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Relationship between body weight and fluid balance in critically ill patients – A prospective observational study

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1. Introduction

Body weight and fluid balance are essential parameters for precise management of patients in an intensive care unit. The positive fluid balance is related to morbidity and mortality in critically ill patients.

Patients' weight is not only limited to dosing of medications. Several calculations, such as nutritional prescriptions using Harris-Benedict's formula [1] or the Cockcroft-Gault estimation of glomerular filtration rate [2], as well as intensive care unit scoring systems, such as SOFA (Sequential Organ Failure Assessment) [3] rely on knowledge of the patients' weight.

The effective management of critically ill patients requires accurate assessment of their fluid balance status. This assessment includes appropriate monitoring of fluid intake and output, as well as the accurate calculation and correct recording of this data. Because, over a short period, changes in body weight is probably associated with change in body fluids, measurement of body weight may be a more accurate way of estimating fluid status. However, the relationship between recorded fluid balance and actual body weight is impacted by insensible fluid losses and inaccuracies associated with fluid balance documentation.

The body weight measurements by bed scales may help to assess fluid status in patients with acute kidney injury, which is conventionally done by assessing fluid balance. This data along with other routine cardiovascular and physical examination may be useful for optimal management of the patient where positive fluid balance is associated with increased morbidity and mortality.

To our knowledge, only three studies [6-8] have assessed the relationship between change in body weight and fluid balance in critically ill patients. Therefore we designed this study to determine the correlation and agreement between changes in 24-h fluid balance and changes in actual body weight.

2. Methods

We conducted this study in a 26-bedded level 3 ICU in Westmead Hospital (800 bedded tertiary referral center affiliated to University of Sydney). The ICU is a mixed medical and surgical unit and admits approximately 1200 patients per year with a mean APACHE II score of 18.0. The case mix includes patients with poly-trauma, cardiac surgery and neurosurgery.

We screened all patients admitted to Westmead ICU over a period of six months (from July 2014 to December 2014) and enrolled those who met the inclusion criteria. We measured weight at midnight in align with the fluid balance calculation for total net loss or gain at this time for five consecutive days. We compared the changes in body weight to that in fluid balance for day three, four and five. We did not study their relationship on day one and two as the correlation between body weight and fluid balance may not be accurate due to possible rapid fluid shifts during the initial resuscitation phase. Our inclusion and exclusion criteria were as below.

Inclusion criteria

- Age > 18 years
- ICU length of stay ≥ five days

Exclusion criteria

- Pregnancy
- Body weight > 225 kg
- Non calibration of a bed prior to admission
- Visit to operating theatre for any surgical intervention on days three to five

2.1. Definitions

2.1.1. Body weight

Patient's actual body weight was checked using Hill Rom Total Care SpO2RT-2 beds [4], which offer easy bed taring and weighing capacities. These beds have been in use for the last seven years at Westmead ICU and all nurses are trained in preparing and taring the beds prior to the patients' admission. All beds were checked and tared before measuring any patients' weight to minimize the errors.

2.1.2. Fluid balance

All fluid movements were recorded by the bedside nurse and were noted in the conventional fluid balance chart. The daily fluid balance was defined as the difference between total inputs (all fluids, nutrition,

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medications and blood products, whatever the route of administration) and total outputs (losses through urinary, gastrointestinal or other drainage tubes). Fluid balance was calculated at midnight for five consecutive days.

2.1.3. Insensible fluid losses (IFL)

These were calculated according to a pre-determined formula [5]:
IFL (milliliters) = 800 + 20% × 800 × (maximum temperature - 37).
This value was divided by two if the patient was intubated.

2.2. Data collection

Following data were collected from patients' case notes:

- Demographics: age, sex, date and time of admission to ICU
- Type of admission: medical, surgical
- Presence or absence of endotracheal tube
- Physiological parameters: Collected daily from the ICU charts
  - o Temperature
  - o Actual body weight
  - o Fluid balance

2.3. Statistical analysis

Continuous data were expressed as mean ± SD and categorical data as numbers and proportions. The Pearson correlation tests were performed to find correlation between body weight and fluid balance. The agreements between fluid balance and actual body weight were compared with the Bland and Altman method with range of agreement being the mean bias ±2 SD. Error graph was used to show 95% confidence interval.

2.4. Ethics

The study was approved by the hospital ethics committee.

