

Training of Ultrasound in Neonatology: Global or Local?

Milan Stanojevic

ABSTRACT

From the beginning of its use in neonatology, ultrasound is used more frequently and for many indications. Number of indications is increasing from year to year, while the training opportunities and curricula are not following the same trend. Nowadays ultrasound has been used for determination of functional hemodynamics in critically sick neonates which increases educational burden on the young neonatologists. This only applies to the developed countries where neonatology is well developed, while in low income so called developing countries some basic health problems of neonates have not been solved and there is substantial lack of health care professionals and equipment as well.

Keywords: Ultrasound, Neonatology, Education.

How to cite this article: Stanojevic M. Training of Ultrasound in Neonatology: Global or Local? *Donald School J Ultrasound Obstet Gynecol* 2013;7(3):338-345.

Source of support: Nil

Conflict of interest: None declared

Global Issues in Neonatal Health: Inequity and Unrecognized Priorities

In many low income countries newborn babies face difficult odds in living past the first month of life. About 3.8 million deaths occur every year in babies younger than 28 days—of which 99% are in the developing world—and deaths in the first month of life account for 42% of deaths in children younger than 5 years.¹⁻⁵

Few countries have reliable national preterm birth prevalence data. Globally, an estimated 13 million babies are born before 37 completed weeks of gestation annually. Rates are generally highest in low- and middle-income countries, and increasing in some middle- and high-income countries, particularly the Americas.⁶ Preterm birth is the leading direct cause of neonatal death (27%); more than 1 million preterm newborns die annually. Preterm birth is also the dominant risk factor for neonatal mortality, particularly for deaths due to infections. Important critical issue is the value put on a baby's life—a newborn baby remains the most vulnerable human and a preterm newborn is even more vulnerable. Data alone will not result in change until society and leaders recognize that these deaths are a loss that can and must count and be prevented.^{6,7} Compared to the year 2000, in the year 2010 more attention has been paid to survival of newborns, which is shown in the Table 1.^{6,8} In the year 2000 there was a lack of data on neonatal health issues, and timely interventions were too complex. In the year 2010 the data are clear and the solutions

are doable.⁷ A recent data on 250,000 disbursements of aid from 2002 to 2010 showed that, before the year 2005, the word 'newborn' barely occurred.⁷ While mention of newborns has since increased, only 0.01% of about 6 billion US dollars in aid refers to newborn care interventions that would reduce infant mortality.⁷ It seems that before the deadline for the Millennium Development Goals, global and national leaders are waking up to the urgency and the opportunity of investing in newborns.⁷ If newborns survive, their families are more likely to choose to have fewer children.⁷ If they are healthy, the nation becomes stronger. Meeting goals for preventable child deaths is more and more dependent on targeting newborns.⁷

Less than 5% of the world's births occur in countries with complete vital registration or networks of representative, facility-based data. One-third of the world's births occur at home.⁶ Therefore, global-level data rely heavily on household surveys and modeled estimates.⁶

While in the high-income countries many health issues of even extremely immature preterm babies have been successfully solved, in low income countries term babies are at great risk for survival because of unavailability of health care including coverage of basic health care needs.

In such circumstances the situation of neonatal health is quite different in low-, middle- and high-income countries which should be taken under consideration when discussing different educational, health care and other needs. Therefore in this paper the training in neonatal ultrasound will be discussed only from the point of view of developed, high-income countries where expensive ultrasound equipment for neonatal assessment is available. Besides the unavailability of the equipment in low-income countries, there is also lack of health care professionals who could use the equipment in order to increase the survival of newborns in whom its' usage is indicated. There are much more basic health care needs in low-income countries which should be solved before introduction of that kind of sophisticated assessment.

Some Important Historical Facts about Neonatal Ultrasound

At the beginning of 1980s, opened anterior fontanelle has been used as an acoustic window for brain assessment of small premature and critically sick newborns.⁹⁻¹³ This was a substantial step forward in neonatal neuroimaging diagnostics.

