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Original Article

Effectiveness of daily fluid balance charting versus body weight measurement as a guide for fluid administration therapy after cardiac surgery

Mohammed Elgazzar[1], Ehab Said[2], Osama Sanad[3], Gamal Lotfy[4], Mahmoud Shafie[1]

[1] Department of Cardiothoracic Surgery, Faculty of Medicine, Banha University, Banha, Egypt

[2] Department of Anaesthesia, Faculty of Medicine, Banha University, Banha, Egypt

[3] Department of Cardiology, Faculty of Medicine, Benha University, Benha, Egypt

[4] Department of Intensive Care, El-Mehalla General Hospital, Egypt

Abstract

Background: Several studies have established a link between fluid overload and an increased risk of death. After cardiac surgery, patients' fluid status should be assessed at close intervals. A daily fluid balance (FB) has several limitations. This study aims to determine the agreement and correlation between fluid status changes calculated by the daily fluid balance through the conventional charting approach and body weight (BW) change using beds equipped with weighing scales.

Methods: This is a prospective observational study that included 50 patients who underwent cardiac surgeries. It evaluates the precision and usefulness of determining body fluid status and requirements using daily fluid balance and body weight measurements.

Results: The mean age of the study group was 52.9 ±10.44 years. The mean weight, height, and BMI were 87.1 ± 16.68 Kg, 170.4 ± 4.59 cm, and 30.12 ± 6.21 kg/m2. The mean duration of mechanical ventilation was 9.5 ±3.73 h. Mean ICU and hospitalization times were 2.4 ± 0.67 and 6.3 ± 1.36 days, respectively. The mean cumulative fluid balance was 0.52 ± 3.21 L, and the overall change in body weight (discharge weight − admission weight) was 0.55 ± 2.89 kg. There was a highly significant positive correlation between overall bodyweight and cumulative fluid balance (r- coefficeient= 0.947, p-value <0.001).

Conclusion: Bodyweight measured by weight-enabled beds could seem sufficiently robust or accurate to replace daily FB in ICU post open heart. Such measurement might be used to monitor overall changes in BW in patients with a prolonged ICU stay.

KEYWORDS

Fluid balance; Body water; Fluid administration therapy

Article History

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Introduction

Water constitutes approximately 50% to 60% of total body weight. The relationship between total body weight and total body water (TBW) is relatively constant for an individual and is primarily a reflection of body fat. TBW is divided into three functional fluid compartments: plasma, extravascular interstitial fluid, and intracellular fluid. Fluid overload occurs when the fluid used to expand the intravascular fluid compartment causes depression of ventricular function due to overfilling, and impaired capillary permeability

Corresponding author: Mohammed Elgazzar elsatoor@hotmail.com

allows fluid to leave the circulation and re-distribute into the extravascular space. This situation is exacerbated when the response to subsequent episodes of hypotension results in impaired kidney function reducing the excretion of sodium and water while more fluid is being administered [1].

In certain cases, the patient may need intrusive hemodynamic testing to determine the circulatory volume's sufficiency. The patient's body fluid status can be determined using non-invasive procedures such as physical examination, regular fluid balances, and body weight shift monitoring. It is critical to understand a patient's body fluid status to maintain a sufficient circulatory volume, avoid fluid overload, and maintain homeostasis [2].

It is a routine nursing task to chart fluid intake and output per hour and to calculate daily fluid balance totals. It is one of several non-invasive techniques used in the ICU to help estimate body fluid status. While subtracting reported fluid output from patient input is a straightforward mathematical operation, managing critically ill patients is difficult as regular fluid balance charting is challenging and time-consuming. This involves fluid infusions such as blood products, liquid nutrition, and intravenous drugs. This vigilance is also required in hourly monitoring of urinary output and other body fluids loss, such as fluid loss through surgical drains. Fluid balance totals charting is prone to error due to recording inaccuracies in inputs and outputs or when the nurse incorrectly calculates fluid balance totals, particularly when large numbers of measurements are involved [3].

