# Intravenous fluid use after cardiac surgery: a multicentre, prospective, observational study

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## ABSTRACT

**Background:** The optimal strategy for fluid replacement after major surgery remains unclear and there is considerable interest in the investigation of more restrictive fluid regimens.

**Objective:** We aimed to establish current practice of fluid administration to patients after cardiac surgery.

**Design, setting and participants:** A multicentre, prospective observational study, over an 8-week period, of consecutive patients admitted to five intensive care units in New Zealand and Australia.

**Main outcome measures:** We collected patient demographic data and details of fluid boluses and all other intravenous (IV) fluids administered in the first 24 hours after ICU admission.

**Results:** We included 235 patients, and 1226 fluid boluses with an average volume of 504 mL/bolus were administered. The median total fluid given for volume expansion in the first 24 hours was 2250 mL (interquartile range [IQR], 1250–3500 mL) from a median total IV fluid intake of 4493 mL/patient (IQR, 2842–5498 mL). The decision to administer a fluid bolus was made 40% of the time by nursing staff, 45% by an ICU resident and 12% by an ICU specialist. The most common reason for fluid administration was hypotension (65%), and crystalloid fluid was used for 65% of the boluses.

**Conclusions:** We showed that fluid boluses are responsible for a large proportion of the positive fluid balance seen in patients after cardiac surgery. These data justify further study to evaluate whether modification of fluid bolus administration can improve patient outcomes.


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The optimal use of postoperative intravenous (IV) fluid after major surgery remains unclear. On return from theatre after cardiac surgery, patients are frequently administered extra IV fluid which may be crystalloid, colloid, a blood product or a combination of products. Numerous studies have shown positive outcomes in some patient groups if a more restrictive fluid administration regimen is used.[1,2] The mechanisms for these beneficial effects include a reduction in tissue oedema and better wound healing.[3] There is no evidence that a restrictive fluid approach is detrimental to haemodynamic or renal status.[4]

To date, there have been no reported studies of perioperative fluid restriction in patients undergoing cardiac surgery. Although many cardiac surgical intensive care units believe that they have a restrictive approach to perioperative fluid management, there is little published evidence of the effectiveness of such a strategy and no evidence that these patients receive less fluid. There is also little high-level evidence about appropriate timing for fluid administration, treatment triggers, type of fluid or indicators of success of therapy. Bolus fluid therapy is frequently used as first-line therapy for treatment of hypotension and may contribute to a positive fluid balance. There is evidence showing that this may result in significant weight gains postoperatively.[5]

We intend to undertake a Phase II trial of a restrictive fluid administration regimen in patients after cardiac surgery. As part of the design phase of the randomised controlled trial, we undertook an observational study to establish current practice for fluid administration after cardiac surgery, so we could design the intervention arm for our trial.

## Methods

### Design and setting

We undertook a multicentre, prospective, observational study in four ICUs in New Zealand and one ICU in Australia. The requirement for informed consent was waived by the ethics committees in each country. We prospectively enrolled consecutive adult patients admitted to the ICU after cardiac surgery. Patients admitted after an emergency procedure, or those already extubated, or with an open chest on admission to ICU, or not expected to survive 24 hours were not enrolled. Enrolment was limited at each site to a maximum of 50 patients over an 8-week period starting 28 May 2012.

### Data collection

Baseline demographics were collected by trained research staff at each site using a standardised data collection form. A data dictionary was provided to each site, with definitions and descriptions for all data points. For every fluid bolus

