Short Communication

# Handheld 3D scanning as a minimally invasive measuring technique for neonatal anthropometry

Edward T. Andrews [a], James J. Ashton [b, c], Freya Pearson [a], R. Mark Beattie [b, d], Mark J. Johnson [a, d, *]

[a] Department of Neonatal Medicine, Princess Anne Hospital, University Hospital Southampton NHS Foundation Trust, UK
[b] Department of Paediatric Gastroenterology, Southampton Children's Hospital, UK
[c] Human Genetics and Genomic Medicine, University of Southampton, UK
[d] National Institute for Health Research, Southampton Biomedical Research Centre, University Hospital Southampton NHS Foundation Trust and University of Southampton, Southampton, UK

## ARTICLE INFO

## SUMMARY

Background: Measurement of length and head circumference (HC) in addition to weight is vital in assessing the nutritional status of preterm infants. Current anthropometry represents an interruption to preterm infants, and may not be possible in unstable infants. Handheld 3D scanning has the potential to perform bedside anthropometry (length and HC) in a less invasive manner. We aimed to evaluate the feasibility and performance of 3D scanning as a 'non-touch' measuring technique for routine anthropometry.
Methods: Preterm infants born before 30 weeks gestation were recruited from a single neonatal unit. HC and length were measured both manually and by a handheld 3D scanner at recruitment and weekly until discharge. The two methods were compared using the Bland-Altman method and linear regression.
Results: Seventeen infants had manual and 3D-scan measurements (67 HC, 87 length). The mean difference (95%CI) between manual and 3D-scan measures, as a percentage of the manual value, was 2.87% (2.27—3.47%) for HC and 3.10% (2.65—3.54%) for length. Correlation between manual and 3D measures was high; HC r = 0.957 and length 0.963. Bland-Altman plots showed reasonable agreement between the two methods, and there was a high correlation between scanner and manual measurements.
Conclusions: These data show a high correlation between measurements gathered from 3D scan images and standard anthropometry. However, 3D measures are not yet precise enough for routine clinical use. Refinement of technique/technology may translate into practical monitoring the growth of preterm infants with minimal handling and without interruption to developmental care.

## 1. Introduction

Routine anthropometry of preterm infants, including weight, head circumference (HC) and length are essential in nutritional assessment and management. In clinical practice HC and length measurements are often omitted because of practicalities (unwell or unstable infant). In recent years there has been an increasing emphasis on the importance of neonatal nutrition with an association between improved nutritional care, neurodevelopmental

outcomes and impact on the risk of non-communicable diseases in later life [1]. Simultaneously there is a greater emphasis on developmental care in neonatal units, with an effort to decrease inappropriate or high intensity environmental stimuli, acknowledging that the infant brain is particularly vulnerable to stress [2]. Current best practice for length measurement involves utilising a recumbent length board with two examiners to holding the infant, while HC is measured using a non-stretch measuring tape, usually in triplicate. A simple "non-touch" technique is clearly desirable in this patient group.

The 3D reconstruction of images in medicine is widely used with common medical imaging techniques, including computed tomography and magnetic resonance imaging, enabling the production of images that can be viewed in a 3D format. Over recent years, optical 3D imaging technology has been developed to give a