Using paper charts to record fluid balance totals, a pocket calculator can help minimize addition and subtraction errors. Although using a computer-based spreadsheet as a part of an information system minimizes calculation errors, it does not solve missed or double entry errors on the bedside monitor [4].

If no adjustments are made for body water loss due to insensible fluid losses, such as breathing and fever, the risk of inaccuracies in fluid balance increases. While obvious fluid losses like urine and surgical drains can be measured, insensible fluid loss is determined by some variables that are difficult to predict, such as fluid loss in expired air. Fluid balance charting becomes less accurate due to these problems with inputs and outputs recording in ICU patients, amplifying the clinical value when errors occur for many days [5]. Therefore, this work aimed to study simple, rapid, and predictive methods to determine body weight changes in critically ill patients.

Patients and methods:

Design and patients:

This research is a comparative observational prospective study that included 50 patients who underwent cardiac surgery. The mean age was 52.9 years, and 80% were males. Data were collected from the Cardiothoracic Surgery Department database. We included critically ill adult patients with severe acute kidney injury requiring renal replacement therapy (RRT), cardiogenic shock who developed significant heart failure, and acute lung injury, which required mechanical ventilation. The body fluid status of those patients was measured using fluid balance and body weight measurements following adult open-heart surgeries (aortic valve replacement, mitral valve replacement, or both and/or coronary artery bypass grafting (CABG). We excluded patients with bodyweight more than 181.4 kg (181.4 kg is the limit of scale validation), length of ICU stay was > 48 hours, and if there were no tarred beds before admission (calibrated with default beddings in place).

Fluid balance calculation:

On an A3 chart, hourly input and output were manually registered (intravenous medications, maintenance fluids, blood products, fluid boluses, and nutrition) and outputs (drain contents, urinary output, and estimation of feces volume). On an hourly basis, the fluid balance (FB) is measured manually and was fixed between 1200 and 2400. The study investigators conducted random tests for measurement errors. Cumulative FB was calculated as daily FBs sum from ICU entry to discharge.

Insensible fluid losses (IFL was calculated according to this formula; IFL (milliliters) = 800 + 20% × 800 × (maximum temperature – 37). In the case of intubation, the value was divided by two.

Study beds:

We used the ArjoHuntleigh Enterprise 9000X acute care hospital bed. These beds feature an easy-to-use bed tarring system and a weighing capacity. The nursing staff received instruction on how to handle and tare the bed prior to the study's start. The necessity of tarring the bed prior to the patient's admission and temporarily removing any additional weight was stressed. Before usage, electronic bed scales were calibrated. The calibration was done while the patient was prepared for admission, usually during the second half of cardiac surgery. Before calibrating the bed, all things except a regular list of beddings and sheets were removed from its surface.

Measurements were done upon ICU admission and then two times per day at 12 p.m. and 12 a.m. to correspond to the 1200- and 2400-hour FB calculations. Nurses removed any excess weight not included in the tare items list before pressing the "weigh" button. Urinary bags, drains, and disinfectant bottles were all examples of these. Nothing was to be touched that was tied to the bedside poles (the measuring system disregards the weights in these places.). Things that were not removable or were difficult to remove (calf compressor devices, intravascular catheters, and additional pillows for patient positioning) were recorded on the data collection sheet. During the data analysis stage, their average weights were subtracted from the recorded weight. Before pressing the "Weigh" button, the bed head had to be lowered by more than 30°. For the analysis, the findings and the number and form of non-removable objects were entered into a data collection tool. On random occasions, proper weighing techniques and sufficient recording were checked.

Endpoints:

The primary endpoint was the cumulative fluid balance. Secondary endpoints were the duration of mechanical ventilation, ICU stay (days) and hospitalization period (days), and ICU mortality.

