Can 3-dimensional cranial ultrasound be used to successfully reconstruct a 2-dimensional image without compromising on image quality in a neonatal population?

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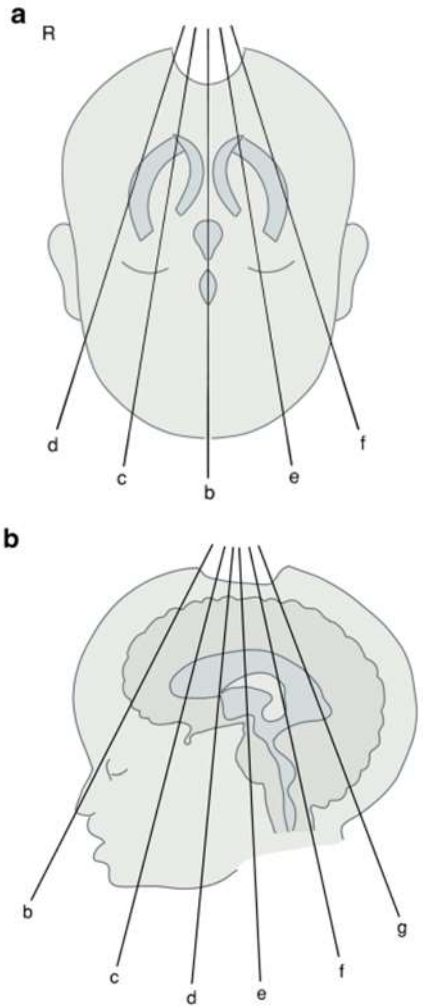
Background

- Advances in perinatal care → reduction in neonatal morbidity & mortality from severe neurological conditions
- Cranial US and MRI → most frequently used imaging techniques for perinatal brain assessment
- US → portable, relative low cost, non-ionising, no patient sedation required
- US → primary method for screening/evaluating intracranial abnormalities in NICU



Standard 2D US coronal (a) and sagittal views (b)

2-D cranial US

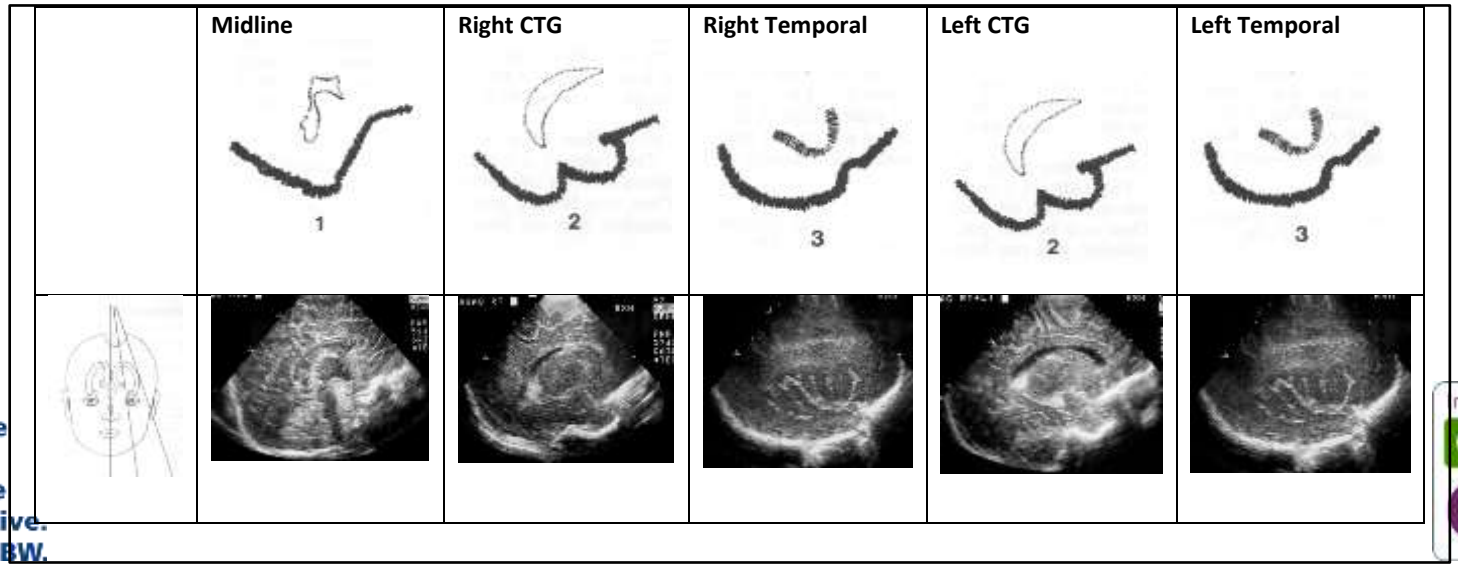
- Time-consuming
- Requires extensive training
- Highly operator-dependent
- Reduced diagnostic confidence/ accuracy → reported by operator who is not interpreting radiologist
- Transfer of neonates to higher level units with experience