**Table 1. Patient characteristics (*N* = 235)**

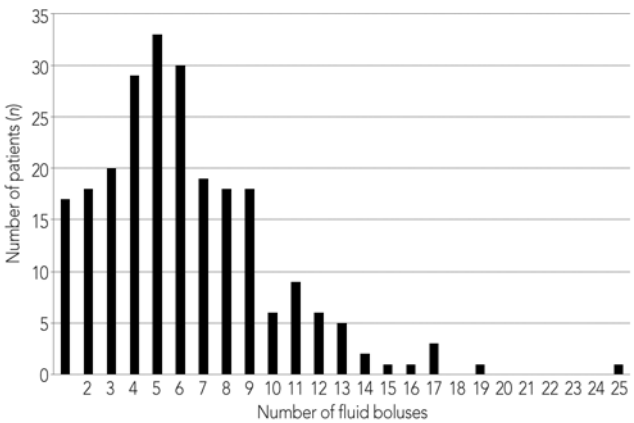
| Characteristic | Data |
|---|---|
| Sex, *n* (%) | |
| Male | 169 (72%) |
| Female | 66 (28%) |
| Ethnicity, *n* (%) | |
| Caucasian | 185 (78.7%) |
| Pacific Island | 20 (8.5%) |
| Maori | 14 (6%) |
| Asian | 9 (3.8%) |
| Other | 7 (3%) |
| Mean weight, kg (SD) | 83.2 (18.8) |
| Mean body mass index (SD) | 28.8 (5.2) |
| Surgical procedure, *n* (%) | |
| Coronary artery bypass graft | 113 (48.1%) |
| Single valve | 53 (22.6%) |
| Complex procedure | 69 (29.4%) |
| Mean cardiac bypass time, minutes (SD; range) | 111.9 (49.8; 33–321) |
| Ventilation time in intensive care unit, *n* (%) | |
| < 6 hours | 112 (47.6%) |
| 6–24 hours | 93 (39.6%) |
| > 24 hours | 30 (12.8%) |

administered for volume expansion in the initial postoperative 24 hours, while the patients remained in the ICU, the following data were collected:

- the type of fluid used (crystalloid, starch, albumin 4%, red blood cells, all other blood products, and a free-text area to record any other fluid)
- the reason for fluid administration (hypotension, low central venous pressure [CVP], tachycardia, low cardiac output [CO]/cardiac index [CI], respiratory swing on arterial trace, low urine output, low haemoglobin, coagulopathy, and a free-text area to record any other reason)
- the person making the decision to administer fluid (bedside nurse, charge nurse, ICU registrar, ICU consultant, and a free-text area to record any other person ordering fluid administration, eg, a surgeon or anaesthetist)
- cardiovascular measurements immediately before administration (blood pressure, heart rate, CVP and CO/CI [if available]).

All blood and blood products were included, as was maintenance fluid and fluid used as a diluent for drug administration. Data were also collected reporting fluid balance, vasopressor and inotrope use in the ICU, and measured patient weight on Day 1 and Day 3 postoperatively.

**Figure 1. Frequency of fluid bolus administration**




### Statistical analysis

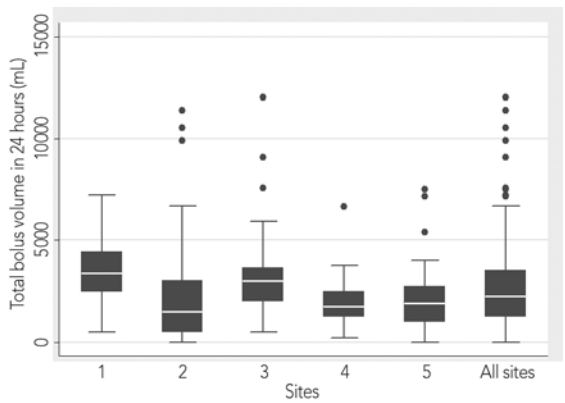
Data were entered by participating sites into Excel (Microsoft) spreadsheets and then extracted into STATA, version 12 (StataCorp) for analysis. All data are presented as means with SDs when normally distributed, and as medians with interquartile ranges (IQRs) when not normally distributed. Descriptive statistics were used for all clinical and demographic data. The Kruskal–Wallis test was used to test differences between sites. Results were considered significant at $P < 0.05$.

## Results

### Cohort characteristics

Between 28 May 2012 and 1 August 2012, 235 patients were included in the study. One hundred and sixty-six patients (70.7%) had a "simple" procedure (defined as isolated coronary artery bypass surgery or single valve repair or replacement). Patient characteristics are shown in Table 1.

**Figure 2. Volume of bolus fluids used, by site**




Box = interquartile range. White line within box = median. Line = highest and lowest observations. Dot = outlier.