3. Results

As presented in Fig. 1, a total of 508 patients were screened during the study period and 197 of these met the inclusion criteria. Complete data was available for 143 patients (mean age 61.4 years, 56.7% males and 69.9% medical). Altogether, 429 data pairs were obtained.

The difference in the change in body weight and change in fluid balance was ≤1.0 kg (Lt) in 31.8% patients, where as it was ≥5.0 kg (Lt) in only 6.0% of the patients.

The correlation between change in body weight and change in fluid balance is presented in Table 1. The Pearson coefficient (r) was 0.38 (95% Confidence interval (CI) 0.23–0.51, *p* value < .001), 0.53 (95% CI 0.40–0.64, *p* value < .001) and 0.38 (95% CI 0.23–0.51, *p* value < .001) on day three, four & five respectively.

The agreement between the paired data (change in body weight and change in fluid balance) for days three, four and five was analyzed using Bland & Altman plots. The mean bias ranged from 0.50 ($p = .044$), 0.42 ($p = .043$) and 0.29 ($p = .186$) on day three, day four and day five respectively and the corresponding limits of agreement were very wide (−5.46 to 6.48, −4.56 to 5.41 and −5.01 to 5.60).

See Fig. 2 (1–3) and Fig. 3 and Table 2.

4. Discussion

4.1. Statement of principle findings

We prospectively studied the relationship between the changes in body weight and changes in fluid balance in143 out of 197 eligible patients in ICU. We found that although the mean bias was small, the limit of agreement between these two variables on day three, four and five was wide.

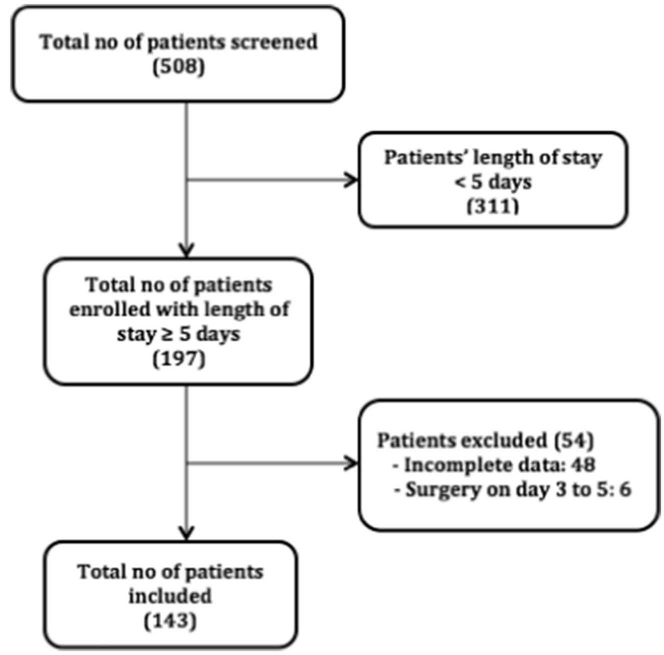

Fig. 1. Participant flow.

4.2. Comparison with previous studies

To our knowledge, only three studies have investigated the relationship between change in body weight and fluid balance in the intensive care settings and our results are consistent with the previous studies.

Schneider et al. [6] assessed the fluid balance and body weight in critically ill patients in 160 ICU admissions. The data was collected from the patients whose stay exceeded two days in ICU. Compliance was a problem and complete data was obtained only in a minority of eligible patients (31.7%). They found that change in body weight over 24 h and fluid balance for the same period was only weakly correlated before or after correction for insensible fluid losses. On Bland-Altman plot, the mean bias was small (0.07 kg), but the 95% limits of agreement were very large (−5.8 and 6.0 kg). This study concluded that the correlation between changes in body weight and fluid balance was weak.

Perren et al. [7] performed a similar study where they prospectively assessed body weight and fluid balance in 147 patients in an ICU setting. Compliance was a problem with this study as well and complete data was obtained only in 38% of eligible patients. This study reported a high error rate for the fluid balance calculation (33%) with errors ranging from −3.6 to 2.0 L. Correlation (r) and Bland-Altman agreement was poor between body weight changes and net cumulative fluid balance (0.552 and − 1.26 ± 5.41 kg) and slightly better between body weight changes and adjusted cumulative fluid balances (0.714 and +0.18 ± 3.68 kg) This study concluded that fluid balance calculations have a high error rate and cumulative fluid balance shows poor agreement with measured body weight changes.

