Drivers of choice of resuscitation fluid in the intensive care unit: a discrete choice experiment

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ABSTRACT

Objective: To understand the fundamental drivers, and their relative importance, of doctors' and nurses' choice of resuscitation fluid in critically ill patients in Australia and New Zealand.

Design: A discrete choice experiment (DCE) administered via an online survey. Respondents were presented with one of four randomly selected DCE choice sets, each including five patient scenarios. The respondent chose between two types of hypothetical resuscitation fluid. The fluid type was characterised by several attributes and each attribute had pre-specified levels.

Participants: Convenience sample of 367 Australian and New Zealand intensive care unit doctors and nurses.

Main outcome measures: The dependent variable was fluid choice, and a regression equation was used to estimate the effect of each fluid attribute on the probability of observing the sequence of choices made over the five patient scenarios. The relative importance of each of the respective fluid attributes was calculated based on the percentage contribution to overall utility (ie, fluid preference).

Results: For doctors, safety concerns, patient type and fluid type were collectively responsible for almost three-quarters of decision-making utility (71%). The volume of intravenous fluid administered was the only clinical parameter not reaching statistical significance as a driver of fluid choice ($P = 0.06$). For nurses, decision making was influenced to a greater extent by the same three attributes (90%), although other unmeasured attributes may have been driving choice.

Conclusions: Doctors and nurses rely on different information when choosing resuscitation fluids, although both cohorts are heavily influenced by safety concerns, patient type and fluid type. This information can be used to modify prescribing behaviour.

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Intravenous (IV) fluid resuscitation is a fundamental intervention in the care of critically ill patients. Recent evidence has shown that the type of fluid used is clinically important, with the use of some fluids being associated with increased risk of acute kidney injury[1-3] and death.[4-6]

Understanding clinician decisions regarding the choice of resuscitation fluid is integral to translating the results of research into clinical practice. Little is known about the factors that substantially influence or drive clinical decision making.

In contrast to traditional surveys, discrete choice experiments (DCEs) are a recognised method to quantify and analyse clinical decision making. DCEs use simulated choice scenarios in which participants choose between attributes that have been pre-determined to be important in decision making, thereby allowing the relative importance of attributes to be determined.[7]

Our aim was to determine characteristics that influence doctors' and nurses' choice of resuscitation fluid in critically ill patients in Australia and New Zealand and the relative importance of these characteristics.

Methods

Study design

Doctors and nurses treating patients in the intensive care unit were asked to choose between two hypothetical IV resuscitation fluids in one of four randomly selected choice sets that included five separate patient scenarios (Figure 1). Nurses were included to reflect current practice in Australian and New Zealand ICUs, where both types of practitioners contribute to the decision to prescribe and administer resuscitation fluid.

The fluid type was characterised by pre-determined attributes and each attribute had pre-specified levels.

We developed the patient scenarios, attributes and attribute levels via a multiple-round consensus process using a panel of experienced Australian ICU doctors and nurses, who were selected through the Australian and New Zealand Intensive Care Society Clinical Trials Group (ANZICS CTG) network. The patient scenarios and fluid attributes were derived using cross-sectional data from an international sample of 391 ICUs from 24 countries; data were collected by our group.[8] The patient scenarios and fluid attributes were tested for clinical applicability in Australia and New Zealand and refined through the consensus process. In each round, the panel were presented with potential patient scenarios, attributes and attribute levels that were subsequently refined to create choices that were clinically applicable in prescribing resuscitation fluid in the ICU.

The final patient scenarios included two diagnostic categories: post-operative sepsis and traumatic brain injury (TBI). Each diagnostic category included two variations of illness severity that were defined according to physiological signs and therapeutic intensity (Table 1). For patients with post-operative sepsis, category A (stable) had a lower severity of illness compared with category B, in which haemodynamic instability was characterised by increasing inotrope and vasopressor requirements. For patients with TBI, category A (stable) had a lower severity of illness compared with category B, which was characterised by increasing intracranial pressure.