**Table 2. Overall fluid types and volumes administered**

| Fluid type | Total doses (%) | Total volume (%) | Average no. boluses per patient | Average dose per bolus (mL) |
|---|---|---|---|---|
| Crystalloid | 64.6% | 72.8% | 3.4 | 561.2 |
| Albumin 4% | 14.2% | 10.9% | 0.7 | 382.9 |
| Starch | 8.3% | 6.5% | 0.4 | 394.1 |
| Blood products | 6.1% | 4.9% | 0.3 | 400.9 |
| Red bloods cells | 5.9% | 4.4% | 0.3 | 369.2 |
| Other | 1% | 0.5% | 0.1 | 247.4 |

**Figure 3. Type of fluid used, by site**

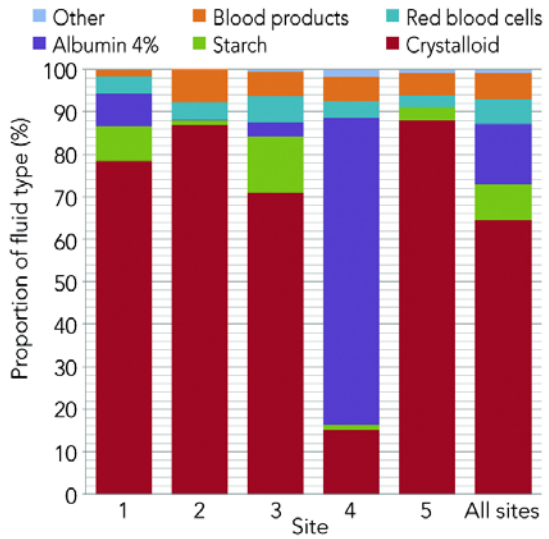
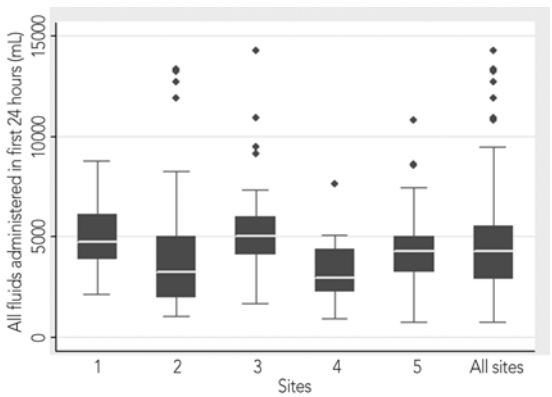
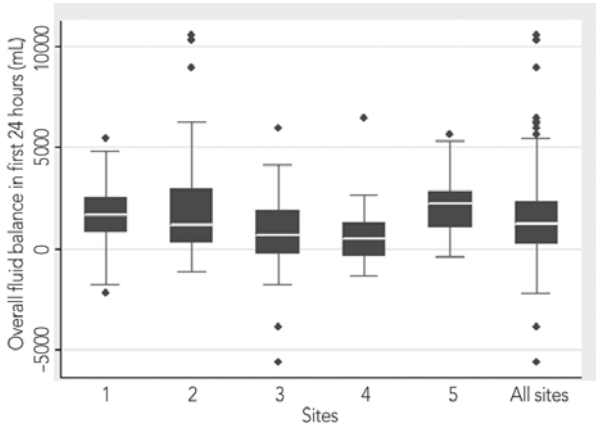



**Figure 4. All fluids administered in first 24 hours, by site**




Box = interquartile range. White line within box = median. Line = highest and lowest observations. Diamond = outlier.

**Figure 5. Overall fluid balance for first 24 hours after intensive care unit admission**




Box = interquartile range. White line within box = median. Line = highest and lowest observations. Diamond = outlier.

On admission to the ICU, nine patients (3.8%) had an intra-aortic balloon pump in situ and 63 (26.8%) had some form of CO monitoring in situ. These devices included continuous CO monitoring using a pulmonary artery catheter ($n = 39$), bolus thermodilution using a pulmonary artery catheter ($n = 22$), and pulse contour analysis using the FloTrac sensor (Edwards Lifesciences) ($n = 1$) and pulse index continuous cardiac output (PiCCO) monitoring ($n = 1$).