Table 1: Global attention to newborn survival in the years 2000 and 2010^{6,8}

	Year 2000	Year 2010
<i>Actor power</i>		
Network	Few individuals working on issue and doing so in isolation	Informal network provides global leadership on issue
Guiding institution	No guiding institution for issue	Effective global guiding institution in the form of the saving newborn lives program
<i>Ideas</i>		
Category creation	Neonates are not recognized as a global health category	Neonates are acknowledged as a vulnerable group, although some individuals are skeptical of value of category
<i>Issue characteristics</i>		
Severity	Few global health organizations acknowledge severity of problem	Severity of problem is recognized: about 4 million deaths every year
Tractability	Problem is largely perceived as intractable in low-income settings	Identification of cost-effective interventions shifts perceptions on tractability
<i>Political context</i>		
Other actors	Few global health organizations address issue	Dozens of organizations participating in addressing issue, although few make it a central priority
Policy window	No global political agreements address issue explicitly	Recognition that Millennium Development Goal 4 cannot be achieved without attention to newborn survival

In comparison with radiological X-ray imaging techniques or magnetic resonance, ultrasonography was more convenient, because of unlimited examination frequency of critically sick newborns in the isolettes, and less costly, without the need for sedation and transportation of infants.¹⁰ Introduction of Doppler studies was a new advancement in the assessment of circulation in neonates in the late 1980s.^{14,15} This technique enabled functional follow-up of the brain, heart, liver, kidney and other organs.¹⁵ In the 1990s, a new exciting technique of 3D and 4D ultrasonography was developed, depicting neonatal organs in the third-dimension and in real-time.¹⁶⁻²⁰ Brain ultrasound became the most widely used technique for evaluation of brain morphology and cerebral lesions in neonates.^{10,15} It can confirm prenatal diagnosis and identify not only the presence of lesions but also their type and extent.²¹ The use of ultrasound in cardiology made substantial improvement in the diagnostics of congenital heart defects as well as the follow-up of the critically sick newborns. Ultrasound became widely used and accepted diagnostic technique in neonatology used not only by radiologists and ultrasonographers but also as the point of care technique used by neonatologists in neonatal intensive care settings.

Because health is understood as a physical, mental and social well-being which goes much further than just the absence of acute suffering or disease, ultrasonographic screening and diagnostic activities in neonatology should be highly prophylactic regarding morphological and functional handicap of newborn child.

Ultrasound in the Hands of Acute Care Neonatologists

In his paper published in the year 2000, Evans concluded that ultrasound in neonatology is moving beyond its traditional boundaries and becoming part of the acute care doctors' diagnostic repertoire. This trend needs to be recognized in the specialty training and the ultrasound accreditation processes.²² Ultrasound can be used by neonatologists in the neonatal intensive care unit and well care nursery, but sometimes it can be performed by radiologists or other specialist in order to make or confirm the diagnosis of diseases and conditions in neonates. The use of ultrasound by neonatologists and other specialists is shown in the Table 2.²³

Point of Care Neonatal Ultrasound

Neonatal cranial ultrasound has been applied for many years as the most often used point of care diagnostic imaging technique in neonatology. It has improved diagnosis cerebral condition in normal, critically sick and malformed neonates and has been useful as screening and unavoidable diagnostic imaging tool.^{24,25} It has been used for many years in many countries all over the world. Although there some international guidelines on neonatal cerebral ultrasound that have been published,²⁶ lack of internationally standardized approach to the application of this kind of examination in neonates was pointed out for many years as well as the lack of the appropriate curriculum for the education of neonatologists. The example of the curriculum for advanced

Table 2: Neonatal applications of ultrasound²³

<i>By neonatologists</i>	<i>By other specialists (non-neonatologists)</i>
<i>Existing</i>	Fetal
Neonatal cranial ultrasound	Head and brain
Neonatal cardiac ultrasound	Cardiac
Neonatal abdominal ultrasound	Chest/diaphragm
Neonatal hip ultrasonography	Abdominal (kidneys and bladder, pylorus, ovaries, uterus, liver gall bladder, spleen, testes, masses, tumors)
	Vascular access
	Eyes
<i>Emerging</i>	?
Bowel	
Lung	
Endotracheal tube	
<i>Potential</i>	?
Other catheters and nasogastric tubes	
Body composition	

head ultrasound performed by clinicians is presented in the Appendix 1. It is very important to point out that whenever performed it should be mentioned whether is it performed by clinician or other imaging specialist. This applies to all ultrasound findings in neonatology.

