

Estimates of fluid balance and insensible loss in the critically ill: A cohort study in a non-metropolitan intensive care unit

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Abstract

Assessment of fluid balance has an integral role in management of critically ill patients. Fluid status measurement is multifactorial, comprising of clinical examination, biochemical investigation, and fluid balance records. Error in fluid balance record is well published, as are the adverse outcomes that result from poor fluid control. The current audit was organised to assess the degree of arithmetic error in fluid balance records in Hawke's Bay Intensive Care Unit (ICU); secondary aims included use and effect of certain diuretic/antidiuretic agents, change in patient fluid

status, and change in weight during admission. Twenty ventilated patients admitted to Hawke's Bay ICU over 14 days (between 1st January 2020 and 24th December 2020) were randomly selected for audit. Twenty-four-hour fluid balance charts were checked, and data regarding secondary outcomes was collected. Seventy point one percent of audited charts were correct, within 0-10 ml from the true fluid balance. Incongruence between change in weight and cumulative fluid balance for 14-day of admission described a 1300 g fluid weight discrepancy, explained by insensible fluid loss.

Key words: Fluid, fluid balance, ICU, weight, input, audit, diuretic, critically ill.

Introduction

Maintaining optimal fluid balance in critically ill patients is essential for treatment of the myriad pathologies encountered in an intensive care setting. In healthy individuals, physiological homeostasis is sustained via hormonal and renal mechanisms. (1) In disease, compensation mechanisms may be insufficient, resulting in either hypo or hypervolaemia. (2) Hypovolaemia can result in decreased organ perfusion and function, including acute kidney injury (AKI), renal failure, and end-organ failure; conversely, hypervolemia can precipitate pulmonary oedema and respiratory distress. (2,3) Payen et al.

(4) and Bouchard et al. (5) showed an association between a positive fluid balance and increased mortality. Understanding a patient's fluid balance therefore has an integral role in treatment.

Patient fluid status assessment is multifactorial. (6) Clinical assessment, particularly cardiovascular examination, can be more meaningful and reliable than any single invasive investigative technique. Biochemical investigation, such as serum and urinary Na⁺, urea, and total protein are complementary of clinical findings and are useful in monitoring disease progression. (7,8) Fluid balance charts are an additional mode of assessing fluid balance, however, to be of benefit accurate documentation is essential. Twenty-four-hour fluid balance records are incorporated into the 24h patient observation notes. Quantities of input and output are measured, recorded each hour, and cumulated at the end of 24h. Fundamental errors in current practice are evident; insensible losses can attribute up to 1.1 l/day of unmeasurable fluid loss, (9) output via bowel motion and vomitus can be difficult to estimate and errors in recording and calculation of total fluid balance are common. Diacon and Bell (10,11) in an audit of 103 24h fluid charts in a South African ICU assessing arithmetic and measurement accuracy,

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showed that over 79% fluid balance charts were inaccurate by more than 50 ml when re-calculated, and over 90% were inaccurate by more than 10 ml. Given that fluid balance charts can be inaccurate without arithmetic and recording error, it is essential to minimise further error, so fluid balance charts remain an appropriate method for guiding clinical decisions.

An audit of accuracy of fluid balance recording in Hawke's Bay Hospital ICU was planned. (12) The primary focus was the recording and arithmetic accuracy of the fluid balance chart, comparing recorded fluid balance to the true measured balance on each 24h fluid balance chart. Secondary outcomes included change in weight, influence of diuretic and antidiuretic agents, serum creatinine and change in fluid status over a patient's first 14 days of admission.

Method

Research design

A descriptive retrospective design was used in this audit.

Aims:

- Assess the degree of arithmetic error within current practices of fluid balance recording.
- Analyse the effect of diuretic and antidiuretic medications (furosemide, acetazolamide, vasopressin) on fluid balance over time.
- Assess cumulative fluid change over the course of a 14-day admission.
- Describe the correlation between patient weights and cumulative fluid balance.