Ethical considerations:

An approval from the Research Ethics Committee in Benha Faculty of Medicine was obtained. Informed written consent was obtained from all participants before participation; it included data. about the aim of the work, study design, site, time, subject and measures, confidentiality

Statistical analysis

The collected data were summarized in terms of mean ± standard deviation (SD) for quantitative data and frequency and percentage for qualitative data. The correlation between the two methods was performed using Pearson correlation. The agreement between the two quantitative measurements was assessed with Bland-Altman analysis. The statistical analysis was conducted using the Software, Statistical Package for Social Science (SPSS Inc. Released 2009- PASW Statistics for Windows Version 21.0. Chicago: SPSS Inc.). Differences were considered statistically significant when the P-value was less than 0.05.

Results:

The study included 50 patients; 40 were males, and 10 were females. Smokers accounted for 62%. Hypertensive patients accounted for 25 (50%), and diabetic patients accounted for 35 (70%). The mean age of the study group was 52.9 ±10.44 years. The mean weight, height, and BMI were 87.1 ± 16.68 Kg, 170.4 ± 4.59 cm, and 30.12 ± 6.21 kg/m2. (Table 1)

The mean duration of mechanical ventilation was 9.5 ±3.73 h. Mean ICU and hospitalization times were 2.4 ± 0.67 and 6.3 ± 1.36 days, respectively. (Table 1)

The mean cumulative fluid balance was 0.52 ± 3.21 L, and the overall change in body weight (discharge weight − admission weight) was 0.55 ± 2.89 kg. The fluid balance and body weight changes over the four days of ICU admission at midday and midnight were presented in Table 2.

There was a highly significant positive correlation between overall bodyweight and cumulative fluid balance (r- coefficeient= 0.947, p-value <0.001). Bland-Altman plot between 50

Table 1: Baseline and postoperative data. Continuous data were presented as mean and SD and categorical data as numbers and percentages.

Variable	n= 50
Males	40 (80%)
Smokers	31 (60%)
Hypertension	25 (50%)
Diabetes mellitus	35 (70%)
Age (years)	52.9 ± 10.44
Weight (kg)	87.1 ± 16.68
Height (cm)	170.4 ± 4.59
Body mass index (kg/m²)	30.12 ± 6.21
Duration of mechanical ventilation (h)	9.5 ± 3.73
ICU stay time (days)	2.4 ± 0.67
Hospitalization period (days)	6.3 ± 1.36
ICU mortality	2 (4%)

changes in body weight and cumulative fluid balance showed agreement between daily bodyweight changes and fluid balance. (Figure 1)

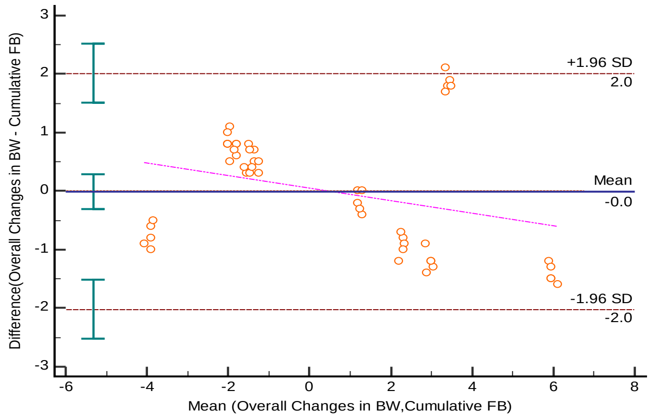

Figure 1: Bland-Altman plot between changes in body weight and cumulative fluid balance showing agreement between daily bodyweight changes and fluid balance

Discussion

The relationship between body weight and fluid balance is the subject of several studies. In contrast to most previous research, this one was conducted in a far more regulated environment; smaller ICU, more stable and experienced workforce, and homogeneous patients due to our restriction to those who underwent cardiac surgery. As a result, a higher percentage of potential weights were collected, implying a higher degree of data reliability.