The role of echocardiography in the neonatal intensive care unit (NICU) has changed over the past few years.²⁷ Previously, nearly all echocardiographic studies in the NICU were performed by pediatric cardiologists to diagnose or

monitor congenital heart disease (CHD) and to screen for patent ductus arteriosus (PDA).²⁷ The initial echocardiographic examination should always be a comprehensive study of both anatomy and function that is to be interpreted by a pediatric cardiologist within a reasonable time frame. Some structural defects, such as anomalous pulmonary venous return or coarctation of the aorta, can be difficult to detect using echocardiography and require extensive training and continued practice.²⁷

Once significant congenital defects have been ruled out, more focused studies can be performed and interpreted by a trained echocardiographer for specific indications. More recently, neonatologists have become interested in the echocardiographic assessment of hemodynamic instability in infants.²⁷ The terms functional echocardiography, point-of-care echocardiography and targeted neonatal echocardiography have been introduced to describe the use of echocardiography as an adjunct in the clinical assessment of the hemodynamic status in neonates.²⁷ The increasing availability of echocardiography, with miniaturization of the technology, has resulted in more widespread use of echocardiography in NICUs around the world.²⁷

Summary of training requirements for echocardiography in neonates are presented in the Table 3.²⁷ Such training is missing in 55% of European NICUs, although in more than 74% of NICUs functional neonatal echocardiography has been used for many indications.²⁸

Table 3: Summary training requirements for echocardiography in neonates²⁷

<i>Type of training</i>	<i>Training level</i>			<i>Accreditation</i>
	<i>Core/basic</i>	<i>Advanced</i>	<i>Expert</i>	
American College of Cardiology (ACC)/American Heart Association (AHA)/American Society of Echocardiography (ASE): pediatric echocardiography				
Number of studies	150 studies performed 150 studies reviewed	200 additional studies performed 200 additional studies reviewed	Not defined	None
Duration of training	4-6 months	Additional 9-12 months		
Association for European Pediatric Cardiology (AEPIC): pediatric echocardiography				
Number of studies	250 studies performed	750 studies performed in total	2,000 studies performed in total	European Association of Echocardiography (EAE) congenital echocardiography exam
Duration of training	Not defined	Not defined	Not defined	
Targeted Neonatal Echocardiography (TNE) Guidelines				
Number of studies	150 studies reviewed 150 studies performed	150 studies reviewed 150 studies performed	Not defined	None
Duration of training	4-6 months	Additional 4-6 months	Not defined	None

Appendix 1: Advanced clinician performed neonatal ultrasound (CPNU)⁴⁰

Purpose: This program is designed to cover the theoretical and practical curriculum for advanced functional imaging of the neonatal heart and brain as well as basic imaging of the abdominal organs and central line localization.

Prerequisites: Learners should have completed the physical principles and instrumentation unit and the introduction to CPNU unit, including submission of their logbook.

Training: Mandatory attendance at a 2 days Australian Society of Ultrasound in Medicine approved Advanced CPNU course.

Assessments: Learners are required to perform supervised ultrasound scans, document them in a logbook and submit the logbook in order to complete the unit.

Course Objective*Scanning the neonate*

On completing this unit, delegates should be able to:

- Demonstrate an understanding of the common conventions of neonatal scanning including image optimization.
- Competently record a series of images to clearly demonstrate normal anatomy.
- Demonstrate proficiency in assessing and interpreting normal and abnormal neonatal cardiac hemodynamics.
- Understand limitations to the accuracy of hemodynamic measurements.
- Recognize common patterns of CHD.
- Recognize common abnormalities found on cerebral ultrasound.
- Use ultrasound to locate intravascular lines.
- Recognize abnormal fluid collections in pleural and peritoneal space and common renal and hepatic abnormalities.
- Recognize when an examination is incomplete and needs to be repeated.

Demonstrate competency in:

- Interpreting heart ultrasound findings to determine the significance of ductal shunting.

Cranial ultrasound

- Using coronal and sagittal cranial ultrasound windows via anterior fontanelle to demonstrate normal anatomical structures.
- Recognizing intracranial bleeding with competent assessment of subependymal, intraventricular and parenchymal bleeding.
- Recognizing common structural abnormalities of cerebral development.
- Performing and interpreting Doppler studies of the anterior and middle cerebral artery.
- Interpreting cranial ultrasound findings in relation to the clinical scenario.

