

Precision of weight measurement in critically ill infants: a technical report

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Fluid accumulation is common in critically ill children, and is associated with adverse outcomes.¹ It is commonly measured by net difference in fluid intake and output,² but change in weight is potentially more suitable. Weighing is performed infrequently due to technical difficulties, patient instability, and difficulties in accounting for the weight of medical equipment and its impact on true changes in the patient's bodyweight. Moreover, there are concerns about poor agreement with fluid balance charts.³⁻⁵ Few studies have investigated the precision of weight measurements in mechanically ventilated children. Therefore, we performed a prospective observational study of the precision of consecutive weight measurements in mechanically ventilated children.

Methodology

A prospective cohort study was performed in children admitted to the Royal Children's Hospital paediatric intensive care unit (PICU) between September 2020 and February 2021. Ethics approval was obtained from the Royal Children's Hospital Human Research Ethics Committee (HREC study number QA/66547/RCHM-2020). Mechanically ventilated children nursed in an Atom infant warmer cot (Parker Healthcare, Melbourne, Australia) were included. Previously enrolled, prone positioned, and clinical unstable children were excluded. After parental verbal consent, two consecutive weight measurements were performed.

Weighing technique

The built-in scales in the Atom infant warmer cot were used after testing for accuracy with calibrated weights (Online Appendix, table 1). The weighing procedure is outlined in the Online Appendix (box 1). Each measurement was performed by the principal investigator (BG) with assistance from nursing staff. The first weight was recorded by staff not involved in performing the measurement. Data were entered into a REDCap database V10.7.1 (Vanderbilt University, 2021).

ABSTRACT

Objectives: To investigate the precision of weight measurements in critically ill infants in a paediatric intensive care unit (PICU).

Design: Prospective cohort study.

Setting: Royal Children's Hospital PICU.

Participants: Mechanically ventilated infants admitted to the Royal Children's Hospital PICU between September 2020 and February 2021.

Main outcome measures: Mean percentage difference and agreement of consecutive weight measurements.

Results: Thirty infants were enrolled, of which 17 were receiving post-surgical care for congenital heart disease and four were receiving extracorporeal membrane oxygenation (ECMO). The median age was 13 days (interquartile range [IQR], 3.1–52.4 days). The mean difference in weight was 1.3% (standard deviation [SD], 1.0%), and the test-retest agreement intraclass correlation was 0.99 (95% CI, 0.99–0.99; $P < 0.01$). The percentage difference between measurements was $\leq 2.5\%$ in 26/30 (87%) children, and the range was $< 0.1\%$ to 3.6%. In 26 children not receiving ECMO, the mean difference in weight was 1.1% (SD, 1.0%). There were no complications.

Conclusions: Weighing mechanically ventilated, critically ill infants in intensive care can be performed safely, with a mean difference between consecutive weights of 1.3%, making it a potentially useful additional measure of fluid accumulation.

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Statistical analysis

Demographic and clinical data were described using frequencies and proportions. Absolute difference (g) and percentage difference (absolute difference \div first weight $\times 100$) between weights were calculated. The

normality of the data was confirmed using the Shapiro–Wilk test (Online Appendix, figure 1) and the mean (standard deviation [SD]) difference was presented. Test–retest agreement was assessed using intraclass correlation (ICC) and Bland–Altman analysis. Sensitivity analysis was performed excluding children receiving extracorporeal membrane oxygenation (ECMO). Analyses were performed with the “irr”, “lpSolve” and “blandr” packages; R software, version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria). The ICC estimates with 95% confidence intervals (CIs) were based on single measurements, using a two-way model, and assessed for agreement. A *P* value < 0.05 was considered statistically significant.

Results

Thirty paired weights were performed. The demographic and clinical characteristics of children are shown in the Online Appendix (table 2).

Weight measurements

The mean first weight of all children was 3611 g (SD, 621 g). The individual paired weight measurements, absolute and percentage differences, and mean (SD) are shown in the Online Appendix (table 3). The test–retest agreement ICC was 0.99 (95% CI, 0.99–0.99; *P* < 0.01). The mean proportional weight difference was 1.3% (SD, 1.0%). The percentage difference was ≤ 2.5% in 26/30 children (87%), and the range was < 0.1% to 3.6% or 1 g to 94 g in two children weighing 2849 g and 2619 g respectively. Figure 1 shows the frequency of percentage weight differences. The Bland–Altman analysis, bias, and limits of agreement are shown in Figure 2 and in the Online Appendix (box 2).