Setting

This audit was conducted in the ICU of Hawke's Bay Hospital, New Zealand. Patients included in the audit were admitted directly to ICU from Emergency Department (ED), other hospital wards, operating theatre, or repatriated from other hospitals.

Administrative design

The audit was conducted over a 3-month period between the 1st of November and 31st of January. An audit terms of reference was defined by the clinical supervisor of Hawke's Bay Hospital ICU, outlining the audit's background, scope and purpose. All data collected remained anonymous. No further data or investigation was undertaken specifically for the audit, all data had been requested on a clinical basis during patient admission.

Population and sampling

The sample population for this audit included ventilated patients (both post-surgical and critical med-

ical care needs, with varying diagnoses) admitted to Hawke's Bay Hospital ICU for longer than 14 days, between 1st January and 24th December 2020. Patients were excluded from the audit if aged less than 16, were pregnant, suffered from burns, or received continuous renal replacement therapy (CRRT) during their admission. Fluid balance charts and relevant documentation spanning 14 days from admission were to be reviewed and recorded accordingly.

Data collection

To maintain consistency data collection from Hawke's Bay Hospital health records was completed by only two researchers. Hourly fluid input and output was re-calculated, assessed for arithmetic error, and compared to that recorded on the fluid balance charts. The reason for any error was recorded and uploaded to a database for future reference. Recorded fluid balance and the fluid balance calculated by the researchers were recorded for analysis. Secondary outcomes were accessed on the hospital clinical information system, and from the 24h observation charts. Patient age, gender, diagnosis, and outcome were recorded and attached to their fluid balance datasheet.

Data analysis

Data was recorded, entries were double checked and stored on Microsoft Excel. Data was analysed as follows:

1. Accuracy was assessed by categorising charts into predetermined deviations (0-10, 10-100, 100-500, 500-1000, and 1000+ ml's) from the true fluid balance. These values were chosen indicatively based on deviations used in similar literature. (11)
2. The effect of diuretics/antidiuretics on net fluid status of patients were evaluated by comparing the average 24h cumulative fluid balance for the 48h prior to drug administration, to the 24h and 48h following use. Data sets for drug use were excluded if a patient had been given diuretics/antidiuretics in the previous 48h to avoid confounding.
3. The average cumulative fluid change for patients during 14-day admission were based on day-by-day basis. Patient weights, where available were compared to the patient's change in cumulative fluid status over the same time course.

Results

Of all Hawke's Bay ICU patient admissions from 1st January 2020 to 24th of December 2020, 24 pa-

tients fulfilled criteria for audit inclusion, of which 20 patients, with a mean (\pm standard error [SE]) age of 65.8 ± 14.70 (median, 70 years; range 25 to 81 years), were randomly selected.

Figure 1 shows the progression of fluid input, output, and net fluid change for patients admitted to Hawke's Bay Hospital ICU during the first 14 days of admission. On average, patients included in the audit were given larger volumes, had lower outputs, and a greater positive fluid balance in the infancy of admission. By day 14 of admission, patients on average had less fluid input, greater output, and lower positive fluid balance changes.

Figure 2 describes the average patient serum creatinine. Throughout a 14-day admission, serum creatinine remains relatively unchanged.

Of 280 fluid balance charts, 276 were in-patient files, 4 were not present (3 of which were for first days of admission). **Figure 3** and **Table 1** show the accuracy of charts with varying tolerance. Seventy point fourteen percent of fluid balance charts were accurate within 0-10 ml of the true balance, 16.90% considered inaccurate within the 10-100 mL, 9.35% within 100-500 ml, 1.80% within 500-1000 ml, and the remaining 1.08% over 1000 ml, with a range of inaccuracy from -2495.5 to +1000 ml. Of the inaccurate fluid balance charts, 49 were underestimated (recorded fluid balance was lower than true fluid balance) compared to 79 overestimated (recorded fluid balance was higher than the true value) (**Figure 4**).