3-D US

- Proven diagnostic capability → multiple radiology sub-specialities
- Semi-automated → reduced input from operator
- Volumetric acquisition → reducing potential for missed pathology
- Increased inter- & intra-operator reproducibility
- Evidence → shorter acquisition times
- Overcomes many limitations of 2-D US

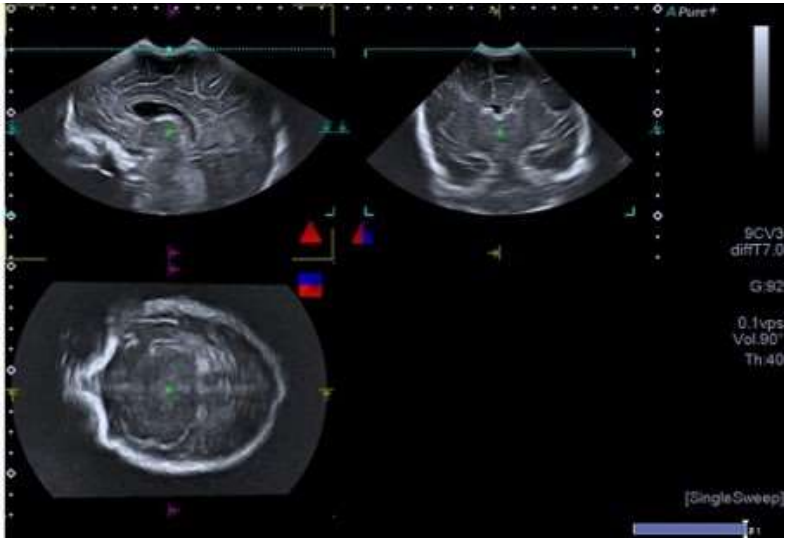
Aims of study

- Determine feasibility for larger scale study 2-D US vs 3-D US
- Compare 2-D vs 3-D US → specific intracranial landmarks
- Assess diagnostic image quality → 2-D US (experienced operator) vs 3-D semi-automated US



Methods

- Prospective study conducted at level 3 NICU
- 20 neonates recruited
- Mix full-term/pre-term infants
- Sub-set patients with pathology
- 2-D US → routine clinical care
- 3-D US → research scan
- 40 images (20 2-D/20 3-D) → assigned random number 1-40
- Readers blinded to acquisition method & participant ID



Safety of 3-D US

- Literature review
- Risk assessment
- Monitor TI/MI
- Follow national guidelines (e.g. BMUS)

