



## Audit

# Intravenous fluid-associated morbidity in postoperative patients

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**Introduction:** There is marked variation in postoperative fluid prescribing which may contribute to postoperative morbidity. However, there are few data regarding the overall incidence of fluid-associated morbidity in postoperative patients.

**Patients and Methods:** Data regarding fluid and electrolyte prescription, fluid balance and intravenous fluid associated morbidity were prospectively collected from 71 patients representing 173 patient days of intravenous fluid therapy.

**Results:** There was no correlation between fluid and electrolytes prescription and pre-operative weight, serum electrolyte levels or ongoing fluid losses. 17% of patients developed significant fluid associated morbidity. 7 patients developed a tachyarrhythmia, which was associated with the prescription of inadequate maintenance potassium. 5 patients developed fluid overload, associated with excessive fluid volume and sodium administration.

**Conclusions:** Surgical house-staff do not appear to use the available fluid balance information when prescribing. The introduction of fluid prescribing protocols may improve practice. This study provides an accurate measure of fluid-associated morbidity in order to measure the efficacy of such protocols.

*Key words:* Postoperative care – Fluid therapy

Intravenous fluid therapy is a basic component of surgical care. Postoperative fluid prescriptions should aim to provide adequate maintenance fluid and electrolytes whilst also replacing on-going losses. There is considerable variation in postoperative fluid prescription.<sup>1</sup> Recent surveys of surgical staff suggest that fluid prescription is the responsibility of pre-registration house officers in most units, even though their knowledge base may be inadequate.<sup>2,3</sup> Inadequate care and poor understanding of the principles of fluid balance have been identified as contributory factors for adverse events in surgical in-patients.<sup>4</sup> There are few data regarding the incidence of

intravenous fluid associated morbidity among post-operative general surgical patients. We performed a prospective audit in order to determine the incidence of intravenous fluid associated morbidity in our unit.

## Patients and Methods

The audit was performed in the colorectal unit of a large district general hospital. The unit takes part in the acute general surgical rota. There is a separate vascular service. Patients admitted to the hospital's high dependency unit (HDU) remain under the care of the surgical house-staff.

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Postoperative patients under the care of the colorectal unit who received intravenous fluids for at least 48 h postoperatively were included. The first 24 h post-surgery were excluded from the analysis as fluid management during this period may be complicated by surgery-induced fluid and electrolyte shifts. Patients who were admitted directly to the intensive therapy unit from the operating theatre and patients who received postoperative parenteral nutrition were also excluded.

All data were recorded by a single observer (SRW). The fluid volume (ml) and quantity of electrolytes (mmol) prescribed per 24 h were recorded. The information available to the prescribing doctor at the time of the prescription was also recorded. For audit purposes, this information was assumed to be the fluid balance chart for the previous 24 h, the most recent serum electrolyte data and the patient's pre-operative weight. Pre-operative weight was used as an index of patient size as body mass index was not routinely recorded during the audit period. Nutritional assessments were not performed. The prescribing doctor's grade and the patient's location (ward or HDU) were recorded.

For the purposes of the audit, intravenous fluid associated morbidity was defined as the development of tachyarrhythmias, fluid overload, hypovolaemia, hypokalaemia or hyponatraemia. A tachyarrhythmia was defined as any heart rate greater than 90 beats/min in any rhythm other than sinus and recorded on a 12-lead electrocardiogram. Fluid overload was defined as the development of tachypnoea, tachycardia, hypoxia, pulmonary crepitations, pulmonary congestion on a chest x-ray and/or the development of gross peripheral oedema. Hypovolaemia was defined as the development of hypotension, tachycardia and oliguria that responded to a fluid bolus and occurred after the first postoperative day. A serum sodium value of less than 132 mmol was considered to represent hyponatraemia. A serum potassium value of less than 3.5 mmol was considered to indicate hypokalaemia.