The effects of vasopressin and furosemide were assessed by comparing the average 24h fluid balance of the previous 48h, to the average 24h fluid balance for the 48h post drug administration (**Figures 5 and 6**). Data sets were excluded if diuretic or antidiuretic agents were used 48h prior to drug administration. When assessing the effects of vasopressin (20 units IV), the average net 24h fluid balance for 48h prior was compared to the average net 24h fluid balance, for the 48h following dosage. The average net fluid change in the 48h pre-administration was +2038.5 ml. In the 24h following, net fluid balance increased to +3374.9 ml, by 48h post-administration, the average net 24h fluid balance change was +2043.04 ml.

The average net 24h fluid balance for 48h prior to furosemide use was +1472.37 ml. Following furosemide administration in any formulation, this decreased to -401.06 ml in the initial 24h, and to -130.10 ml over 48h post furosemide use.

Patients were not routinely weighed on admission or at any stage during ICU. Of the 5 patients that did have weight measured and recorded on admission and after a 14-day period, an average of -4.74 kg

(0.42 kg/day) was lost, and an average net fluid balance of +13426.32 ml (+959.02 ml/day) was seen. **Table 2** compares change in weight to the change in cumulative fluid balance over a 14-day admission.

Discussion

Seventy point five percent (n=196) of all audited fluid balance charts were considered accurate, with a tolerated deviation from true fluid status of 0-10 ml. A further 16.9% (n=47) deviated from the true value by 10-100 ml, 9.4% (n=26) by 100-500 ml, 1.8% (n=5) by 500-1000 ml, and the remaining 0.7% (n=2) by over 1000 ml. The findings of this audit suggest fluid balance record and calculation in Hawke's Bay Hospital ICU had less arithmetic error than fluid balance charts in similar studies by Diacon and Bell (10,11) and by Asfour. (13) The former showed over 79% of fluid balance charts deviated >50 ml from the true fluid status and 90% were inaccurate by more than 10 ml, the latter showed fluid balance charts to have an accuracy of 65%.

Analysis of true patient fluid status showed that patients were on average fluid positive per day, with net +3314 ml on day 1 of admission, and net +870 ml by day 14, with an average cumulative fluid balance by day 14 of +15,345 ml. When the data set available for patients with 14-day weights was analysed, a 14-day cumulative balance of +13,426 ml (+959 ml per day) and an average of -4.74 kg (-0.34 kg per day) was seen. Patient weight in an acute setting is primarily modulated by fluid status. Given that one millilitre of fluid represents one gram of water, the weight discrepancy could be described in terms of +1300 ml of fluid weight per patient per day admitted to Hawke's Bay ICU; a large proportion likely to be insensible fluid loss. This was greater than described by Cox, (14) who estimated insensible loss of 800-1000 ml in critically ill patients, more so when considering patients who are intubated and ventilated with humidified air reduce insensible loss by up to 40% in the same cohort. (15) Similarly, Perren et al. (16) in a prospective study of 147 ICU patients, found a poor correlation between change in body weight and net cumulative fluid balance. If this insensible loss in Hawke's Bay Hospital ICU patients were to be incorporated into estimating fluid status, the net daily fluid gain of patients within this audit on day 1 would be only two-thirds that currently estimated; and by day 14 would be fluid restricted rather than fluid positive as suggested by recorded chart balance. Substitutes to fluid balance charts have proved just as ineffective. Serial body weight measurement is one alternative non-invasive method for monitoring fluid status.

