, we would ensure that obtaining images will not delay other necessary clinical actions (restricting imaging time to < 5 minutes).

Limitations

Our numbers are small to make deductions of differences for skill acquisition between RRTs and RTNs. Also, the self-reported study time might be subject to recall bias.

Conclusion

RNs and RRTs can be trained to perform and reliably interpret focused cardiac ultrasound examinations to assess cardiac contractility and filling. The average time required for training these personnel was 8.6 hours. This skill could enhance clinical care on neonatal transport with appropriate interventions to manage suspected hypotension or shock.

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