### Fluid bolus characteristics

Overall, 220 patients (93.6%) received at least one fluid bolus within the 24-hour study period (median, 4.1 boluses; IQR, 2.2–6.7 boluses) (Figure 1). A total of 1226 fluid-bolus episodes were recorded, with a mean of 504 mL/bolus.

The median amount of fluid given per patient for volume expansion in the first 24 hours was 2250 mL (IQR, 1250–3500 mL; range, 0–12 013 mL) (Figure 2), with 64.6% of the total fluid administered being crystalloid (Table 2). The average bolus of fluid given each time was higher if crystalloid was used instead of colloid (561 mL v 387 mL).

Apart from one site which used predominantly albumin for bolus fluid administration, most fluid administered was crystalloid (Figure 3).

Differences were seen in the total amount of all fluids given per site, total amount of all fluids out, and total urine output per site (Figure 4), and the overall fluid balance up to the first 24 hours after admission to the ICU (Figure 5).

Four sites recorded measured patient weights preoperatively and on Day 1 and Day 3 postoperatively. The median weight gain (measured on Day 3 and compared with preoperative weight) was 2.75 kg (IQR, 4.3 kg).

**Table 3. Indications for fluid administration**

| Indication | Primary, *n* (%) | Secondary, *n* (%) |
|---|---|---|
| Hypotension | 785 (64.7%) | 91 (17.5%) |
| Low central venous pressure | 134 (11%) | 223 (42.9%) |
| Tachycardia | 18 (1.5%) | 22 (4.2%) |
| Low cardiac output/cardiac index | 46 (3.8%) | 32 (6.2%) |
| Respiratory swing | 15 (1.2%) | 26 (5%) |
| Low urine output | 75 (6.2%) | 39 (7.5%) |
| Low haemoglobin | 32 (2.6%) | 15 (2.9%) |
| Coagulopathy | 48 (4%) | 7 (1.4%) |
| Other | 60 (5%) | 65 (12.5%) |
| *Total* | *1213* | *520* |

**Table 4. Influence of cardiac output (CO) monitoring on assessment of indication**

| Indication | CO monitoring, *n* (%)* | No CO monitoring, *n* (%) |
|---|---|---|
| Hypotension | 183 (52%) | 602 (69.9%) |
| Low central venous pressure | 43 (12.2%) | 91 (10.6%) |
| Tachycardia | 2 (0.6%) | 16 (1.9%) |
| Low CO | 44 (12.5%) | 2 (0.2%) |
| Respiratory swing | 1 (0.3%) | 14 (1.6%) |
| Low urine output | 28 (8%) | 47 (5.5%) |
| Low haemoglobin | 12 (3.4%) | 20 (2.3%) |
| Coagulopathy | 11 (3.1%) | 37 (4.3%) |
| Other | 28 (8%) | 32 (3.7%) |
| *Total* | *352* | *861* |

* Percentages do not total 100 due to rounding.