* Corresponding author. Department of Neonatal Medicine, Princess Anne Hospital, University Hospital Southampton NHS Foundation Trust, Coxford Road, Southampton, UK. Fax: +23 8120 8522.
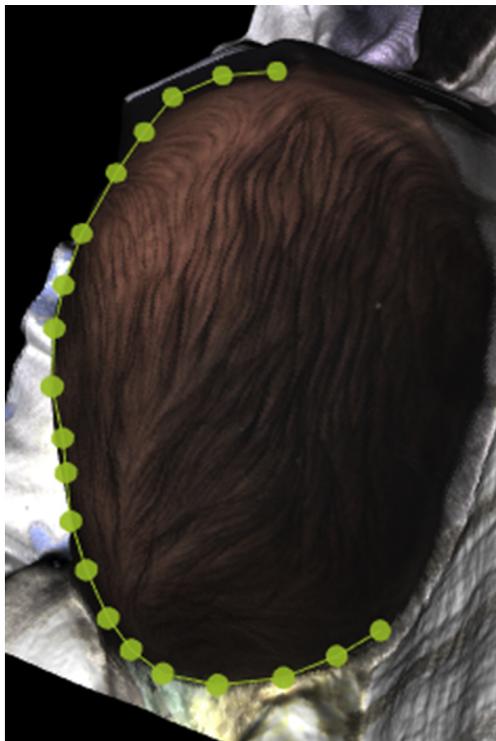E-mail address: M.Johnson@soton.ac.uk (M.J. Johnson).

high level of accuracy and image resolution, with technology becoming more durable and portable [3]. There is increasing availability of 3D imaging sensors that are designed for the human body with the ability to provide high resolution surface data [3]. This has been used in many areas of medicine including prosthesis fitting, plastic surgery, orthodontics, disease detection, 3D imaging for facilitation of 3D bioprinting of stem cells and anthropometry [3–7]. Medical imaging and 3D scanning of humans provides challenges, with humans unable to remain absolutely still (this is especially true of holding uncomfortable positions and parts of the body that are difficult to isolate) and body parts not being simple geometric shapes [4]. Optical 3D imaging technology may offer a way of carrying out neonatal anthropometry in a less invasive way.

We report a study of preterm infants who have had head circumference and length measures performed weekly via a handheld 3D scanner.

## 2. Methods

Preterm infants were recruited from a single UK neonatal unit. All infants with a gestational age (GA) at birth of below 30 weeks were considered eligible. Exclusion criteria were genetic syndromes known to impact on growth and surgical transfers into the neonatal unit. Data were collected from 01 February to 31 May 2018. Scans were taken weekly for infants in the study.

SCANIFY, a handheld point-and-shoot 3D scanner using a stereo optical camera set-up, was used to carry out 3D scans [8]. The best and most suitable image taken was selected at each time point. Measurement of HC and length were performed on the 3D images in triplicate using a digital measuring tool (see Fig. 1) with a mean value subsequently calculated. Length measurements were taken from directly above the infant and HC measurements were taken in

line with the top of the head (or as close as possible) to obtain an image of the largest possible HC. Length was measured by following the lateral contour of the infants along bony landmarks. Manual routine weekly measures for HC and length were taken by trained staff and used as the reference for the 3D scan measurements.

Bland-Altman plots, Pearson's correlation coefficient and linear regression analysis were used to compare the manually measured HC and length against the measurements obtained from the 3D scans. Both the mean differences between the manual and 3D scan measures, and the mean of the residuals (the size of the difference between manual and 3D measures expressed as a positive integer) were calculated and compared. Data were analysed using SPSS (version 24). This research study received approval from NHS research Ethics Committee and all parents gave informed consent to measure their infants (Oxford A, ref 14/SC/1275).

## 3. Results

Seventeen infants were recruited (see Table 1) with 90 HC and 91 length 3D scan images taken. Four (2 HC and 2 length) were not paired with manual measurements and were excluded from further analysis. Twenty-three scans were not able to be measured due to technical insufficiency of the images obtained (21 HC and 2 length). Eighteen of the 21 technically insufficient HC scans were performed on infants receiving continuous positive airway pressure (CPAP) respiratory support who wore a uniformly white CPAP-securing hat which decreased image capture quality.

### 3.1. Bland-Altman plots

Bland-Altman plots compared 3D scan measures to the reference of manual measurement were produced for HC and length (Fig. 2A and B respectively). Nearly all plot points fell within the limits of agreement, though these were wide (+/−2 cm) for both HC and length.

### 3.2. Absolute and residual mean differences between 3D scans and manual measurement

The mean results for HC and length measured manually and by scan are displayed in Table 1. Mean residual differences when expressed as a percentage of the manual measurement were 2.87% (2.27–3.47) for HC and 3.1% (2.65–3.54) for length, suggesting the 3D scan technique was accurate to within <4%.