➡ Additional 3-D scan - considered low risk

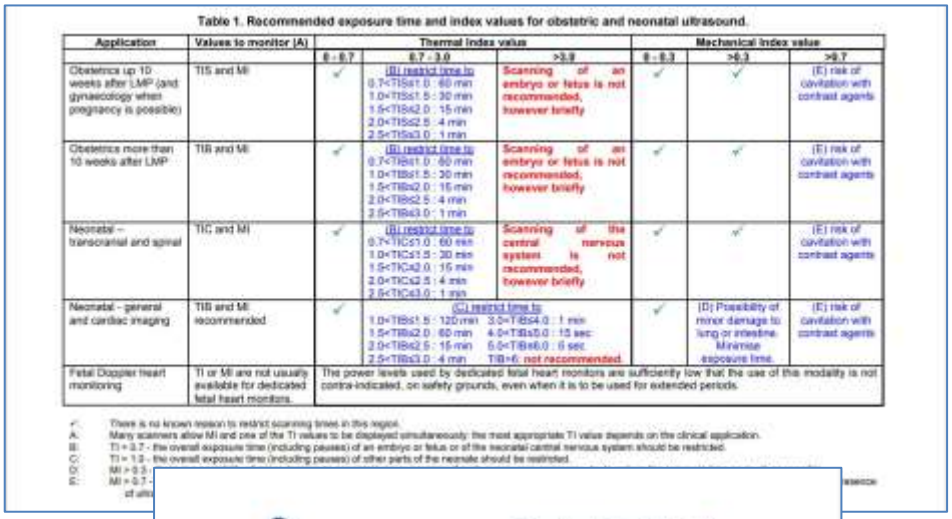


Table 1. Recommended exposure time and index values for obstetric and neonatal ultrasound.

Application	Values to monitor (A)	Thermal Index value			Mechanical Index value		
		0 - 0.7	0.7 - 3.0	>3.0	0 - 0.3	>0.3	>0.7
Obstetrics up 10 weeks after LMP (and gynaecology when pregnancy is possible)	TIS and MI	✓	(B) restrict time to: 0.7<TIS≤1.0 : 60 min; 1.0<TIS≤1.5 : 30 min; 1.5<TIS≤2.0 : 15 min; 2.0<TIS≤2.5 : 4 min; 2.5<TIS≤3.0 : 1 min	Scanning of an embryo or fetus is not recommended, however briefly	✓	✓	(E) risk of cavitation with contrast agents
Obstetrics more than 10 weeks after LMP	TIB and MI	✓	(B) restrict time to: 0.7<TIB≤1.0 : 60 min; 1.0<TIB≤1.5 : 30 min; 1.5<TIB≤2.0 : 15 min; 2.0<TIB≤2.5 : 4 min; 2.5<TIB≤3.0 : 1 min	Scanning of an embryo or fetus is not recommended, however briefly	✓	✓	(E) risk of cavitation with contrast agents
Neonatal – transcranial and spinal	TIC and MI	✓	(B) restrict time to: 0.7<TIC≤1.0 : 60 min; 1.0<TIC≤1.5 : 30 min; 1.5<TIC≤2.0 : 15 min; 2.0<TIC≤2.5 : 4 min; 2.5<TIC≤3.0 : 1 min	Scanning of the central nervous system is not recommended, however briefly	✓	✓	(E) risk of cavitation with contrast agents
Neonatal – general and cardiac imaging	TIB and MI recommended	✓	(C) restrict time to: 1.0<TIB≤1.5 : 120 min; 1.5<TIB≤2.0 : 60 min; 2.0<TIB≤2.5 : 15 min; 2.5<TIB≤3.0 : 4 min; 3.0<TIB≤4.0 : 1 min; 4.0<TIB≤5.0 : 15 sec; 5.0<TIB≤6.0 : 6 sec; TIB>6: not recommended.		✓	(D) Possibility of minor damage to lung or intestine. Minimise exposure time.	(E) risk of cavitation with contrast agents
Fetal Doppler heart monitoring	TI or MI are not usually available for dedicated fetal heart monitors.	The power levels used by dedicated fetal heart monitors are sufficiently low that the use of this modality is not contra-indicated, on safety grounds, even when it is to be used for extended periods.					

✓: There is no known reason to restrict scanning times in this region.
A: Many scanners allow MI and one of the TI values to be displayed simultaneously: the most appropriate TI value depends on the clinical application.
B: TI > 0.7 - the overall exposure time (including pauses) of an embryo or fetus or of the neonatal central nervous system should be restricted.
C: TI > 1.0 - the overall exposure time (including pauses) of other parts of the neonate should be restricted.
D: MI > 0.3 -
E: MI > 0.7 -
of ultr

British Association of Perinatal Medicine BMUS

Guidance document on ultrasound safety issues when scanning a neonate

Prepared by the Physics and Safety Committee of the British Medical Ultrasound Society

Recommendations

- Neonatal ultrasound training courses should include awareness of safety considerations.
- Neonatal departments should ensure that ultrasound scanning protocols follow safety guidelines and recommendations.
  - When setting up neonatal scanner pre-sets, advice from Medical Physics departments or Application Specialists should be sought.