I. Neonatal cranial ultrasound

i. Anatomy

Normal cranial anatomy of the brain will be presented, including:

- Ventricular structure
- Anatomy of major sulcal patterns
- Thalamus
- Caudate nucleus
- Corpus callosum
- Cerebellum

ii. Skills

Courses will teach learners the following imaging skills:

- Obtaining coronal and sagittal cranial ultrasound windows via anterior fontanelle to demonstrate normal anatomical structures.
- Recognizing intracranial bleeding with competent assessment of subependymal, intraventricular and parenchymal bleeding.
- Recognizing common structural abnormalities of cerebral development.
- Performing and interpreting Doppler studies of the anterior and middle cerebral artery.

iii. Recording

Courses will teach learners the common conventions of cranial scanning and how to competently record a series of images to clearly demonstrate normal cranial anatomy or any abnormality.

iv. Limitations

All scans should be reviewed by a competent scanner (or pediatric radiologist). There is a need to recognize when referral is mandatory because of an incomplete scan or a possible anatomical or functional abnormality. Important management decisions should not be made without such experienced review.

v. Interpretation

Courses will teach learners to interpret the cranial ultrasound findings in relation to the clinical scenario. Important topics covered will include:

- Grading common patterns of peri/intraventricular hemorrhage.
- Recognizing common structural abnormalities of cerebral development.
- Recognizing the common parenchymal and Doppler changes seen in the asphyxiated infant.

II. Neonatal cardiac ultrasound

i. Anatomy

Normal anatomical structure of the heart as it relates to the standard echocardiographic windows will be presented, including:

- Surface anatomy of the heart and great vessels
- The three-dimensional structure of the heart
- Derivation of the two-dimensional images obtained using heart ultrasound
- Anatomy of the inflow tracts
- Anatomy of the great vessels (outflow tracts)
- Anatomy of the heart valves
- Anatomy of the cardiac chambers

Contd...

Contd...

ii. Skills

Courses will teach learners the following image optimization skills related to hemodynamic assessment:

- Assessing size and shunt direction of the PDA
- Measuring right and left ventricular output
- Measuring superior vena cava flow
- Assessing myocardial function using M-mode and other means
- Assessing significance and direction of interatrial shunting
- Measuring or assessing pulmonary artery pressure using tricuspid incompetence, ductal shunt velocities, or pulmonary artery Doppler acceleration times.
- Recognizing common CHD, including:

When to involve a pediatric cardiologist as set out in the 'appropriate use' statement.

- Recognizing indirect markers to the presence of CHD. For example, large or small vessels and chambers, and abnormal movement of myocardium or valves.
- Assessing infants with cyanosis of unknown cause.
- Recognizing echocardiographic features of persistent pulmonary hypertension (PPHN).
- Recognizing common cyanotic CHD that can mimic PPHN [e.g. total anomalous pulmonary venous connection (TAPVC), transposition of great arteries (TGA)].
- Recognizing other common cyanotic CHD, including ductal dependent pulmonary circulations.
- Assessing infants with respiratory distress, heart failure and or shock.
- Recognizing common ductal dependent systemic circulation lesions.
- Recognizing other common CHD, including pulmonary stenosis, Fallot's Tetralogy and atrioventricular canal defects.
- Recognizing muscular and perimembranous ventricular septal defects.

iii. Recording

Courses will teach learners the common conventions of cardiac scanning and how to competently record a series of images to clearly demonstrate normal cardiac anatomy.

iv. Limitations

Advanced CPNU courses will discuss:

- Understanding limitations to the accuracy of hemodynamic measurements.
- Recognizing when an examination is incomplete and needs to be repeated.

During the introductory stage, all scans should be reviewed by a competent scanner (or pediatric cardiologist). There is a need to recognize when to refer because of an incomplete scan or a possible anatomical or functional abnormality. Important management decisions should not be made without such experienced review.

v. Interpretation

Courses will teach learners the skills needed to competently interpret the heart ultrasound findings in relation to the following criteria to determine the significance of ductal shunting:

- Interpreting abnormal and normal ventricular outputs
- Interpreting normal and abnormal superior vena cava flow
- Interpreting normal and abnormal myocardial function
- Interpreting normal and abnormal atrial shunting
- Interpreting normal and abnormal pulmonary artery pressures.