### 3.3. Linear regression and Pearson's correlation

Linear regression was conducted and scatter plots for length (Fig. 2C) and HC (Fig. 2D) produced. Linear regression (beta) coefficients were 0.976 and 0.944 for HC and length respectively, suggesting that 3D scan measures of length and HC predict manual measurement accurately. Correlation was high with correlation coefficients of 0.956 and 0.963 for HC and length respectively.

## 4. Discussion

These data suggest that handheld 3D scanning has significant potential for use as a non-touch method to conduct anthropometric measures in preterm infants. The variability between scans and manual measurements was similar, and the size of the difference between the two methods was relatively small (around 3%) for both HC and length. Despite this the precision of the individual measurements does not yet equate to a technique suitable for clinical use, with refinement of the technology required. Nevertheless, the



**Fig. 1.** Digitally reconstructed 3D image of a preterm infants' head, the image has been rotated to allow the examiner to begin to apply the digital measuring tool (displayed in green).

**Table 1**
Patient characteristics and results comparing HC and length manual reference measures and digital scan measures, with 95% CI where applicable. CPAP - Continuous Positive Airway Pressure; SVIA - Spontaneously Ventilating in Air.

| | | |
|---|---|---|
| Patient number | 17 | |
| Male | 12 | |
| Female | 5 | |
| Gestational age range at birth | $24 + 0 - 29 + 5$ (mean $= 26 + 0$) | |
| CGA range at time of scan | $24 + 2 - 41 + 4$ (mean $= 32 + 1$) | |
| Total number of scan episodes | 97 | |
| Patient in incubator during scan | 73 (75.3%) | |
| Mode of respiratory support during scans: | | |
| Invasive ventilation | 27% | |
| CPAP | 27% | |
| Nasal cannula | 25% | |
| SVIA | 22% | |

| Measure | Head circumference (95% CI) | Length (95% CI) |
|---|---|---|
| Total number of paired scans | 67 | 87 |
| 3D scan mean | 26.83 cm (26.03–27.64) | 36.36 cm (35.37–37.35) |
| Manual measure mean | 26.94 cm (26.11–27.78) | 36.64 cm (35.67–37.61) |
| Mean Difference (manual − scan measure) | 1.8 mm (−0.6 to 4.2) | 2.7 mm (0.3–5.4) |
| Mean residual difference between manual and scan measure | 7.7 mm (6.1–9.3) | 10.1 mm (9.4–12.2) |
| Mean % residual difference between manual and scan measure | 2.87% (2.27–3.47) | 3.10% (2.65–3.54) |
| Measured vs 3D scan Pearson correlation | 0.957 (p=<0.001) | 0.963 (p=<0.001) |
| Coefficient of variation of manual measures | 0.01 | 0.02 |
| Coefficient of variation of scan measures | 0.01 | 0.02 |
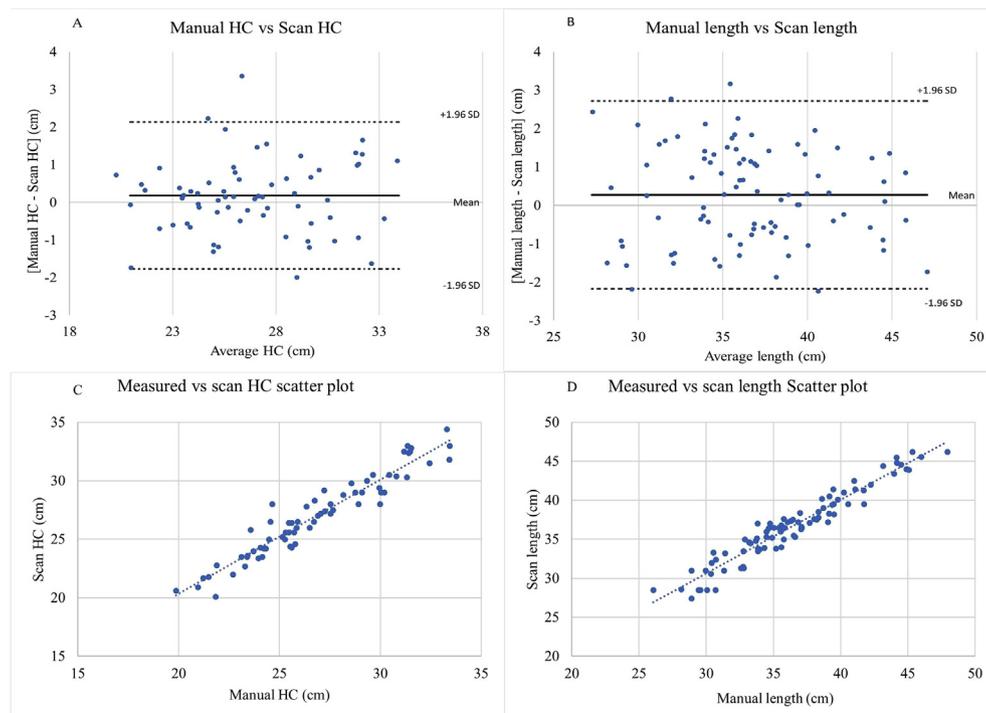