Scope

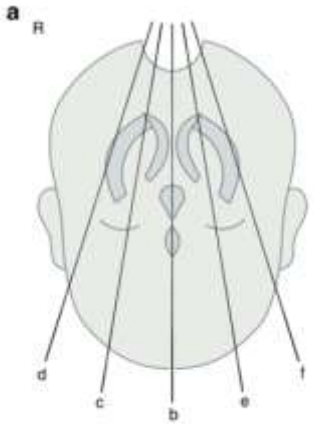
This guidance document has been written by the Physics and Safety Committee of the British Medical Ultrasound Society (BMUS). It has been prepared in conjunction with the Royal College of Paediatrics and Child Health.

The note is intended for any clinician who performs diagnostic ultrasound imaging of the neonate. It should be read in conjunction with the detailed guidelines published by BMUS "Guidelines for the safe use of diagnostic ultrasound equipment." https://www.bmus.org/static/uploads/resources/BMUS-Safety-Guidelines-2009-revision-FINAL-Nov-2009.pdf

Image Acquisition – 2-D

- Toshiba PVT-712BT (11CM4)
- Standard 5 coronal/ 6 sagittal views
- 77 anatomical landmarks

Toshiba 4.3-11 MHz probe



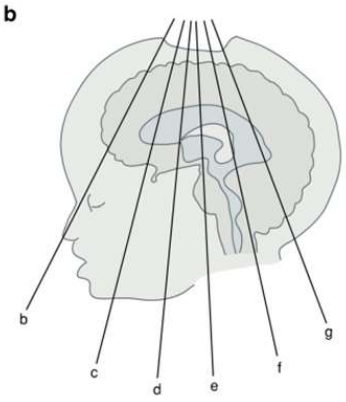


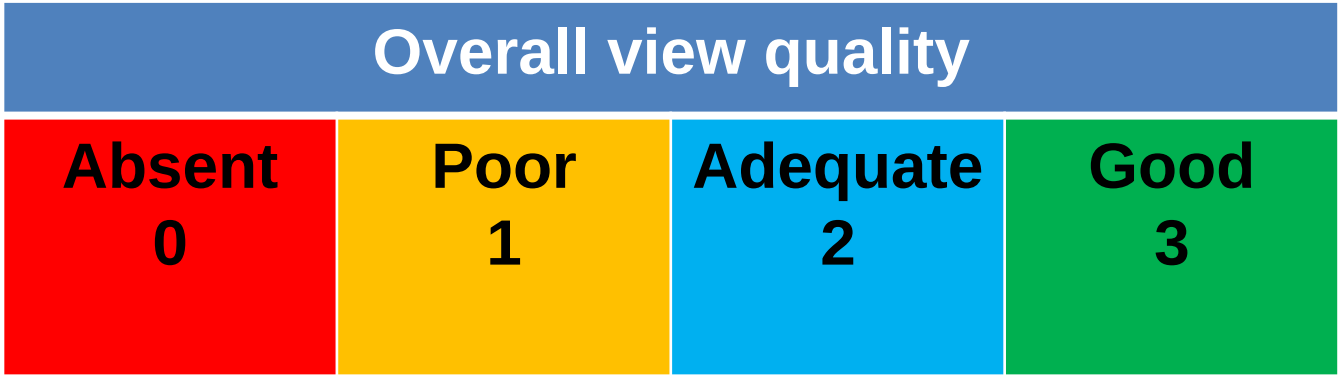
Image Acquisition – 3-D

- Toshiba PVT-681MVL (11CV3)
- Small footprint
- Optimised preset → used for all participants
- Operators trained
- Operator → baseline positioning of the probe
- Data reconstructed → standard views

3-D/4-D 3.6–11 MHz probe

Image assessment

- 3 experienced readers
- Visualisation of anatomical landmarks (absent / present)
- Overall quality (scale 0-3)