III. Neonatal abdominal ultrasound

i. Anatomy

Normal abdominal anatomy will be presented, including:

- Anatomy and relationships of major organs
- Anatomy and relationships of inferior vena cava (IVC) and abdominal aorta

ii. Skills

Courses will teach learners the following imaging skills:

- IVC and abdominal aorta including umbilical catheter and percutaneous intravenous catheter tip location
- Ascites/pleural effusions
- Locating and identifying the kidneys
- Locating the bladder, and assessing relative volume.

iii. Recording

Courses will teach learners the common conventions of abdominal scanning and how to competently record a series of images to clearly demonstrate normal abdominal anatomy.

iv. Limitations

All scans should be reviewed by a competent scanner (or pediatric radiologist). There is a need to recognize when referral is mandatory because of an incomplete scan or a possible anatomical or functional abnormality. Important management decisions should not be made without such experienced review.

v. Interpretation

Courses will teach learners the skills needed to competently interpret the ultrasound findings in relation to the clinical scenario, including:

- Recognizing and localizing fluid in the pleural, peritoneal and pericardial spaces.
- Recognizing common renal abnormalities, such as pelvic dilatation, hydronephrosis and large or small kidneys.
- Recognizing and assessing volume of bladder contents.
- Assessing for intravenous catheter tip position, particularly to exclude an intracardiac tip position.

Contd...

Contd...

Limitations and Pitfalls

Standards and appropriate use of Neonatal Clinician Performed Ultrasound

It is expected that the CCPU in neonatal ultrasound is to be used for provision of ultrasound at the point of care in a neonatal intensive care unit to enhance the clinical care of the infant and not to raise revenue.

Limitations of Use

Holders of the CCPU in neonatal ultrasound are expected to consult and request appropriate advice by a pediatric cardiologist or radiologist under the following circumstances:

By a Pediatric Cardiologist

- If the primary clinical concern is the possibility of CHD.
- If specific treatment is being instituted for CHD based on a clinician performed ultrasound (CPU).
- If transfer to a pediatric cardiology unit is being planned based on a CPU.
- If the clinical findings or course are 'NOT' consistent with the CPU findings.
- If the baby is no longer in an Neonatal Intensive Care Unit setting, e.g. after discharge.

By a Radiologist

- For documentation and confirmation of abnormal cranial ultrasound results.
 - For provision of routine cranial ultrasound services if this already exists.
- Performance of a CPU is not expected to be equivalent to a study performed by an imaging consultant and as such should not be relied upon to exclude significant pathology.

Documentation

It is recommended that documentation of CPU studies specifically mention that ultrasound scans are clinician performed to distinguish them from studies by a consultative diagnostic imaging specialist. So, document 'clinician performed cardiac ultrasound' or 'clinician performed cerebral ultrasound' and avoid terms, such as 'echocardiogram'.

Standards for CCPU in Neonatal Ultrasound Teaching Institutions and Courses

Recognized Institutions

Recognized institutions for training in the CCPU (neonatal ultrasound) should have the following:

- Be associated with a neonatal intensive care unit
- Close affiliation with a radiology and pediatric cardiology service
- At least one clinician whose qualification is recognized by the ASUM council as a qualification for training
- Access to a level of ultrasound equipment to allow appropriate quality accuracy and repeatability of scanning. Equipment should be no older than 10 years.

Assessment and Logbook

- Documentation to show attendance and completion of 'advanced CPNU' CCPU course.
- Submission of a minimum of five ultrasound scans: four cardiac and one cerebral, in digital format (DICOM or .avi) on USB stick or CD for review by the examiner. These scans should include all the views as defined in the 'CCPU Neonatal Outline of Level 2 (advanced) cardiac scan,' and available on the ASUM website, www.ASUM.com.au.
- Completion of logbook to satisfy requirements as set out below.

Logbook Requirements

- The logbook requirements should be completed and submitted within 2 years of finishing an ASUM accredited 'advanced CPNU' CCPU course.
- The advanced logbook may be recorded in continuity with the 'Introduction' logbook.
- Complete 25 cardiac ultrasounds 25 cerebral ultrasounds and 10 abdominal scans to show the ability to perform advanced cerebral, functional cardiac and basic abdominal scanning. All scans should be clinically indicated.
- At least half of these studies should demonstrate some pathology.
- These studies should be stored digitally for review, if required.
- These studies should all be signed off by an ASUM approved supervisor, which includes a recertified neonatal CCPU, anyone on the neonatal supervisor register, DDU, DMU, AMS or other recognized ultrasound qualification or specialist radiologist or cardiologist.

