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Defining normal neonatal abdominal wall musculature with ultrasonography☆

Adam Ofri [a,d,*], Tim Schindler [b], Anthony Dilley [a], John Pereira [c,d], Susan Adams [a,e,f]

[a] Department of Paediatric Surgery, Sydney Children's Hospital, Randwick, New South Wales, Australia
[b] Department of Neonatal Intensive Care, Royal Hospital for Women, Randwick, New South Wales, Australia
[c] Department of Radiology, Sydney Children's Hospital, Randwick, New South Wales, Australia
[d] Conjoint Lecturer, University of New South Wales, Randwick, New South Wales, Australia
[e] Neuroscience Research Australia, Randwick, New South Wales, Australia
[f] School of Women's and Children's Health, Randwick, New South Wales, Australia

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ABSTRACT

Introduction: The development of new surgical approaches for the management of congenital abdominal wall defects may be facilitated by using an animal model. However, because the anatomy of the neonatal abdominal wall has not been described, a suitable model is yet to be identified. We aimed to evaluate and define the neonatal abdominal wall musculature using ultrasound, to be used as a reference to identify an appropriate animal model for the neonatal abdominal wall in the future.
Methods: Infants with a postconceptual age of less than one month weighing between 2 and 3 kg were eligible. With ethical approval, ultrasonography of three abdominal wall locations bilaterally was performed. The depth of the skin to external oblique and the thickness of the three abdominal wall muscles, external oblique (EO), internal oblique (IO) and transversus abdominis (TA), were measured.
Results: Ten males and seven females were recruited with median postconceptual age of 36 weeks (IQR 36–38), median postnatal age of 8 days (IQR 3–30) and median weight of 2.35kg (IQR 2.26–2.56).
The mean depth of EO from skin was 2.06 mm (± 0.44). The mean thicknesses of the muscles were: EO 1.02 mm (± 0.33), IO 1.16 mm (± 0.39) and TA 1.02 mm (± 0.37). There was no statistical difference between the thickness of EO, IO or TA ($p = 0.43$).
Conclusions: It is possible to consistently identify and measure the components of the neonatal abdominal wall musculature with ultrasonography. We hope this can aid in developing an appropriate animal model, with the ultimate aim of facilitating innovation in surgical management of neonatal abdominal wall pathology.
Levels of evidence: Study of Diagnostic test, Level IV.

Gastroschisis and omphalocele are the commonest congenital abdominal wall defects [1]. Primary reduction with operative closure of the fascia is ideal but can cause an increase in intraabdominal pressure owing to the loss of domain in the peritoneal cavity [2], resulting in significant morbidity and mortality. Adult surgeons have encountered similar domain-associated difficulties in large ventral abdominal wall hernias. A well described approach is the component separation technique (CST) [3,4]. By separating the external oblique aponeurosis laterally, skin and muscle are closed ventrally without increasing intraabdominal pressure. Its use has been reported in infants with giant omphalocele [2]; however CST was first described, and has been modified based off porcine model studies prior to human application [5,6]. Subsequent application to neonates is inappropriate since the baby pig is relatively large and has a subcutaneous abdominal wall muscle, *cutaneous trunci*, changing the overall abdominal wall musculature properties [6].

Defining the structure of the human neonatal anterior abdominal wall will assist in developing an appropriate animal model to facilitate the development of less invasive techniques of CST applicable in the neonate. Adult studies have reported use of ultrasonography to delineate and measure abdominal wall anatomy [7–9] but this has not been done in neonates. This study aims to determine whether it is possible to reproducibly describe and measure the abdominal wall anatomy of a neonate with ultrasonography. The main areas of interest were to determine the appearance of the musculature under ultrasonography, the muscles' depth from the skin and the thickness of each muscle layer.

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* Corresponding author at: Department of Paediatric Surgery, Sydney Children's Hospital, Randwick, New South Wales, Australia.
E-mail address: adamofri@gmail.com (A. Ofri).

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This will inform the development of an appropriate animal model of the neonatal abdominal wall for future refinement of the CST when applied to this age group.

1. Methods

1.1. Study setting

Ethical approval was obtained to conduct a prospective study involving bed-side ultrasonography at the Royal Hospital for Women's Neonatal Intensive Care Unit in Randwick, Australia. Neonates were opportunistically recruited based on personnel and equipment availability. Legal guardians were approached and provided with verbal and written information prior to giving written consent for the infant's involvement in the study.