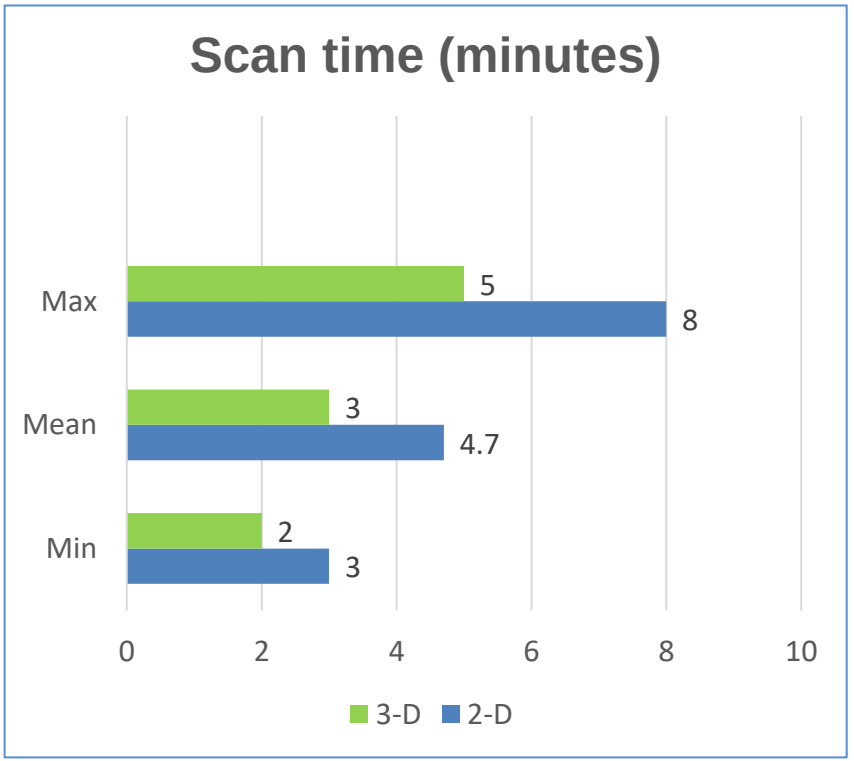


Statistical analysis

- mixed model analysis of variance (ANOVA)
- SPSS (IBM) and Statistica (TIBCO Software)
- P-value of $<0.05 \rightarrow$ statistically significant

Results

- 40 studies total (20 2-D, 20 3-D)
- 12 female, 8 male infants
- Mean age 24 days (range 7- 52)
- Mean scan time 2-D = 4.7 mins (range 3 - 8 mins)
- Mean scan time 3-D = 3 mins (range 2 - 5 mins)

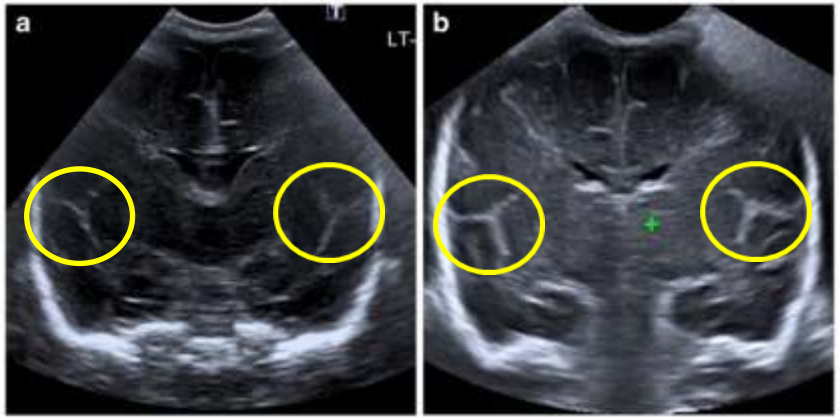


Results - Anatomical Structures

- 3-D → identified 80%
- 2-D → identified 77%

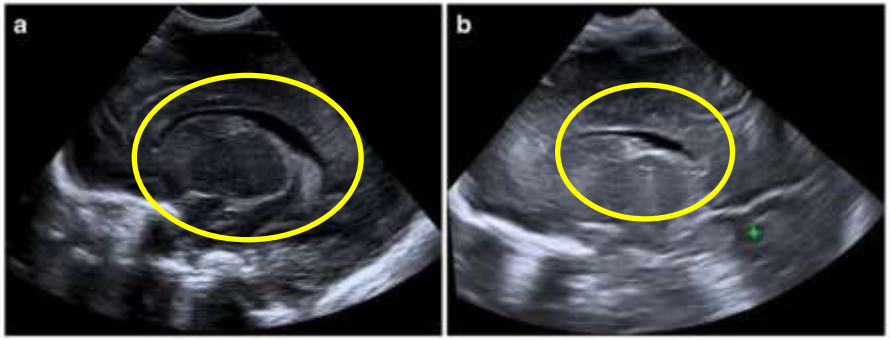
Trends:

- 3-D → identified more structures in coronal plane/ generally higher view quality
- 2-D → identified more structures in sagittal plane/ generally higher view quality



Left: 2-D Right: 3-D

Sylvian fissure

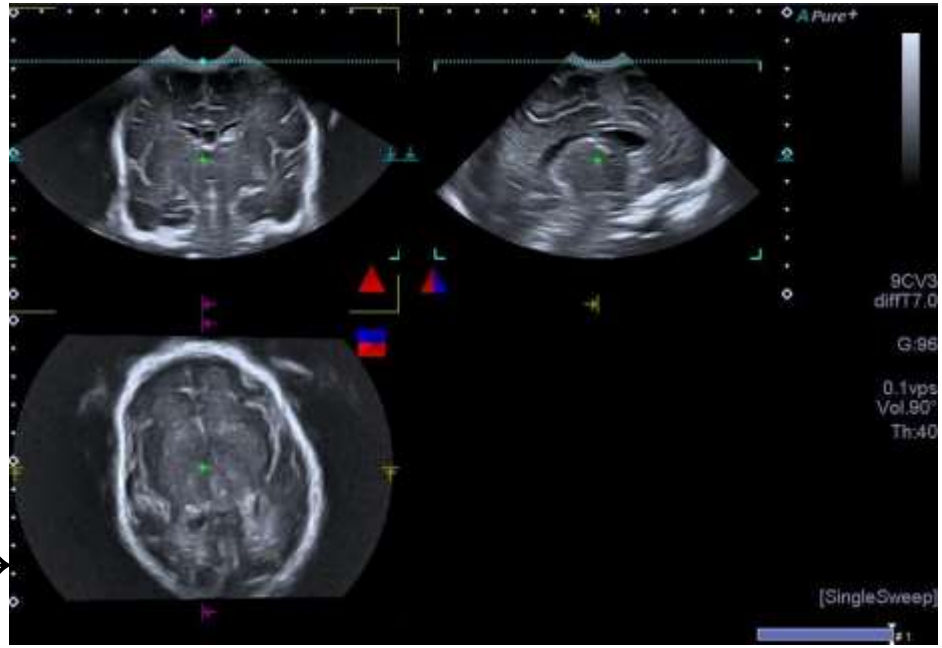


Left: 2-D Right: 3-D

caudothalamic groove

Conclusion

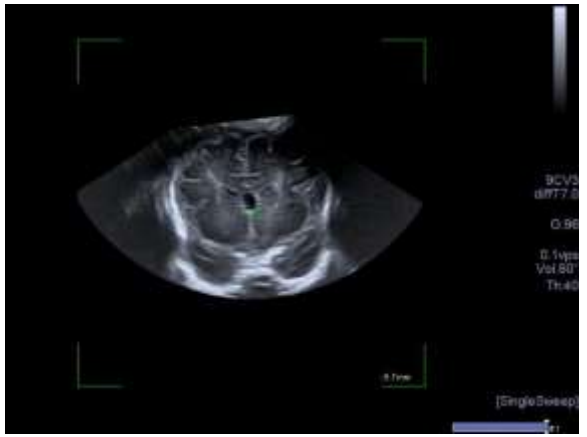
- Successful pilot at level 3 NICU
- 3-D performs similarly to 2-D US performed by an experienced operator
- 3-D US → reduced acquisition times
- Potential for 3-D US acquisition at remotes sites → no experienced operator
- Enable remote reporting by experienced radiologist



Potential for worldwide health support

Limitations

- Readers could only access reconstructed images not entire volume acquired
- Readers not fully blinded to 2-D vs 3-D
- Participants were mix of term & pre-term infants; no age-related data collected
- Pathology group small, results seen as trends



Future Work

- Aim to extend the current proof-of-concept study to a larger number of patients
- Power calculation → sample size of 50 for future study
- Pathology group → inform design of further studies

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https://link.springer.com/article/10.1007/s00247-024-05886-9

Thank you for listening.

Any questions?