The final fluid attributes included type of resuscitation fluid, time to achieve haemodynamic stability, level of evidence supporting its use, pre-specified safety concerns, pre-specified mortality benefit, volume of IV fluid administered and overall cost of the fluid to the participating hospital (see "Final attributes and levels" in Appendix, online at cicm.org.au/Resources/Publications/Journal).

Each patient scenario ended with a clinical decision to administer resuscitation fluid. Respondents then chose one of two hypothetical fluids, described by its attributes (see Figure 1), or elected to administer no fluid. Those electing no fluid were then mandated to nominate one of the two hypothetical fluids that they thought would be best in the given scenario.

Experimental design

A d-efficient design (d-error = 0.3)[9] was generated based on Bayesian prior probabilities using Ngene software (ChoiceMetrics) to systematically vary the attribute levels across the choice sets. This type of experimental design links statistical efficiency to the likely econometric model that is to be estimated from discrete choice data. The final experimental design included a total of 20 possible scenarios, divided (or blocked) into four versions of five questions (see "Experimental design" in Appendix). Respondents conducted one block selected at random.

Sample size

From the d-efficient design, a theoretical minimum sample size of 44 doctors and 44 nurses was required to achieve statistical efficiency, assuming $\alpha = 0.05$ and $\beta = 0.8$.[10] After the survey was divided into four versions of five patient

Table 1. Final clinical scenarios presented to respondents

	ICU diagnostic category			
	Post-operative intra-abdominal sepsis*		TBI, intracranial pressure monitor insertion†	
Parameter	Scenario A	Scenario B	Scenario A	Scenario B
Age, years; sex	61; male	61; male	25; male	25; male
Medical history	COPD	COPD	na	na
Day of ICU stay	Day 1	Day 1	Day 1	Day 1
Vital signs				
Mean arterial pressure, mmHg	64	54	64	64
Heart rate, beats/min	102	120	102	120
Temperature, °C	38.1	39.5	37.6	37.7
Urine output, mL/h	20	10	20	10
Arterial lactate, mmol/L	2	3.5	2	2
Intracranial pressure, mmHg	–	–	14	20
Serum albumin, g/L	20	20	15	20
Serum sodium, mmol/L	135	135	140	147
Serum chloride, mmol/L	105	105	105	105
pH	7.35	7.35	7.35	7.35
Serum creatinine, µmol/L (on day before; on day measured)	90; 90	90; 150	na	na
Inotrope or vasopressor requirement	Stable	Increasing	Stable	Increasing
Inspired oxygen (Fio_2)	0.6	0.6	0.4	0.4

ICU = intensive care unit. TBI = traumatic brain injury. COPD = chronic obstructive pulmonary disease. na = not applicable. * From perforated diverticulum after Hartmann procedure; sedated, mechanically ventilated, not actively bleeding. † After emergency surgery and intracranial pressure monitor insertion for TBI after motor vehicle accident; cranial computed tomography scan showing diffuse axonal injury; sedated, mechanically ventilated.

scenarios, and assuming the same parameters as above, the theoretical minimum sample size increased to 176 per group.

Study sample selection

We recruited site principal investigators via an email invitation sent through the ANZICS CTG mailing list. To mitigate selection bias, principal investigators were instructed to distribute the electronic survey to a minimum of 10 ICU doctors and 10 ICU nurses at their nominated site, with a range of clinical experience.