This method bestows its own issues; incapacitated patients make weighing patients by conventional methods impractical, and “smart beds” with built in scales require proper training and can be time intensive. Davies et al. (15) demonstrated the unreliability of serial body weight measurement as an indicator of fluid status, with accuracy depending on the standardisation of weighing procedure. Current fluid management practice warrants further investigation for the benefit of patient outcome. (4,17-19). The effect of vasopressin on fluid retention over 24h in Hawke’s Bay Hospital ICU patients was assessed, by comparing the net 24h fluid change in the 48h prior, and 48h post drug administration. Patients retained an average of +1336.59 ml more fluid in 24h after vasopressin use; by 48h, the 24h fluid status had returned to +4.65 ml from pre-vasopressin levels. This may be explained by diuretic mechanisms such as atrial natriuretic peptide (ANP) or aldosterone overriding the antidiuretic hormone (ADH) effect previously emitted by the exogenous vasopressin. Vasopressin in an intensive care setting is used primarily for vasopressor support in patients with uncontrollable hypotension due to its potent effect on arterial smooth muscle receptors (V-1). It is not possible to distinguish whether the return of fluid output is a direct effect of the discontinued vasopressin infusion, or whether clinical findings (i.e increased urine output) of the patient provided reason for discontinuing vascular support. The effect of furosemide in any formulation on fluid status

was assessed in the same manner and has similar limitations. Patients net fluid decreased by 1873.42 ml following furosemide use compared to the average 24h balance in the previous 48h. By 48h, a net fluid change of 1602.47 ml was seen, compared to the 48h prior to furosemide use. The therapeutic effect of furosemide is typically between 6-8h, however the effect was seen to continue 48hr post dose in this dataset. In some cases, this was attributable to repeat dosing, but was also seen in patients who received furosemide once only.

The findings in this audit were limited by the small sample size and single centre sample population; however, may be considered as a pilot study for future investigation.

Conclusion

The current audit found 70.1% of 24h fluid balance charts to be accurate to within 10 ml of the true fluid balance measurement, a lower error rate than seen in comparable publications. Nevertheless, error occurred in recording fluid balance and as a result was best used as an adjunct to more effective measures of fluid status. A large unaccounted discrepancy between patient body weight and cumulative fluid balance over a 14-day period, likely explained as insensible fluid loss, was also noted. Further research may help define areas in which fluid balance recording can improve and, how insensible losses may be better represented in current fluid balance practice.

Table 1. Table of results; accuracy of fluid balance charts

24hr fluid balance chart accuracy	Number	%
0-10 ml	195	70.14388489
10-100 ml	47	16.90647482
100-500 ml	26	9.352517986
500-1000 ml	5	1.798561151
1000 ml +	3	1.079136691
Total charts	276	100

Table 2. Δ in weight and fluid status for five patients with weights available from day of admission and 14 days later

Patient weight vs fluid balance net after 14 days	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Average	Average/day
Change in weight (kg)	-3	-16.7	-3	-1	0	-4.74	-0.34
Change in net fluid (ml)	3004	8129	14,044	15,204.9	26,749.7	13,426.32	959.00

Figure 1. Change in fluid balance for patients in Hawke’s Bay Hospital over time of admission