The statistical analysis was performed using the Statistical Package for Social Sciences Version 10.0.1 (SPSS Inc., 1999) and Statsdirect (Statsdirect Ltd, 2002). Values for volume and sodium are presented as mean (SD). Values for potassium are presented as median (interquartile range). Continuous data were compared using the Student's *t*-test and the Mann-Whitney U-test for

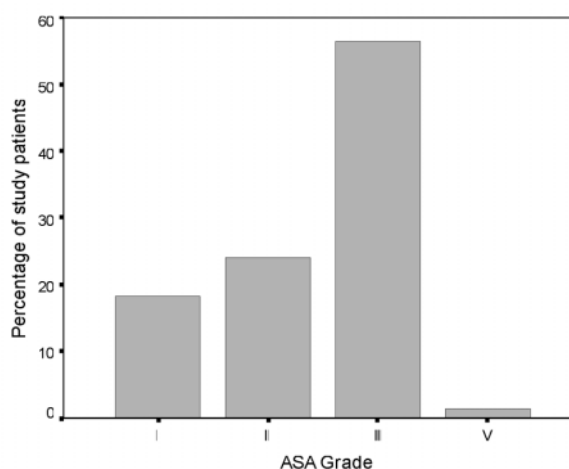


Figure 1 ASA grade of study patients.

parametric and non-parametric data, respectively. Correlations were tested using the Spearman correlation co-efficient. Categorical data were compared using the chi-test or Fisher's exact test as appropriate. Non-parametric data was tested for trend using the Cuzick trend test.<sup>5</sup> Potential risk factors for fluid associated morbidity in the univariate analysis were entered in to a forward-stepwise logistic regression model to test for independence. Significance was assumed at the 5% level. All *P*-values are two-sided.

## Results

The audit was conducted over 4 months. A total of 71 patients (39 female, 32 male) representing 173 patient-days of intravenous fluid prescription were included. Median age was 72 years (interquartile range, 59–77 years). Of the study group, 76% underwent elective procedures and 24% had emergency surgery. The majority of patients had significant co-morbidity producing functional impairment (ASA 3) on their pre-operative anaesthetic assessment (Fig. 1).

The pre-operative weight was available in the medical or nursing notes for 65% of the patients. When available, there was no correlation between pre-operative weight and volume of fluid prescribed per 24 h (Fig. 2). There

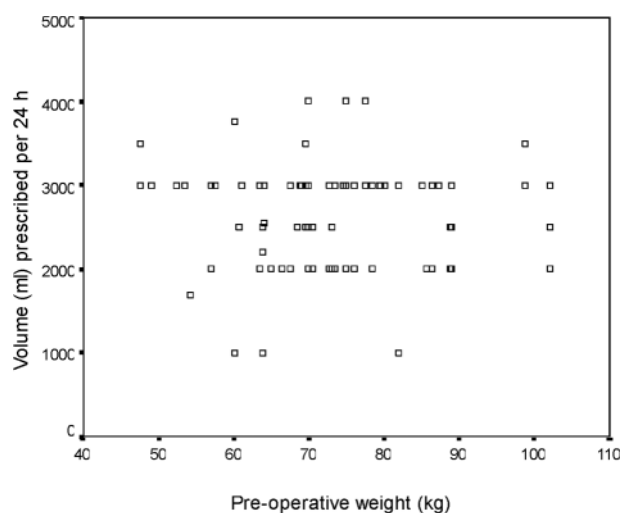
Table 1 Fluid and electrolyte prescriptions per 24 h: PRHOs versus SHOs/SpRs

	PRHO	SHO/SpR	95% CI of difference	Test statistic	<i>P</i>
Volume	2626 (599)	2504 (484)	-94.55 to 338.45	0.98	0.26*
Sodium	268 (114)	194 (144)	9.78 to 131.03	2.37	< 0.01*
Potassium	20 (0–40)	40 (0–40)	-30.9 to -6.76	-3.386	< 0.01**

\*Student's *t*-test; \*\*Mann-Whitney U-test; CI = confidence interval.

Table 2 Trends in mean serum electrolyte values

	Day 2	Day 3	Day 4	Day 5	Test statistic	P
Sodium	138.8 (3.38)	139 (2.52)	139.8 (2.97)	138.4 (2.48)	0.07	0.95
Potassium	4.2 (3.8–4.4)	4.1 (3.9–4.35)	4 (3.65–4.25)	3.9 (3.675–4.325)	-2.06	0.04



**Figure 2** Volume prescribed per 24 h versus patients' pre-operative weight ( $r = 1.0$ ;  $P = 0.771$ ).

was no correlation between serum sodium and the quantity of sodium prescribed ( $r = 0.06$ ;  $P = 0.49$ ), serum potassium and quantity prescribed ( $r = -0.1$ ;  $P = 0.25$ ) or losses in the previous 24 h and volume prescribed ( $r = -0.094$ ;  $P = 0.22$ ). There was no difference in the correlation co-efficients for pre-registration house officers (PRHOs) versus senior house officers (SHOs) and specialist registrars (SpRs).