**Figure 6. Clinician ordering fluid, by site**

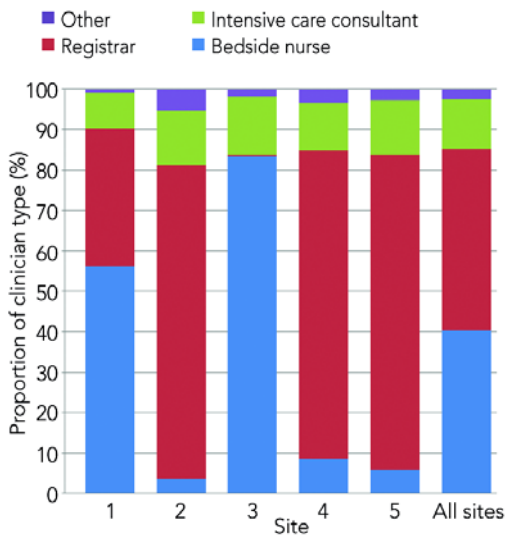



**Figure 7. Type of fluid used, by clinician**

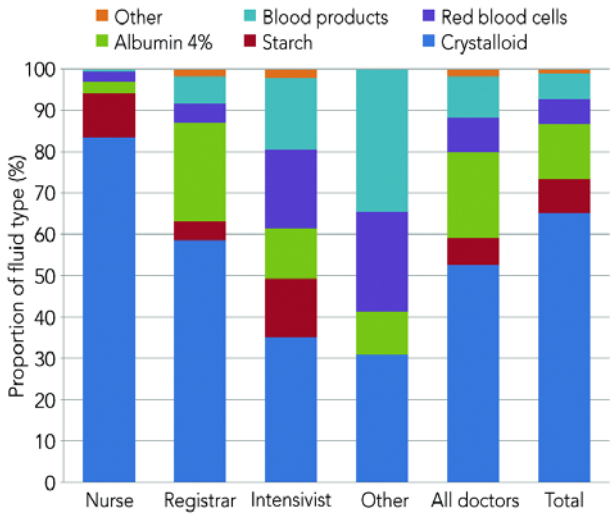
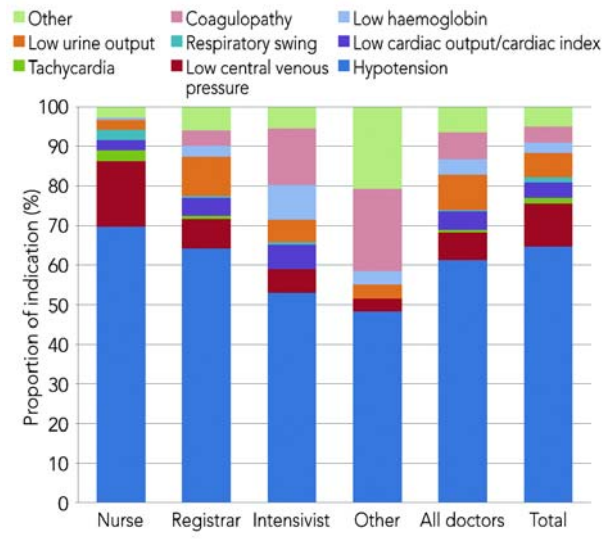



**Figure 8. Indication for fluid administration, by clinician**




Up to the time of extubation (censored at 24 hours after ICU admission for those still intubated at that time), a mean of 2047 mL (IQR, 508–2750 mL) of fluid was given, representing 77% of the total bolus fluid administered in the 24-hour period.

### Decision-making characteristics

Over all sites, the decision to administer a fluid bolus was made 40% of the time by the bedside nurse, 45% of the time by the ICU resident and 12% of the time by an ICU consultant, although we found variation between sites (Figure 6).

### Indications for fluid administration

The most common primary indication cited for fluid bolus administration was hypotension (64.7%) (Table 3). Clinicians could also nominate up to two secondary reasons for fluid administration, with low CVP most frequently cited (42.9%).

We found a difference between clinicians in the choice of fluid (Figure 7) and the indication cited (Figure 8) for fluid administration, with nurses more likely than doctors to administer crystalloid (83.6% v 52.7% of boluses) and more likely to cite hypotension (69.9% v 61.3%) or low CVP (16.4% v 7%) as the primary indication.

In the 63 patients with CO monitoring in situ, hypotension was still cited as the primary reason for fluid administration, with low cardiac output only being cited on 12.5% of occasions (Table 4). Of those with a measured CO available, in 60.6% the cardiac index was $\geqslant 2.5$ L/min/m$^2$ at the time of fluid administration.

## Discussion

### Key findings

Our multicentre, observational study suggests that postoperatively, cardiac surgical patients receive 4–5 L of fluid input in the first 24 hours, of which almost 50% is from fluid boluses prescribed by nursing or junior medical staff for the indication of hypotension.

### Relation to previous work

A combination of significant volume administration coupled with the potential for myocardial dysfunction and vascular endothelial leakage supports the concept that fluid administration may have deleterious effects for patients having cardiac surgery.[6] Although there is some evidence in the general surgical population that fluid balance may affect outcomes,[7] little research has been published to date in cardiac surgical patients.