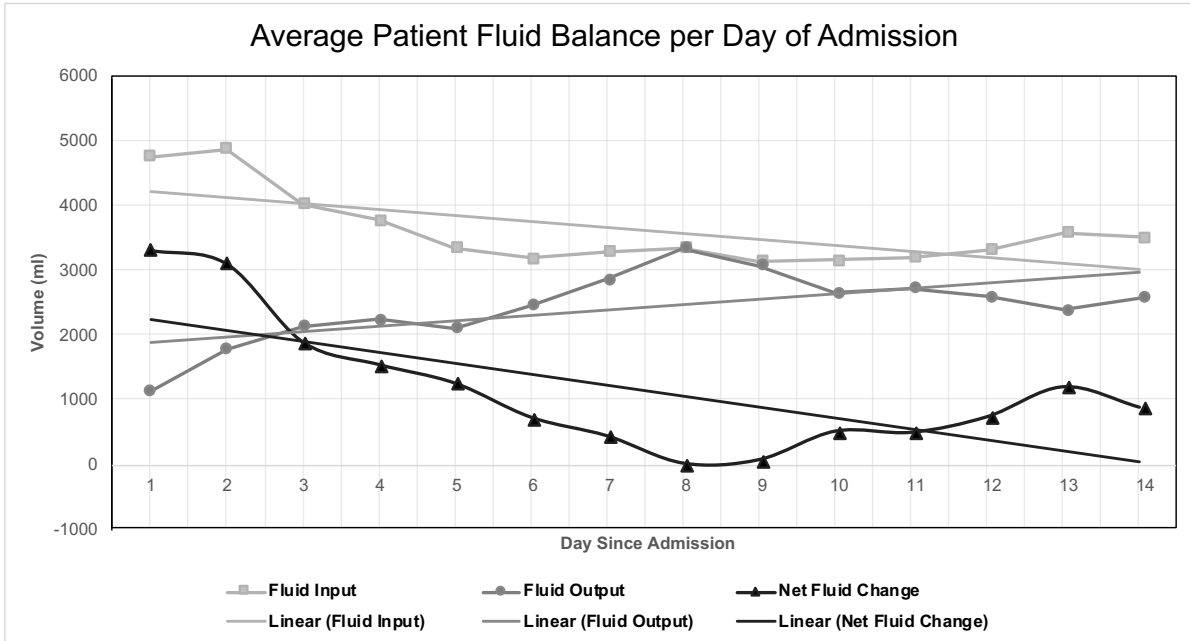


Figure 2. Δ in average patient creatinine during admission