Statistical analysis

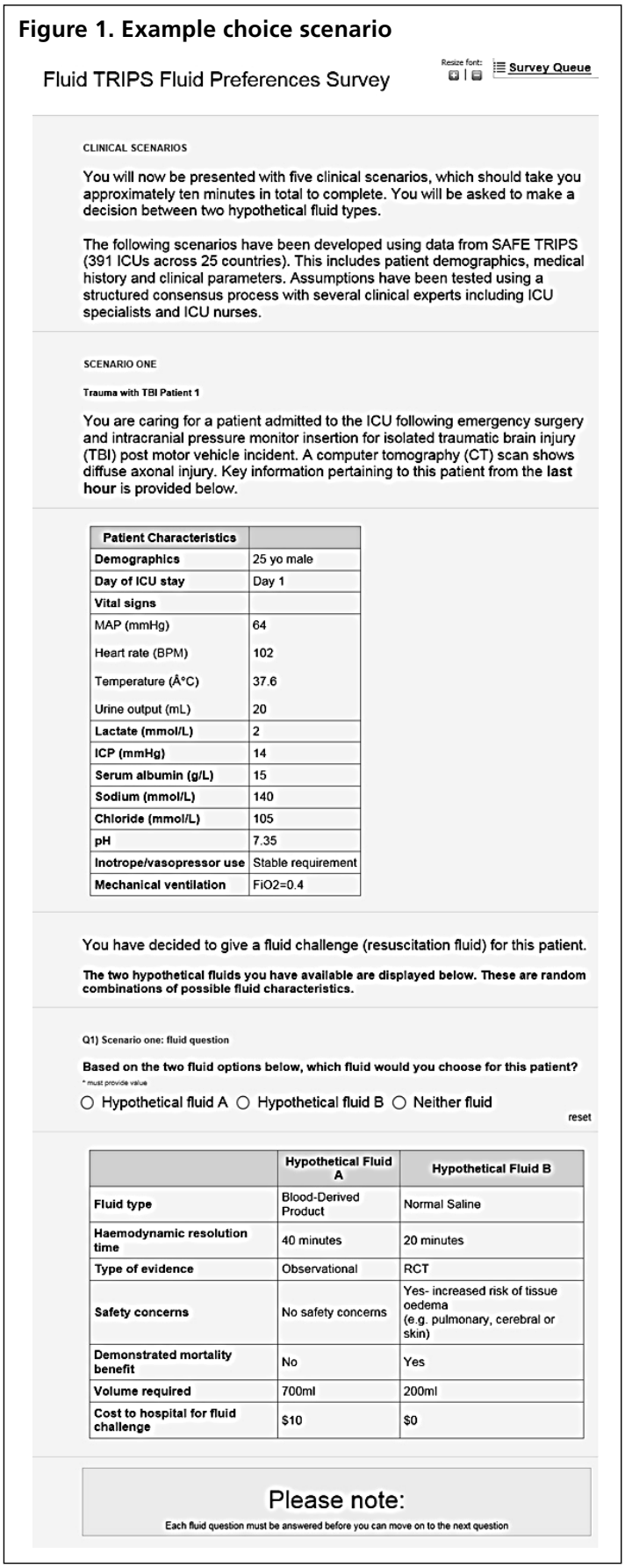
To investigate changes in utility (ie, preference for fluid), a mixed multinomial logit model (NLOGIT, version 4.0; Econometric Software) was fitted to the data (see "Final model" in Appendix).

Three models were fitted, using doctors-only data, nurses-only data and data from the full cohort. In each model, the dependent variable was fluid choice and a regression equation was used to estimate the effect of each attribute on the probability of observing the sequence of choices made over the five choice tasks. The analysis started with a fully adjusted model that included all covariates. The model complexity was reduced based on the likelihood ratio test while retaining the significant covariates that predict choice ($P < 0.10$). Internal validity was tested by examining the signs and significance of parameter estimates relative to pre-specified expectations.

Odds ratios (ORs) and 95% confidence intervals for choosing fluid were derived for each model comparison (ie, OR = exp[β]), where an OR > 1 indicates a preference for fluid with each unit change in that attribute, or for effects-coded attributes, with the attribute level compared with the nominated reference category (see "Reference categories for variables in final model" in Appendix). We analysed attributes including cost, time to haemodynamic resolution and volume administered as continuous variables. All statistical significance tests were conducted at the $\alpha = 0.05$ level. The relative importance of each of the respective attributes was calculated based on the percentage contribution of each attribute level range (across attribute levels) to overall utility.

Pseudo R^2 was used to evaluate model fit. This metric is analogous to the overall fit, or R^2, from a linear regression model and can be calculated when the data are non-linear.[11] In addition, an alternative specific constant was specified as a covariate in the model representing the average role of all the unobserved sources of utility in the decision scenarios.[11]

Figure 1. Example choice scenario



Fluid TRIPS Fluid Preferences Survey

Resize font: Survey Queue

CLINICAL SCENARIOS

You will now be presented with five clinical scenarios, which should take you approximately ten minutes in total to complete. You will be asked to make a decision between two hypothetical fluid types.