We found significant differences in the types of fluids used across the participating sites. For example, one site used predominantly albumin 4% for volume resuscitation, but in the other four sites the main fluid used was crystalloid. This may represent geographic or international differences in the availability and cost of albumin. No evidence exists that fluid resuscitation with colloids improves outcomes when compared with use of crystalloids in patients after surgery.[8] It was also found that starch solutions were used in all participating ICUs, but the frequency of use was not high. This study was conducted before the publication of landmark studies suggesting that the use of hydroxyethyl starch solutions may be associated with an increased incidence of renal dysfunction requiring renal replacement therapy, and with mortality at Day 90.[9,10] Both these findings may have implications for patient treatment choices and the cost of ICU stay.

The differences shown in prescribing practices across sites may reflect the availability of medical staff and the existence of standing orders. For example, in sites 1 and 3, there were standing orders covering the administration of up to 3 L of fluid for volume resuscitation at the discretion of the bedside nurse. One of these sites was also a private surgical ICU and did not have registrar cover available, which may have resulted in the nursing staff having more autonomy in decision making. The effect of standing orders may explain the observed difference in fluid choice between nurses and doctors.

We found that the most common reason for fluid administration was hypotension, and the use of CO monitoring appeared to have little influence on this. Even patients who were likely to have an adequate CO after cardiac surgery (defined as $\geqslant 2.5$ L/min/m$^2$) received fluid primarily for the management of hypotension. Low CVP was also frequently cited, despite being shown to be a poor predictor of fluid responsiveness.[11,12] Our results suggest that training and experience may have an influence on this, with senior doctors less likely to cite low CVP as the primary reason for fluid administration than junior doctors or nurses.

### Clinical implications

Our results show that any protocol designed to reduce the amount of fluid given after cardiac surgery will have to focus on alternative management options for hypotension (eg, accepting lower blood pressure targets or using vasoconstrictors), eliminating the targeting of specific CVP levels, and restricting fluid administration to patients who have a known or suspected inadequate perfusion and who are likely to be fluid responsive.

### Strengths

A major strength of our study is that data were collected prospectively at the time that fluid was administered, by the person administering the bolus, so the rationale behind each bolus was captured contemporaneously. This may be more accurate than an assessor-determined rationale provided by a retrospective review of patient notes. We now have comprehensive data regarding fluid type, volume and indication to inform study design.

This study also collected data at sites where most cardiac surgery is undertaken in New Zealand and thus represents current practice there.

### Limitations

Our study involved a small number of sites, and enrolled a convenience sample, hence the conclusions may be limited

and not universally applicable. We did not take into account fluid that had been administered before admission to the ICU (eg, in the operating theatre). We also did not attempt to collect any data on long-term therapy outcomes, such as the incidence of acute kidney injury, wound infections, oxygenation, or ICU or hospital length of stay. Finally, no information on fluid administration was collected preoperatively or perioperatively, but the purpose of our study was to understand early postoperative fluid bolus practice, in order to understand whether or not this may be a potentially modifiable intervention to study further.

There may have been a shift in practices during the course of the study, but this seems unlikely, given the short time frame over which the study was conducted. We had also previously conducted this study at the lead study centre, and the results were not different.[13]

### Future studies

We intend to conduct a randomised controlled trial to assess the efficacy of a goal-directed strategy aimed at reducing fluid administration in patients after cardiac surgery (www.ANZCTR.org.au; ACTRN12612000754842). The information presented here has been used as the basis for the development of a fluid administration protocol which we believe could result in less IV fluid being administered. If the study shows that the use of this protocol results in the administration of significantly less IV fluid, with improved patient outcomes, we plan to conduct a multicentre Phase II study of the effects of a restrictive fluid regimen in patients undergoing cardiac surgery.

## Conclusion

We have shown that fluid boluses are responsible for a large proportion of the positive fluid balance seen in patients after cardiac surgery. These data justify further study to evaluate whether modification of fluid bolus administration can improve patient outcomes.

## Acknowledgements

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## Competing interests

None declared.

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