1.2. Selection criteria

Infants less than one month of postconceptual age, weighing between 2 and 3 kg, and between 10th and 90th centile for weight, who were hemodynamically normal, not requiring respiratory support and in low level care were eligible for inclusion. Infants were excluded if they had chromosomal abnormalities, intraabdominal or abdominal wall pathology or had undergone abdominal surgery.

1.3. Standard ultrasound technique

All ultrasound imaging was performed using a GE Vivid E9 ultrasound machine (GE Healthcare, Sydney, Australia) equipped with a 9 L-D MHz linear array transducer. The ultrasound settings used in all examinations were: Frequency 10 MHz; Gray Map G; Focus Number 1; Focus Position 0.2; Depth 4 cm; Dynamic Range 78; Focal Spread 87.7; Persistence 5.6; Compression 3; Speckle Reduction 2. The same operator performed imaging for all infants. Four measurements were recorded per scan in millimeters; depth of external oblique muscle (EO) from skin, and the thickness of the three abdominal wall muscles — EO, internal oblique (IO) and transversus abdominis (TA). Left and right sides were initially analyzed independently to ensure abdominal wall symmetry.

Fig. 1. Markings of superior, umbilical and inferior abdominal ultrasonography locations.

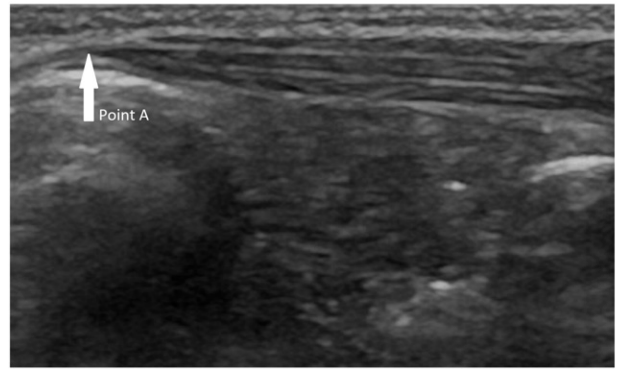

Fig. 2. The saved deidentified ultrasound imaging of the abdominal wall musculature. Point A refers to the medial landmark, the medial aspect of the internal oblique muscle.

1.4. Data collection

The study was conducted over 4 consecutive months from 1st December 2015 to 12th March 2016. All infants were scanned in their cots and given sucrose as required to ensure relaxation. The abdomen was scanned at 6 constant locations; superior, paraumbilical and inferior on both sides (Fig. 1). The most medial point of the IO, as it becomes the aponeurosis at the lateral edge of the rectus abdominis, was routinely identified on the ultrasound image and used as the most medial point of reference (Point A) prior to saving the deidentified image (Fig. 2). A distance 2 cm lateral to this point was the standardized location at which depth measurements were made. Measurements included the depth of the EO from skin and the thickness of the EO, IO and TA (Fig. 3). Measurements were performed on the ultrasound machine to improve accuracy and reproducibility. The same operator who performed ultrasonography also performed measurements to ensure consistency and accuracy. Deidentified saved images with measurements were then reviewed by a pediatric radiologist.

1.5. Statistical analysis

Continuous variables were analyzed with unpaired Student t-test and 3-way ANOVA. Statistical significance was regarded as $P < 0.05$. Statistical analysis was performed using GraphPad Prism 7 (GraphPad Software Inc., San Diego, CA).

2. Results

2.1. Clinical results

102 individual images on 17 neonates were recorded, with no images excluded from analysis. There were ten males and seven females with median postconceptual age of 36 weeks (IQR 36–38), median postnatal age of 8 days (IQR 3–30) and median weight of

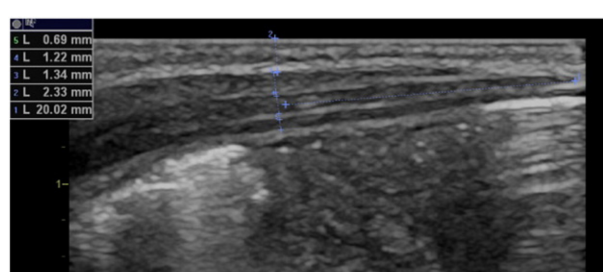

Fig. 3. An example of the measurements performed on a saved deidentified ultrasound image of the abdominal wall musculature.

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