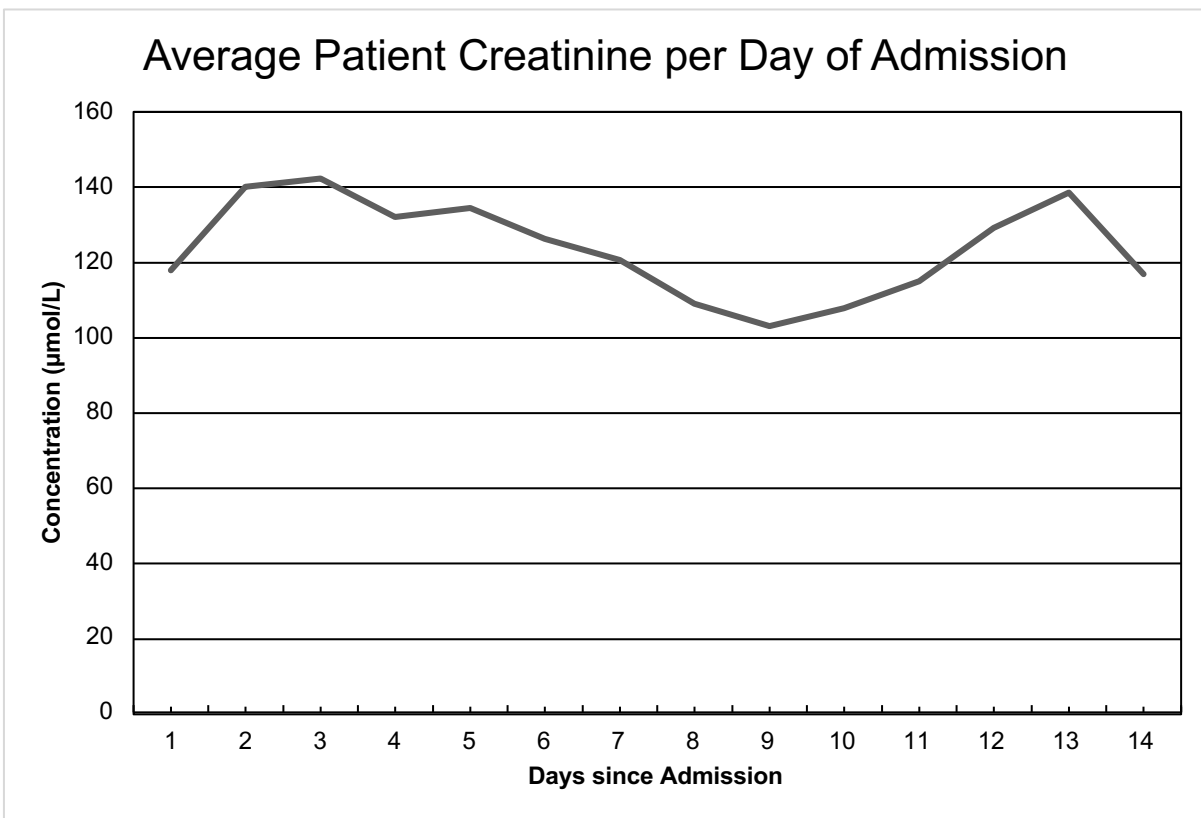


Figure 3. Accuracy of fluid balance charts in Hawke’s Bay Hospital ICU, to variable deviations