Table 1
Correlation between change in body weight and change in fluid balance.

Change in body weight – Change in fluid balance	Correlation	95% Confidence interval	*p*
Day three	0.38	0.23–0.51	<.001
Day four	0.53	0.40–0.64	<.001
Day five	0.38	0.23–0.51	<.001

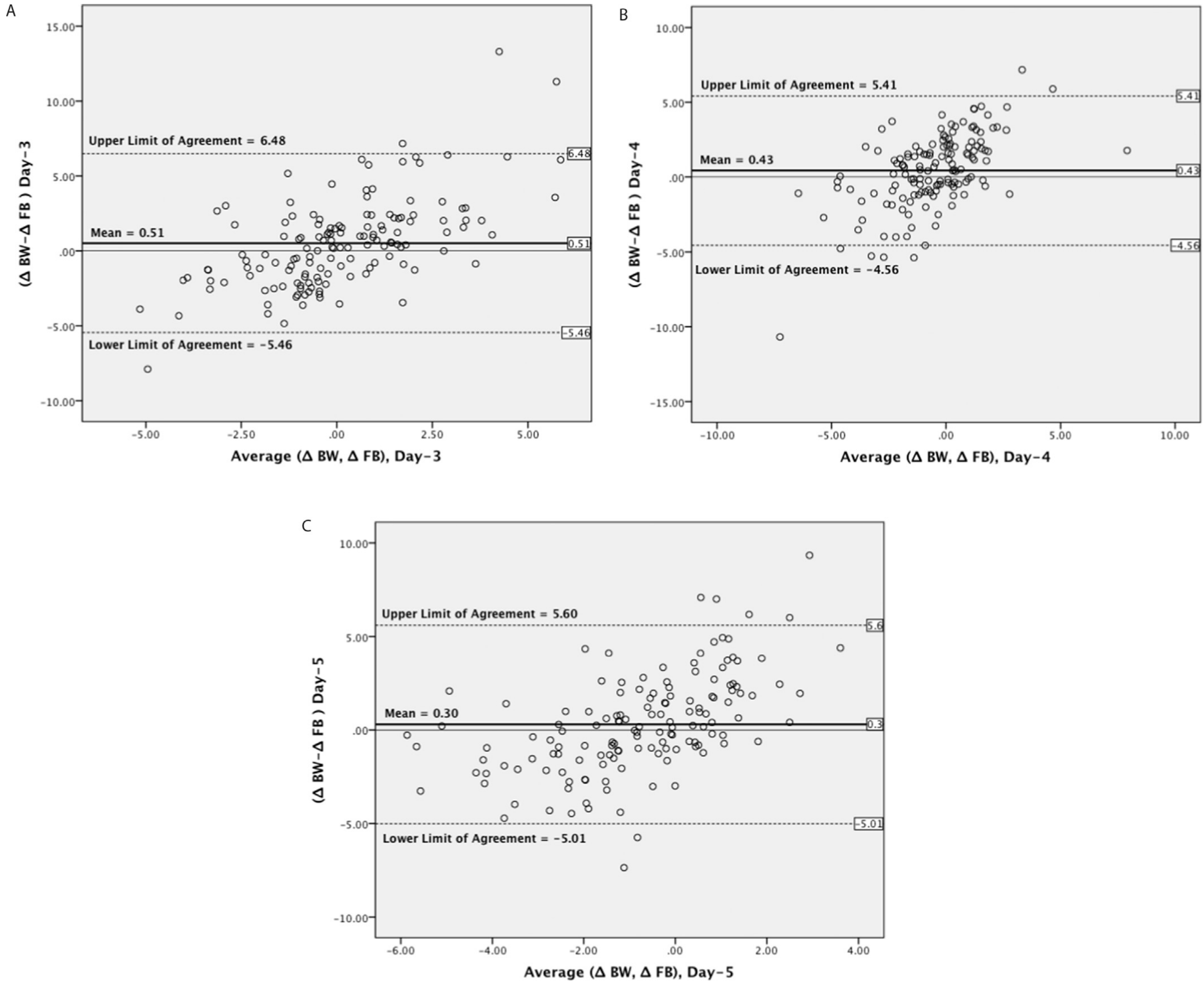

Fig. 2. 1) Bland Altman plot (Change in body weight and Change in fluid balance) for day three. 2) Bland Altman plot for (Change in body weight and Change in fluid balance) for day four. 3) Bland Altman plot (Change in body weight and Change in fluid balance) for day five.