Of the prescriptions, 81% were by PRHOs. They prescribed greater volumes of fluid per 24 h although this did not reach statistical significance (Table 1). PRHOs prescribed significantly more sodium and less potassium per 24 h. The prescriptions were also analysed according to the location of the patient – ward or HDU. The findings were similar to the differences between PRHOs and more senior doctors (data not shown).

Serum electrolyte levels from day 2 until day 5 were analysed for trend. Insufficient patients received intravenous fluids for greater than 5 days to allow any meaningful analysis beyond day 5. The results are shown in Table 2. The serum sodium concentrations of the patients remained

Table 3 Distribution of tachyarrhythmias between patients who became hypokalaemic and those who remained normokalaemic

	Hypokalaemia	Normokalaemia
Tachyarrhythmia	2	5
No tachyarrhythmia	7	57

Fisher's exact test; 1 degree of freedom;  $P = 0.25$ .

constant. There was a downward trend in the serum potassium levels. Three patients developed biochemical hyponatraemia. None were symptomatic and the lowest recorded serum sodium concentration in any of the patients was 129 mmol/dl. Nine patients developed hypokalaemia; 2 of these patients also developed a tachyarrhythmia (fast atrial fibrillation in both).

In total, 7 patients (10%) developed fast atrial fibrillation. No other tachyarrhythmias were observed. These patients had received less potassium in the days preceding the onset of their tachyarrhythmia compared to patients who remained in sinus rhythm. The median amounts prescribed were 0 mmol (range, 0–40 mmol) and 20 mmol (range, 0–120 mmol), respectively ( $P = 0.08$ ). There were no differences in the fluid volume and sodium prescriptions between these two groups. The distribution of tachyarrhythmias between hypokalaemic and normokalaemic patients is shown in Table 3.

Five patients (7%) developed fluid overload. Three of these patients had pulmonary oedema. The other two patients had isolated gross peripheral oedema. These patients were prescribed significantly more fluid and more sodium per 24 h (Table 4). Fluid volume and sodium were entered into a forward stepwise logistic regression model of fluid overload (chi-square = 11.56;  $P = 0.001$ ) to test for independence. Only volume prescribed per 24 h retained significance (chi-square = 11.57; beta = 0.003;  $P = 0.002$ ).

There were 8 episodes of hypovolaemia after the first postoperative day. There were no significant differences in prescribing between those who developed hypovolaemia and those who did not. There were two unplanned critical

Table 4 Fluid and electrolyte prescriptions per 24 h: patients developing fluid overload versus those not developing fluid overload

	Fluid overload	No fluid overload	95% CI of difference	Test statistic	P
Volume (ml)	3400 (894)	2583 (558)	306.95 to 1326.31	3.16	0.022*
Sodium (mmol)	390 (227)	253 (115)	30.13 to 243.82	2.53	0.032*

\*Student's *t*-test; CI = confidence interval; values presented as mean (SD).

care admissions, both due to pulmonary oedema; these two patients survived. There was one death due to respiratory failure on the fourth day after emergency repair of a strangulated femoral hernia. The patient had a long history of severe respiratory disease. The morbid events were evenly distributed between elective and emergency patients (chi-square 14.22; 1 degree of freedom;  $P = 0.33$ ).