The documentation in the logbook must include:

- Date of study and initials of patient
- Brief summary of findings
- Signature of supervisor
- A summary of the number of each type of scan performed demonstrating compliance with requirements for logbook (absolute, at least half with pathology).

Documentation to be presented with the logbook and the scans in digital format demonstrating completion of these requirements must also include:

- Evidence of satisfactory completion of training sessions within a recognized institution in neonatal ultrasound.
- Evidence that all of the cases have been signed off by a suitably qualified clinician (see above).
- A completed ASUM Neonatal Logbook Assessment for CCPU (neonatal) form available at http://www.asum.com.au/newsite/Files/Documents/Education/CCPU/NewCCPU/6.%20Logbook%20Templates/Logbook%20Assessment%20checklists/Assessment%20Checklist_2012%20Neonatal.pdf

The preference of the neonatal CCPU committee is that there should be direct supervision of learners by an accredited supervisor. If learners have problems finding a supervisor to sign off the logbook, the committee will be prepared to consider direct electronic submission of ultrasound scans to demonstrate competence.

Neonatal abdominal ultrasound is very important in the diagnosis of renal and other congenital malformations as well as some infections and other conditions like necrotizing enterocolitis.²⁹ Besides that some birth injuries like adrenal gland hemorrhage.³⁰

Use of ultrasound in the diagnosis of the developmental dysplasia of the hip (DDH) in neonates is still controversial. There is still insufficient evidence to give clear recommendations for practice.³¹ There is inconsistent evidence that universal ultrasound results in a significant increase in treatment compared to the use of targeted ultrasound or clinical examination alone.³¹ Neither of the ultrasound strategies have been demonstrated to improve clinical outcomes including late diagnosed DDH and surgery.³¹ The studies are substantially underpowered to detect significant differences in the uncommon event of late detected DDH or surgery.³¹ For infants with unstable hips or mildly dysplastic hips, use of delayed ultrasound and targeted splinting reduces treatment without significantly increasing the rate of late diagnosed DDH or surgery.^{31,32}

Respiratory distress syndrome due to hyposurfactosis is still one of the most severe and most frequent morbidity in premature infants causing severe mortality.³³ The diagnosis of the condition rely mainly on thoracic X-ray, while the role of ultrasound is increasing.³⁴⁻³⁶

Ultrasound-guided umbilical catheter placement is a faster method to place catheters requiring fewer manipulations and X-rays when compared with conventional catheter placement, although it is still not widely used due to the lack of proper training.³⁷ Real-time ultrasound could be used to place a peripherally inserted central catheter (PICC). This method of placement of PICC reduces catheter insertion duration, and is associated with fewer manipulations and radiographs when compared with conventional placement.³⁸

Ultrasound provides a noninvasive, portable method of assessing changes in subcutaneous adipose tissue and muscle accretion and appears sufficiently sensitive to detect influences of macronutrient intakes on accretion rates in preterm infants from birth.³⁹ The method warrants further investigation as a bedside tool for measuring body composition of preterm infants.³⁹

CONCLUSION

From the beginning of its use in neonatology, ultrasound is used more frequently and for many indications. Number of indications is increasing from year to year, while the training opportunities and curricula are not following the same trend. Nowadays ultrasound has been used for determination of functional hemodynamics in critically sick neonates which

increases educational burden on the young neonatologists. This only applies to the developed countries where neonatology is well developed, while in low-income so called developing countries some basic health problems of neonates have not been solved and there is substantial lack of health care professionals and equipment as well.