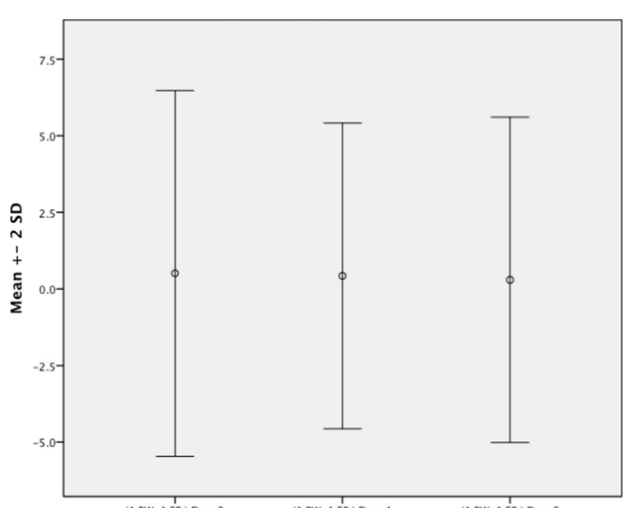

Fig. 3. Mean ± 2 SD for (Change in body weight and Change in fluid balance) on day three, four and five.

Eastwood [8] assessed the change in body weight with the fluid balance in 32 patients undergoing cardiac surgery. They found poor agreement between fluid balance and body weight. Body weight changes were overestimated in 31.2% patients (range, +0.33 to +5.25 kg), underestimated in 59.4% patients (range, −0.26 to +6.57 kg) and correctly estimated only in 9.75% of patients. This study demonstrated poor agreement between recorded fluid balance and change in body weight for patients undergoing cardiac surgery.

Freitag et al. [9] compared six different types of weighing scale in critically ill patients. Three methods were selected by the expert panel for the comparison. The results were compared to a 'standing scale' as the 'gold standard' for body weight. A range between 4.4 and 9.1 kg was displayed by the Hill—Rom weigh-bed, which was the middle range compared with the gold standard. The Mercury bed scale displayed the narrowest range of 1.6–6.8 kg to the gold standard. This range produced by the Mercury bed scale correlated closest to the 'gold standard' measurements and was therefore determined as the most accurate method. This study concluded that critically ill patients could be weighed effectively and accurately with a scale usable for every type of bed available in this ICU.

Table 2
Bland Altman analysis.

Change in body weight − Change in fluid balance	Mean	SD	*p*	Minimum	Maximum	Upper limit of agreement	Lower limit of agreement
Day three	0.51	2.99	.044	−7.89	13.3	6.48	−5.46
Day four	0.43	2.49	.043	−10.69	7.16	5.41	−4.56
Day five	0.3	2.66	.186	−7.36	9.34	5.6	−5.01

4.3. Strengths and limitations

Our study has several strengths. First, we prospectively collected the data and were able to obtain complete data for 72.5% of eligible patients. Second, we sent all beds to our biomedical engineering department who recalibrated them prior to the commencement of the study in order to minimize the errors. Third, we trained all nursing staff to accurately measure weights with and without specified items on the bed. Four, our ICU is a level three tertiary referral center and a trauma unit and hence the results are applicable to other ICUs of similar nature.

There are few limitations to our study. First, we were unable to measure the insensible fluid losses accurately. Currently there is no consensus in the literature on the ways to calculate it. We disregarded the body weight change due to solid feces. Second, we did not check the accuracy of the fluid balance that was calculated manually by the nursing staff. Third, our study is performed in one unit only and hence the results may not be generalizable.

4.4. Implications for future research

More studies are needed to investigate body weight changes in critically ill patients and accuracy of conventional recorded fluid balance charting methods. Currently, there are no ways of calculating gastrointestinal losses. Therefore, further research is needed to study more objective ways of calculating insensible fluid losses.

5. Conclusion

We found wide limits of agreement between the changes in fluid balance and body weight. Body weight measured by electronic weighing beds was not sufficiently robust or accurate to replace daily fluid balance in ICU. The accuracy of body weight as a surrogate marker for fluid balance is unreliable.

Acknowledgements

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