**Fig. 2.** Bland-Altman Plot showing relative differences plotted over the means of both methods for HC (A) and length (B), limits of agreement (dashed) and mean difference values demonstrated. Fig. 2C and D: Scatter plots of the scan measured and manually measured HC (C, with trendline $y = 0.976x + 0.816$ (p=<0.001) $r = 0.956$) and length (D, with trendline $y = 0.944x + 2.320$ (p=<0.001) $r = 0.963$).

extreme prematurity of some of the infants imaged ($24 + 2$ weeks) as well as 75% of scanning episodes being performed with infants in incubators, without the need to disturb or touch them, provides clear clinical utility.

There is little data on 3D scanning as a measure of neonatal anthropometry. A previous study detailed a stereoscopic imaging technique for length using a 3D measurement algorithm for pairs of 2 dimensional pictures [9]. Sokolover et al. demonstrated the technique in 54 infants (CGA 34–39 weeks at measurement), demonstrating a high degree of accuracy (technical error of measurement of 2.57 mm) compared to length measured on a board [9].

However, infants were undressed and measured outside of incubators, not fulfilling a non-touch standard.

As quality of scanning technology continues to improve, alongside development of software (including automated algorithms) able to provide better measurement and aid image processing, there is likely to be an increase in application of these techniques. Our study is limited by the small sample size and use of a single commercially available scanner. Whilst the majority of data points were within the limits of agreement, these were wide at +2.1/−1.8 cm for HC and +2.7/−2.2 cm for length. Currently such a difference is likely to be clinically important (leading to miss-

allocation of the correct growth centile), especially in smaller infants. Refinement should translate into much more accurate measures and will be an important next step in translating this technique into routine care. Further replication and validation, to assess the accuracy of other hand-held 3D scanners and assess inter-user variability bias is required. A significant future application of 3D scanning technology would be an estimate of body volume, allowing improved body composition measurements and more accurate medication dosing.

We demonstrate that handheld 3D scan measurements can produce useful measures of neonatal anthropometry, which closely correlate with manual measurements, with minimal disruption to preterm infants. Further improvement of the process and technology, alongside validation of accuracy are required before clinical adoption is possible.

## Statement of authorship

ETA, JJA, FP, RMB and MJJ completed substantial contributions to conception and design of the study and interpretation of the data, as well as drafting and revising the article and approving the final version to be published. ETA completed substantial contributions to the acquisition of the data and analysis of the data.

## Conflict of interest statement

The authors have no financial ties to products in the study or potential/perceived conflicts of interest.

## Funding sources

## Statement of financial support

## Acknowledgements

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