REFERENCES

1. Lawn JE, Kerber K, Enweronu-Laryea C, Masee Bateman O. Newborn survival in low resource settings--are we delivering? *BJOG* 2009 Oct;116(Suppl 1):49-59.
2. Lawn JE, Cousens S, Zupan J. Lancet Neonatal Survival Steering Team. 4 million neonatal deaths: When? Where? Why? *Lancet* 2005 Mar;365(9462):891-900.
3. Lawn JE, Cousens SN, Darmstadt GL, Bhutta ZA, Martines J, Paul V, Knippenberg R, Fogstad H. Lancet Neonatal Survival Series steering. 1 year after The Lancet Neonatal Survival Series—was the call for action heard? *Lancet* 2006 May; 367(9521):1541-1547.
4. Lawn JE, Wilczynska-Ketende K, Cousens SN. Estimating the causes of 4 million neonatal deaths in the year 2000. *Int J Epidemiol* 2006 Jun;35(3):706-718.
5. Darmstadt GL, Bhutta ZA, Cousens S, Adam T, Walker N, de Bernis L. Lancet Neonatal Survival Steering Team. Evidence-based, cost-effective interventions: how many newborn babies can we save? *Lancet* 2005 Mar;365(9463):977-988.
6. Lawn JE, Gravett MG, Nunes TM, Rubens CE, Stanton C. GAPPS Review Group. Global report on preterm birth and stillbirth: definitions, description of the burden and opportunities to improve data. *BMC Pregnancy Childbirth* 2010 Feb;10(Suppl 1): S1.
7. Lawn J. Why focus on babies? Inter Press Service: Apr 2013. Available from: <http://www.globalissues.org/news/2013/04/08/16273>.
8. Shiffman J. Issue attention in global health: the case of newborn survival. *Lancet* 2010 Jun; 375(9730):2045-2049.
9. Dubowitz LMS, Levene MI, Morante A, Palmer P, Dubowitz V. Neurologic signs in neonatal intraventricular hemorrhage: a correlation with real-time ultrasound. *J Pediatr* 1981 Jul;99(1):127-133.
10. Fischer AQ, Anderson JC, Shuman RM, Stinson W. Pediatric neurosonography: clinical, tomographic and neuropathologic correlates. New York, Chichester, Brisbane, Toronto, Singapore: A Wiley Medical Publication; 1985.
11. Levene M, Dowling S, Graham M, Fogelman K, Galton M, Philips M. Impaired motor function (clumsiness) in 5-year-old children: correlation with neonatal ultrasound scans. *Arch Dis Child* 1992 Jun;67(6):687-690.
12. Levene MI, Wigglesworth JS, Dubowitz V. Cerebral structure and intraventricular hemorrhage in the neonate: a real-time ultrasound study. *Arch Dis Child* 1981 Jun;56(6):416-424.
13. Papile LA, Burstein J, Burstein R, Koffler H. Incidence and evolution of subependymal and intraventricular hemorrhage: a study of infants with birth weights less than 1,500 gm. *J Pediatr* 1978 Apr;92(4):529-534.
14. Newman PG, Rozycki GS. The history of ultrasound. *Surg Clin North Am* 1998 Apr;78(2):179-195.
15. Peng SS, Lin JH, Lee WT, Tsao PN, Shih JC, Liu HM, Li YW, Hsieh FJ, Tsou KI. 3-D power Doppler cerebral angiography in