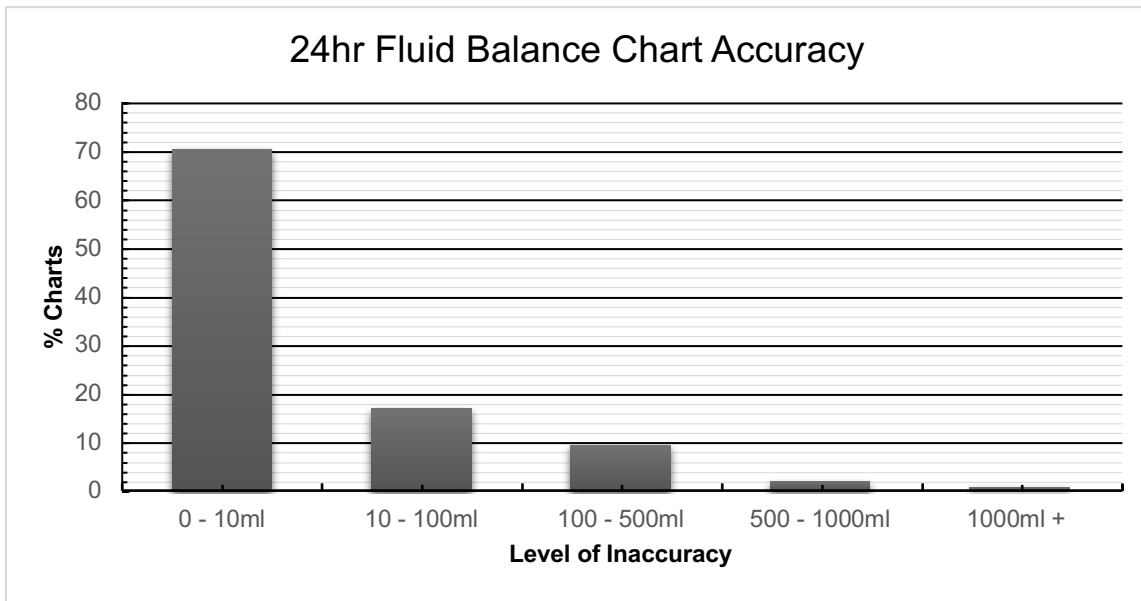


Figure 4. Quantity of fluid balance charts over/under-estimated

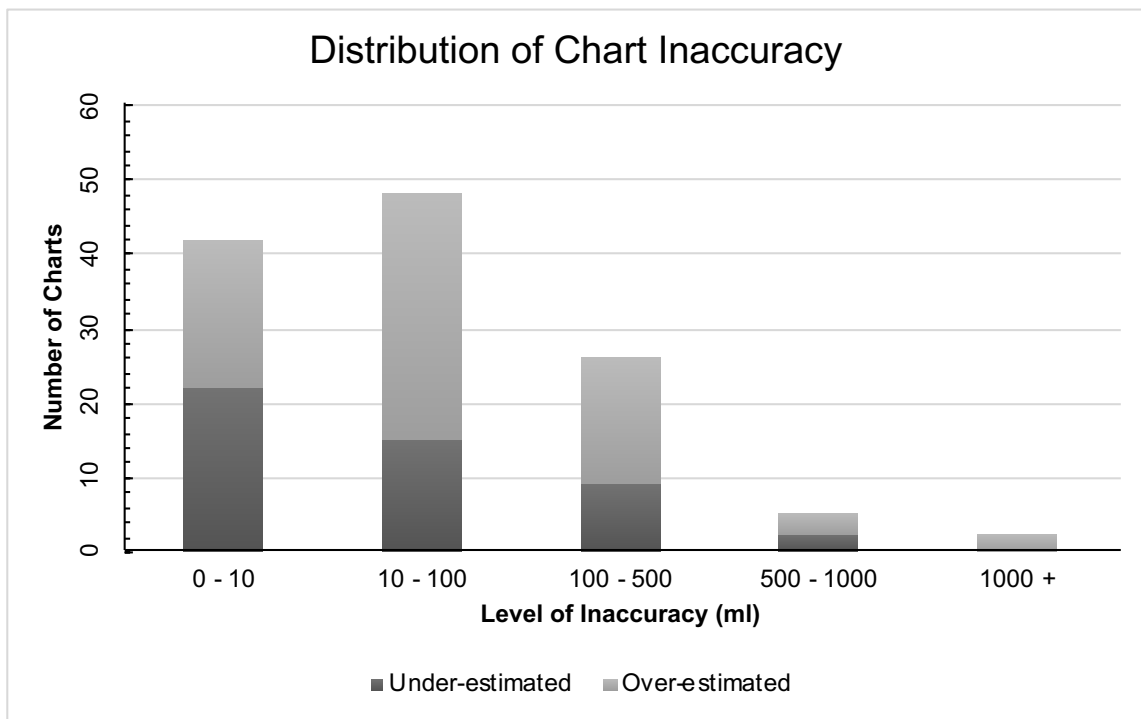


Figure 5. Δ in average 24h fluid balance prior and subsequent to administration of vasopressin, 20 units IV