The following scenarios have been developed using data from SAFE TRIPS (391 ICUs across 25 countries). This includes patient demographics, medical history and clinical parameters. Assumptions have been tested using a structured consensus process with several clinical experts including ICU specialists and ICU nurses.

SCENARIO ONE

Trauma with TBI Patient 1

You are caring for a patient admitted to the ICU following emergency surgery and intracranial pressure monitor insertion for isolated traumatic brain injury (TBI) post motor vehicle incident. A computer tomography (CT) scan shows diffuse axonal injury. Key information pertaining to this patient from the **last hour** is provided below.

Patient Characteristics	
Demographics	25 yo male
Day of ICU stay	Day 1
Vital signs	
MAP (mmHg)	64
Heart rate (BPM)	102
Temperature (Â°C)	37.6
Urine output (mL)	20
Lactate (mmol/L)	2
ICP (mmHg)	14
Serum albumin (g/L)	15
Sodium (mmol/L)	140
Chloride (mmol/L)	105
pH	7.35
Inotrope/vasopressor use	Stable requirement
Mechanical ventilation	FiO2=0.4

You have decided to give a fluid challenge (resuscitation fluid) for this patient.

The two hypothetical fluids you have available are displayed below. These are random combinations of possible fluid characteristics.

Q1) Scenario one: fluid question

Based on the two fluid options below, which fluid would you choose for this patient?

* must provide value

○ Hypothetical fluid A ○ Hypothetical fluid B ○ Neither fluid

reset

	Hypothetical Fluid A	Hypothetical Fluid B
Fluid type	Blood-Derived Product	Normal Saline
Haemodynamic resolution time	40 minutes	20 minutes
Type of evidence	Observational	RCT
Safety concerns	No safety concerns	Yes- increased risk of tissue oedema (e.g. pulmonary, cerebral or skin)
Demonstrated mortality benefit	No	Yes
Volume required	700ml	200ml
Cost to hospital for fluid challenge	$10	$0

Please note:

Each fluid question must be answered before you can move on to the next question

Results

Participants

Principal investigators distributed the survey link to an estimated 1321 potential respondents, comprising 817 nurses and 504 doctors. A total of 367 respondents completed the survey: 193 doctors (52.6%) and 174 nurses, including five respondents indicating "other" professions (47.4%). This represented an estimated response rate of 27.8% (38.3% doctors; 21.3% nurses/other).

Participant characteristics are shown in Table 2. Most respondents were from tertiary or metropolitan hospitals. Doctors had a mean of 9.0 years' (SD, 8.5 years) ICU clinical experience and nurses/other had a mean of 12.1 years' (SD, 8.7 years) experience.

Discrete choice experiment results

Three models were constructed, for doctors only, nurses only and the full cohort (see "Full cohort results" in Appendix). Unadjusted results for each model are also presented in the Appendix.

Doctors

Results for the doctors-only model are shown in Table 3. Doctors preferred fluids characterised by lower cost (OR per $1 increase, –0.99 [95% CI, 0.98–0.99]; $P = < 0.001$), faster time to haemodynamic resolution (OR per min increase, 0.99 [95% CI, 0.98–1.00]; $P < 0.001$); high-quality evidence (OR for randomised controlled trial v observational, 1.34 [95% CI, 1.19–1.5]; $P < 0.001$); mortality benefit (OR for mortality benefit v not, 1.23 [95% CI, 1.07–1.41]; $P < 0.01$).

Relative to stable patients with post-operative sepsis (Category A), doctors were more likely to prescribe a fluid to a haemodynamically unstable patient (category B) (OR, 1.88 [95% CI, 1.40–2.52]; $P < 0.001$). Similarly, relative to stable patients with TBI (Category A), doctors were less likely to prescribe a fluid to patients with intracranial hypertension (Category B) (OR, 0.55 [95% CI, 0.4–0.74]; $P < 0.001$). The preference to prescribe a fluid to a Category A patient with TBI was not significantly different to that for a Category A patient with post-operative sepsis (OR, 1.07 [95% CI, 0.79–1.44]; $P = 0.67$).