Sensitivity analysis

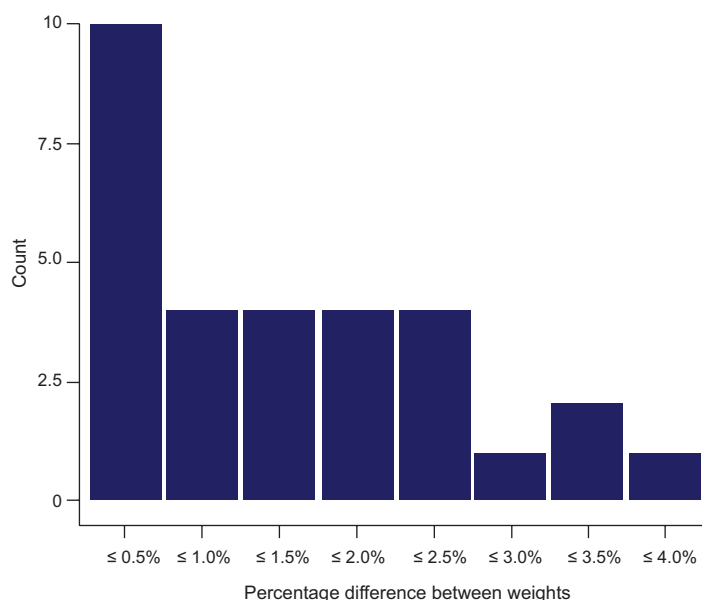
In 26 children not receiving ECMO, the mean proportional weight difference was 1.1% (SD, 1.0%). The interobserver agreement ICC was 0.99 (95% CI, 0.99–0.99; *P* < 0.01). No complications occurred during weighing.

Discussion

Key findings

In this study, we showed that weighing mechanically ventilated infants can be performed safely with precision. The mean difference between sequential measurements was 1.3%, and when excluding children receiving ECMO, the mean difference was 1.1%. The test–retest agreement

Figure 1. Frequency of percentage differences between two consecutive weight measurements (*n* = 30 infants)



was high, and a high proportion of measurements had a mean difference ≤ 2.5%.

Weighing children and adults in intensive care

Measuring weight in critically ill children is uncommonly performed⁶ due to technical difficulties. In critically ill adults, weight change poorly correlates with recorded measurements of fluid balance;⁷ (*r* = 0.34)³ and (*r* = 0.28).⁴ In children, the correlation is better (*r* = 0.63); however, high mean differences challenge its clinical utility.⁵ Inaccuracies of both weight and recorded measures of fluid balance make their comparison difficult.

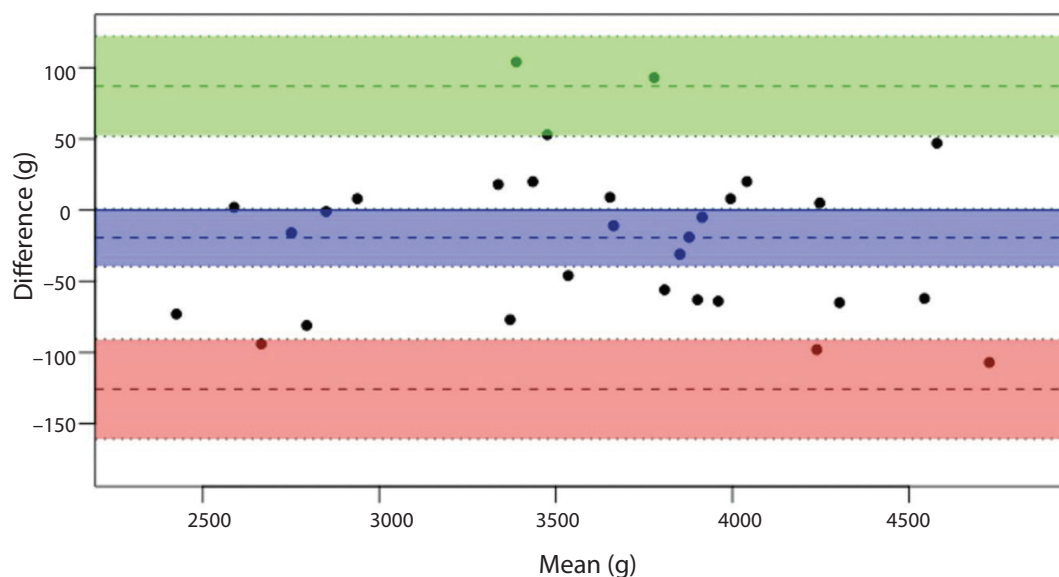
Implications of findings

A mean difference in sequential weight measurement of 1.3% is a clinically acceptable margin for assessing fluid accumulation, particularly considering that fluid accumulation is commonly assessed in 5–10% increments^{2,8,9} and even dichotomised at 20%.¹⁰ Four weight differences were between 3% and 4%, indicating the need for optimising the technique. But in absolute terms, the peak difference was 94 g — infants are more prone to higher proportional changes.

Strengths and limitations

The strength of this study is the standardisation of weighing technique using accurate scales and consistent operators.

Figure 2. Bland–Altman plot for analysis of agreement between two weights (n = 30)



The limitations are that we only studied infants weighing up to 5 kg. However, this population has greater proportional margin for difference in weight. We did not subtract the weight of attached devices, but consecutive weights were performed without interval change in the number of devices.

Conclusion

Weighing critically ill infants can be performed safely, with a mean test–retest agreement of 1.3%, making it a potentially useful additional clinical measure of fluid accumulation.

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Competing interests

No relevant disclosures.

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