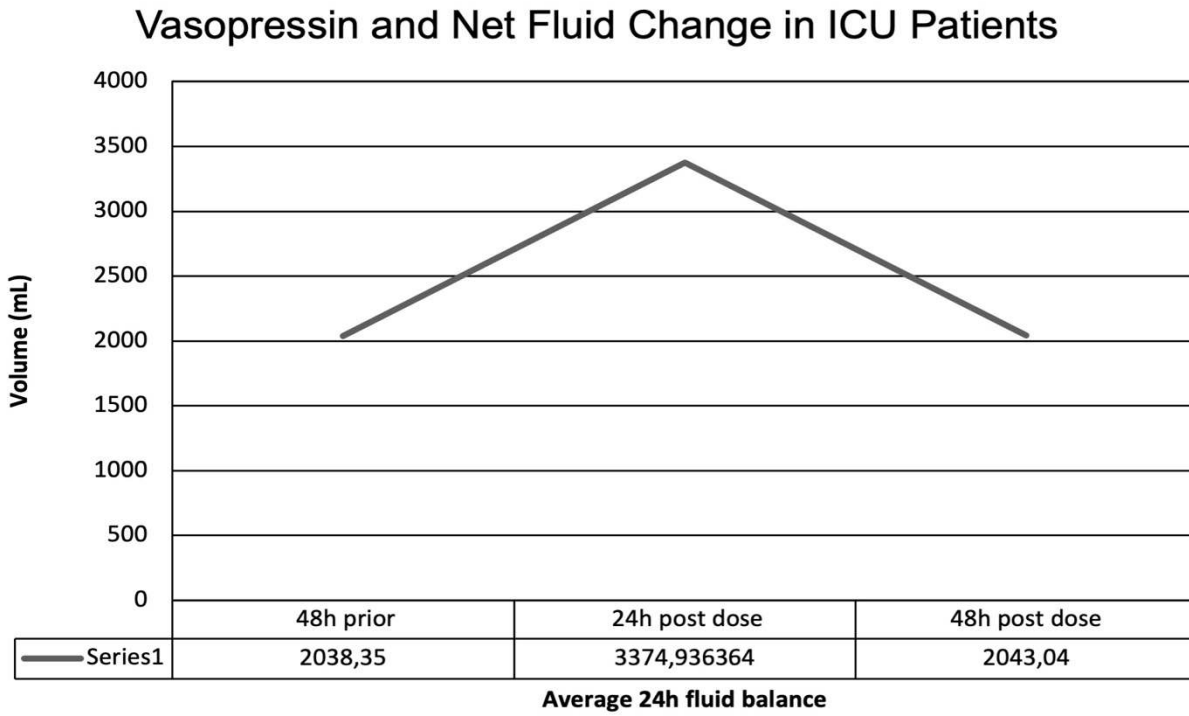
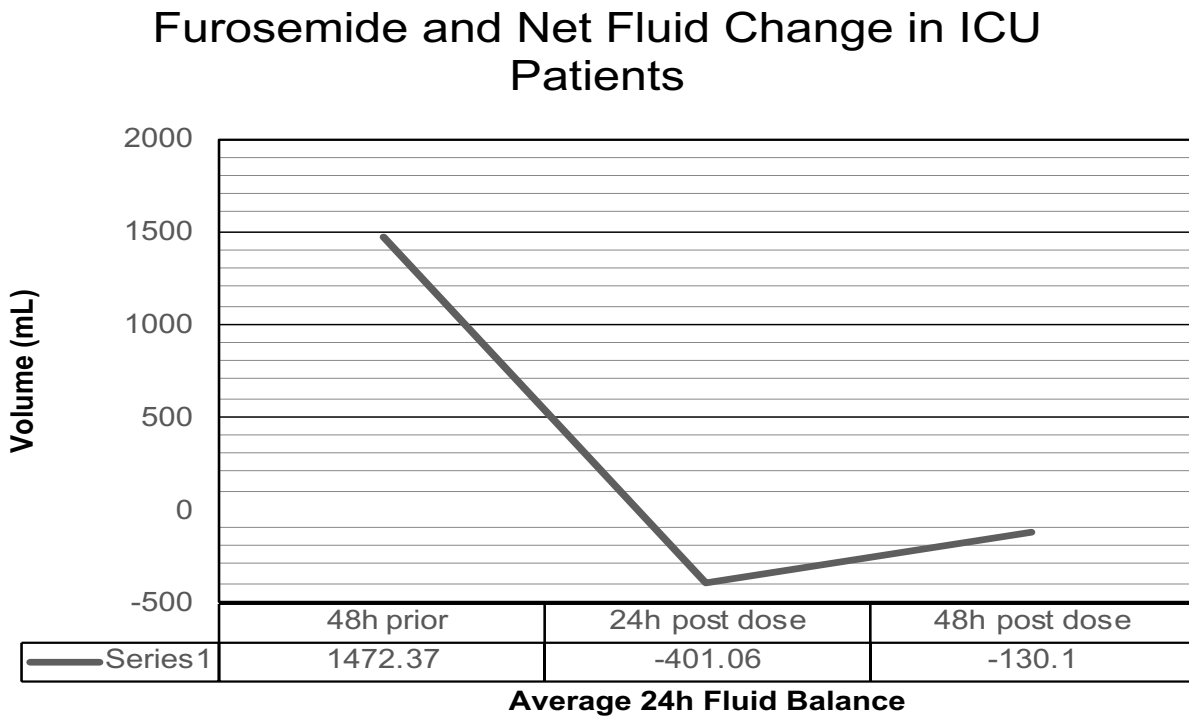


Figure 6. Δ in average 24h fluid balance prior and subsequent to administration of furosemide in any formulation



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