## Discussion

Sub-optimal fluid and electrolyte prescription may contribute to a range of potentially morbid events amongst postoperative patients. The problem of iatrogenic hyponatraemia secondary to excess dextrose administration is well recognised.<sup>6-8</sup> Fluid overload affects 40% of patients in surgical intensive care units, with a weight gain of 20% of original body weight associated with a significantly greater mortality.<sup>9</sup> Postoperative pulmonary oedema affects 2.6% of patients with no other co-morbid factors in the US. It may account for just over 8000 deaths per year and is associated with a mean net fluid retention of over 67 ml/kg/day (over 4.5 l/day in a 70-kg adult).<sup>10</sup> About 10% of surgical patients develop a tachyarrhythmia.<sup>11</sup> Electrolyte abnormalities contribute to about one-third of these.<sup>12</sup> However, there are few data regarding the overall morbidity associated with intravenous fluids. The introduction of fluid prescription guidelines for junior staff has been shown to reduce the incidence of iatrogenic hyponatraemia among elderly orthopaedic patients.<sup>13</sup> Similar guidelines may improve fluid prescribing practice in general surgical patients. Accurate information about the incidence of fluid associated morbidity is required in order to assess the efficacy of any such guidelines.

About 10% of patients in this series developed postoperative fast atrial fibrillation. It has been suggested that tachyarrhythmias in general surgical patients are often precipitated by sepsis.<sup>14,15</sup> However, potassium deficiency may also trigger arrhythmias.<sup>16</sup> *Batra et al.*<sup>12</sup> noted that 12 out of 23 patients who developed a tachyarrhythmia in HDU were hypokalaemic at the time. While 9 patients in our series developed hypokalaemia during their time on intravenous fluids, a tachyarrhythmia was noted in only two. This did not statistically differ from the number of tachyarrhythmias in normokalaemic patients although this series lacks sufficient power to detect such a difference. No patient had clinical sepsis at the time of their tachyarrhythmia. Patients developing a tachyarrhythmia received less potassium per 24 h. The median daily amount prescribed in these patients was 0 mmol per 24 h. The daily maintenance requirement of potassium is approximately 60 mmol. A downward trend was observed in serial serum potassium values. Failure to replace or maintain

body potassium may be contributing to the development of tachyarrhythmias.

We used a clinical definition of fluid overload. Arieff used much more stringent criteria for the definition of fluid overload in his series,<sup>10</sup> requiring either a post-mortem diagnosis or pulmonary artery flotation catheter data. He found that 7.6% of surgical patients developed fluid overload. Our figure of 7% is similar and suggests that a clinical definition of fluid overload is adequate. Both fluid volume and sodium prescribed were significantly associated with fluid overload in the univariate analysis. Previous investigators have reported that the administration of 450 mmol of sodium per day in the form of intravenous fluids may result in fluid overload.<sup>17</sup> We found that fluid overload was associated with the administration of 390 mmol of sodium per day. The three patients who developed pulmonary oedema received a mean of 500 mmol of sodium per day, 5 times the recommended maintenance intake. The dangers of dextrose-induced hyponatraemia are well recognised.<sup>6-8,18</sup> However, the prescription of large amounts of sodium is of concern, especially in the light of recent work demonstrating that positive sodium and water balance may also lead to prolonged postoperative ileus and longer hospital stay in colorectal patients.<sup>19</sup>

Overall, the data suggest that fluid associated morbidity in the form of tachyarrhythmias or fluid overload may affect 17% of general surgical patients. In spite of this, fluid prescription remains largely the responsibility of PRHOs. The most junior members of the surgical team accounted for 81% of fluid prescriptions in this series. The grade of prescribing physician was not independently related to fluid-associated morbidity, raising the question of whether the PRHOs were simply carrying out the instructions of SHOs/SPRs. PRHOs prescribed greater quantities of sodium and fluid and smaller quantities of potassium than more senior doctors, suggesting that senior house staff were not directing the PRHO prescriptions. It is well known that there is poor correlation between serum sodium and potassium values and total body quantities of these electrolytes. However, serum values are the only index currently available in routine clinical practice. The lack of correlation between prescriptions and pre-operative weight, serum electrolyte data and input-output charts suggests that the available information is not consulted when prescribing fluids, regardless of the grade of doctor concerned. In some units, this may be due to inability to access electrolyte data from the ward easily, especially out-of-hours. However, our trust has a long-established computer information system providing easy access to such data from all clinical areas within the trust as soon as the samples have been analysed in the laboratory.

## Conclusions

Nearly one in five postoperative general surgical patients develop intravenous fluid associated complications. The introduction of fluid balance guidelines combined with other measures such as the addition of daily electrolyte values to the prescription charts may improve practice. This audit provides an accurate assessment of current levels of fluid associated morbidity in order to measure the efficacy of such interventions.

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