- neonates and young infants: comparison with 2-D Doppler angiography. *Ultrasound Med Biol* 1999 Jul;25(6):947-951.
16. Kampmann W, Walka MM, Vogel M, Obladen M. 3-D sonographic volume measurement of cerebral ventricular system: in vitro validation. *Ultrasound Med Biol* 1998 Oct;24(8):1169-1174.
 17. Kurjak A, Hafner T, Kos M, Kupesic S, Stanojevic M. Three-dimensional sonography in prenatal diagnosis: a luxury or necessity. *J Perinat Med* 2000;28(3):194-209.
 18. Merz E. Aktuelle technische Möglichkeiten der 3D-Sonographie in der Gynäkologie und Geburtshilfe. *Ultraschall in Med* 1997;18(5):190-195.
 19. Nagdyman N, Walka MM, Kampmann W, Stowver B, Obladen M. 3-D ultrasound quantification of neonatal cerebral ventricles in different head positions. *Ultrasound Med Biol* 1999 Jul;25(6):895-900.
 20. Nelson TR, Pretorius DH. Three-dimensional ultrasound imaging. *Ultrasound Med Biol* 1998 Nov;24(9):1243-1270.
 21. Mercuri E, Dubowitz L, Paterson Brown S, Cowan F. Incidence of cranial ultrasound abnormalities in apparently well neonates on postnatal ward: correlation with antenatal and perinatal factors and neurological status. *Arch Dis Child Fetal Neonatal Ed* 1998 Nov;79(3):F185-F189.
 22. Evans N. Echocardiography on neonatal intensive care units in Australia and New Zealand. *J Paediatr Child Health* 2000 Apr;36(2):169-171.
 23. Kim JH. Introducing neonatologist performed ultrasound to the NICU. San Diego, CA: UC San Diego Medical Center. Available from: <http://healthcare-professionals.sw.org/resources/docs/division-of-education/events/neonatology-conference/2012/Breakout.NEC.Kim.pdf>.
 24. Rennie JM, Hagmann CF, Robertson NJ. Neonatal cerebral investigation. Cambridge: Cambridge University Press; 2008.
 25. Volpe JJ. Neurology of the newborn. 5th ed. Philadelphia: Saunders Elsevier; 2008.
 26. American Institute of Ultrasound in Medicine. AIUM practice guideline for the performance of neurosonography in neonates and infants. *J Ultrasound Med* 2010 Jan;29(1):151-156.
 27. Mertens L, Seri I, Marek J, Arlettaz R, Barker P, McNamara P, Moon-Grady AJ, Coon PD, Noori S, Simpson 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). *J Am Soc Echocardiogr* 2011 Oct;24(10):1057-1078.
 28. Roehr CC, Te Pas AB, Dold SK, Breindahl M, Blennow M, Rüdiger M, Gupta S. Investigating the European perspective of neonatal point-of-care echocardiography in the neonatal intensive care unit—a pilot study. *Eur J Pediatr* 2013 Jul;172(7):907-911.
 29. Bohnhorst B. Usefulness of abdominal ultrasound in diagnosing necrotising enterocolitis. *Arch Dis Child Fetal Neonatal Ed* 2013 Apr 9. [Epub ahead of print].
 30. Yao W, Li K, Xiao X, Zheng S, Chen L. Neonatal suprarenal mass: differential diagnosis and treatment. *J Cancer Res Clin Oncol* 2013 Feb;139(2):281-286.
 31. Shorter D, Hong T, Osborn DA. Screening programmes for developmental dysplasia of the hip in newborn infants. *Cochrane Database Syst Rev* 2011 Sep 7;(9):CD004595.
 32. Bracken J, Ditchfield M. Ultrasonography in developmental dysplasia of the hip: what have we learned? *Pediatr Radiol* 2012 Dec;42(12):1418-1431.
 33. Sun H, Xu F, Xiong H, Kang W, Bai Q, Zhang Y, Zhou C, Zhuang F, Wang X, Zhu C. Characteristics of respiratory distress syndrome in infants of different gestational ages. *Lung* 2013 Aug;191(4):425-433.
 34. Copetti R, Cattarossi L, Macagno F, Violino M, Furlan R. Lung ultrasound in respiratory distress syndrome: a useful tool for early diagnosis. *Neonatology* 2008;94(1):52-59.
 35. Raimondi F, Migliaro F, Sodano A, Umbaldo A, Romano A, Vallone G, Capasso L. Can neonatal lung ultrasound monitor fluid clearance and predict the need of respiratory support? *Crit Care* 2012 Nov;16(6):R220.
 36. Lovrenski J. Lung ultrasonography of pulmonary complications in preterm infants with respiratory distress syndrome. *Ups J Med Sci* 2012 Mar;117(1):10-17.
 37. Fleming SE, Kim JH. Ultrasound-guided umbilical catheter insertion in neonates. *J Perinatol* 2011 May;31(5):344-349.
 38. Katheria AC, Fleming SE, Kim JH. A randomized controlled trial of ultrasound-guided peripherally inserted central catheters compared with standard radiograph in neonates. *J Perinatol* 2013 Jun 13. [Epub ahead of print].
 39. McLeod G, Geddes D, Nathan E, Sherriff J, Simmer K, Hartmann P. Feasibility of using ultrasound to measure preterm body composition and to assess macronutrient influences on tissue accretion rates. *Early Hum Dev* 2013 Aug;89(8):577-582.
 40. Australasian Society for Ultrasound in Medicine. Promoting excellence in ultrasound. Certificate in Clinician Performed Ultrasound (CCPU). Advanced Clinician Performed Neonatal Ultrasound. July 2012. Available from: <http://www.asum.com.au/newsite/Education.php?p=CCPU-Neonatal>.

ABOUT THE AUTHOR

Milan Stanojevic

Department of Obstetrics and Gynecology, Medical School University of Zagreb, Neonatal Unit, Clinical Hospital, Sv. Duh, Zagreb, Sv. Duh 64, 10000 Zagreb, Croatia, DIU, Libertas, Dubrovnik International University, Croatia, Phone: ++38513712316, Fax: ++38513745534, e-mail: milan.stanojevic@optinet.hr