Despite these distinctions, the findings obtained with a highly significant strong positive correlation and broad agreement limits between BW and FB changes were comparable to those obtained in previous studies.

Table 2: Changes in fluid balance and bodyweight

Variable		
Changes in fluid balance(L)		**Mean ± SD** (range)
Day1 (n=50)	*Midday*	0.83 ± 0.52 (0.3 – 1.8)
	Midnight	0.29 ± 0.76 (-1.1 - 1)
Day2 (n=50)	*Midday*	-0.02 ± 0.55 (-0.9 – 0.6)
	Midnight	0.02 ± 0.62 (-1.2 – 0.9)
Day3 (n=15)	*Midday*	0.37 ± 0.73 (-0.4 – 1.3)
	Midnight	-0.07 ± 0.52 (-0.6 – 0.6)
Day4 (n=5)	*Midday*	0.82 ± 0.08 (0.7 – 0.9)
	Midnight	0.62 ± 0.08 (0.5 – 0.7)
Changes in BW(Kg)		
Day1 (n=50)	*Midday*	0.81 ± 0.37 (0.3 – 1.6)
	Midnight	0.31 ± 0.68 (-0.9 – 1.4)
Day2 (n=50)	*Midday*	0.08 ± 0.75 (-0.7 – 1.4)
	Midnight	0.13 ± 0.69 (-0.7 – 1.3)
Day3 (n=15)	*Midday*	0.23 ± 0.68 (-0.5 – 1.1)
	Midnight	0.1 ± 0.61 (-0.5 – 0.9)
Day4 (n=5)	*Midday*	1.1 ± 0.14 (1 – 1.3)
	Midnight	1.56 ± 0.11 (1.4 – 1.7)

Numerous studies have examined the measured FB accuracy and compared it to the BW measured at admission and discharge. Eastwood and colleagues evaluated the FB's accuracy by comparing it to changes in body weight in thirty-two patients undergoing cardiac surgery. The BW was determined before surgery and after ICU discharge. Patients were weighed using standard scales, and those unable to sit on the scale were removed from the sample. This study established the possible drawbacks of cumulative FB throughout an ICU stay [6].

This is easily explained by the errors' accumulation (in encoding, estimation, or otherwise) through the ICU stay period. As the stay duration increases, the measured accumulated FB moves away from the accurate value. However, as shown in this report, BW calculation is also subjected to various potential errors.

Indeed, our research contradicts this one regarding the association between cumulative FB and BW changes, even in patients with a short ICU stay (2.4 ± 0.67 days). Perren and coworkers recently conducted a study in a general ICU, and 147 patients were weighed on admission and discharge using a MultiCare bed. Notably, they collected sufficient data on only 38% of patients admitted during the study. They found a moderate correlation ($r2 = 0.714$) between adjusted FB and BW changes and found large limits of agreement [7]. We weighed just 50 patients on ICU admission and discharge using a MultiCare bed. Additionally, our research contradicts this study and its findings, as our study found a highly significant positive correlation and agreement between BW and FB changes. Additionally, Perren and associates reported a high FB calculation error rate (33%), with errors ranging from -3.6 to 2.0 L. They concluded that FB is an unreliable method for assessing fluid changes in ICU patients. Consistent with this analysis, we also discovered that BW and FB changes had large agreement limits. However, in our study, we used a computer-based FB record and automated calculation, eliminating concerns about calculation errors but not completely eliminating double or missing entries or keying errors [7].

Using integrated bed scales, Schneider and associates found no correlation between accumulated fluid balances (with and without insensible perspiration adjustment of 10 ml/kg BW/day) and related changes in body weight after 12 hours [8].

Schneider and coworkers also found a weak correlation and wide agreement limits between BW and FB changes. But in our study, we found a good positive correlation and also wide agreement limits between BW and FB changes [8].

Gil Cama and Mendoza Delgado recently conducted a prospective study in which they compared body weight shifts with measured fluid balance in twenty critically ill patients admitted to the ICU. Every 48 hours, each patient was weighed on a minimum of three times, and their cumulative balance for the duration of their ICU stay was measured. The results indicated that regardless of oral diet, feces, fever, mechanical ventilation, or diaphoresis, the cumulative balance adequately represented body weight changes after the sixth day. Further review of their findings showed that weight fluctuations were more closely represented by the cumulative balance in patients weighing less than 75 kg at admission than in those weighing more [9].

We weighed fifty patients every 12 hours and measured their cumulative balance throughout their ICU stay. On the other hand, Roos and coworkers performed a prospective, consecutive sample analysis to ascertain improvements in body weight in critically ill patients. Thirty-one patients were analyzed using estimated weight changes in conjunction with accumulated fluid balance corrections for insensible losses compared to the assessed weight shift. There was no discernible relationship between the observed weight change and the estimated weight change derived from the fluid balance chart. They concluded that determining one's body weight remains a critical component of fluid assessment. Thus, while the reliability of cumulative fluid balance may be insufficient for patients with brief ICU stays, this restriction may not extend to patients with intermediate to long-term ICU stays post-operatively [10].

Implications for clinicians:

Weight-enabled beds cannot replace FB recording or vice versa. Errors in BW measurement have a clinically important impact. Both the high degree of compliance and expertise of nursing staff imply that the weighing procedure is being followed. Indeed, the most plausible reason for the correlation absence is the significance of non-removable objects left on the bed.

Missing one pillow or blanket results in a more than 1-kg overestimation of BW. These types of errors are common, difficult to diagnose immediately, but potentially significant clinically. As a result, these ICU bed BW measures cannot be used to render clinical judgments.

On the other hand, patterns in BW shifts over time could be less prone to error accumulation. As a result, such adjustments may be used to assess mid-to-long-term fluid status changes. This, however, should be verified by additional research. Finally, our results cast doubt on the cost-effectiveness and clinical value of bed weighing in ICU patient management.

Strengths and limitations of the study:

This analysis has several advantages. We conducted a prospective study of fifty consecutive patients admitted to our intensive care unit following cardiac surgery. FB was adjusted for insensible fluid losses to eliminate errors, and analyses were performed on intubated and non-intubated patients. We gathered accurate information at the time of the weigh-in about the things on patients' beds.

Regarding limitations of this study, changes in BW were compared to changes in FB in the absence of a criterion norm. Those comparisons, as discussed previously, have a slew of flaws. Despite its imprecision, such FB is unlikely to underestimate or overestimate body fluids changes by more than 0.5 L/kg over a 12-hour duration. The literature has no consensus about the method for calculating insensible losses. Data were provided both with and without correction to account for this ambiguity.

We conducted this research in a small, highly qualified intensive care unit, and only patients undergoing cardiac surgery were included. As a result, our results could not be applicable to other units. However, such an ICU and such patients were purposefully selected to optimize BW measurements' reliability and minimize errors due to lack of experience, stability, or motivation.

Suppose BW cannot be reliably calculated repeatedly in a setting with such homogeneous patients in the context of a clinical study. In that case, we believe that achieving better results, chances in a "natural" ICU under standard working conditions would be meager.

Another issue with this clinical technology application is that nurses were only able to achieve a baseline weight in 50% of patients, possibly due to acute initial patient care demands. Finally, based on our findings, it is unknown if weight-enabled beds are cost-effective or beneficial in ICU patients clinical management or not

Conclusion

Bodyweight in patients who undergo cardiac surgery fluctuated over the perioperative period. Recording fluid balance charts to reflect the change in body weight for patients undergoing cardiac surgeries was deemed reliable but not accurate enough. Using weight-enabled beds for bodyweight monitoring could be robust or reliable enough to substitute regular in the intensive care unit (ICU) post open heart. It may be used to track overall improvements in patients admitted to the intensive care unit for an extended period.

Conflict of interest: Authors declare no conflict of interest.

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