Relative to saline, doctors were more likely to prescribe a buffered salt solution (OR, 2.32 [95% CI, 1.88–2.88]; $P < 0.001$) and less likely to prescribe synthetic colloids (OR, 0.38 [95% CI, 0.30–0.48]; $P < 0.001$) and blood-derived products (OR, 0.73 [95% CI, 0.61–0.88]; $P < 0.001$).

Table 2. Respondent characteristics

Characteristic	Total, *n* = 367	Doctors, *n* = 193	Nurses/other, *n* = 174
Country, *n* (%)			
Australia	283 (77%)	155 (80%)	128 (74%)
New Zealand	84 (23%)	38 (20%)	46 (26%)
Hospital type, *n* (%)			
Tertiary	235 (64%)	112 (58%)	123 (71%)
Metropolitan	73 (20%)	45 (23%)	28 (16%)
Regional/rural/private	54 (15%)	31 (16%)	23 (13%)
Data missing	5 (1%)	5 (3%)	0
Experience, years			
Mean (SD)	10.5 (8.7)	8.97(8.45)	12.14 (8.65)
Median (range)	9 (0–35)	7 (0–35)	10.5 (0–35)
0–5, *n* (%)	115 (31%)	47 (24%)	68 (39%)
6–14, *n* (%)	118 (32%)	64 (33%)	54 (31%)
> 14, *n* (%)	134 (37%)	82 (43%)	52 (30%)

Table 3. Predictors of fluid choice, doctors only

Attribute and attribute level	OR (95% CI)	*P*
Alternative specific constant (reference: no fluid)	1.42 (0.88–2.30)	0.1518
Cost, per $1 increase	0.99 (0.98–0.99)	0.0002
Patient		
(reference: sepsis, category A)		
Sepsis, category B	1.88 (1.40–2.52)	< 0.0001
Traumatic brain injury, category A	1.07 (0.79–1.44)	0.6697
Traumatic brain injury, category B	0.55 (0.40–0.74)	0.0001
Fluid type (reference: normal saline)		
Buffered salt solution	2.32 (1.88–2.88)	< 0.0001
Synthetic colloid	0.38 (0.30–0.48)	< 0.0001
Blood-derived product	0.73 (0.61–0.88)	0.0007
Haemodynamic resolution time, per min increase	0.99 (0.98–1.00)	0.0001
Level of evidence (reference: observational)		
Randomised controlled trial	1.34 (1.19–1.50)	< 0.0001
Safety concerns (reference: no safety concerns)		
Acute renal injury	1.25 (0.82–1.91)	0.3027
Coagulopathy	1.08 (0.79–1.47)	0.6229
Metabolic acid–base disorder	0.14 (0.05–0.41)	0.0003
Tissue oedema	1.62 (1.13–2.32)	0.0086
Mortality benefit (reference: no benefit)	1.23 (1.07–1.41)	0.0037
Volume, per mL increase	1.00 (1.00–1.00)	0.0593
Hospital type (reference: tertiary)		
Metropolitan	1.00 (0.77–1.30)	0.9803
Regional/rural	1.19 (0.88–1.61)	0.2616
Professional experience, years		
(reference: 0–5 years)		
6–14	0.83 (0.67–1.03)	0.0974
≥ 15	0.96 (0.76–1.22)	0.7344

OR = odds ratio.

Relative to no safety concerns, doctors were less likely to prescribe a fluid with a risk of metabolic acid–base disorder (OR, 0.14 [95% CI, 0.05–0.41]; $P < 0.001$) and were more likely to prescribe fluid with a risk of tissue oedema (OR, 1.62 [95% CI, 1.13–2.32]; $P < 0.01$).

Figure 2 shows the relative importance of attributes and the contribution to decision utility. For doctors, the three most important attributes were pre-specified safety concerns, type of resuscitation fluid and patient type. These were followed by time to achieve haemodynamic stability, the type of evidence, the overall cost of fluid to the participating hospital, whether or not there was an associated reduction in mortality and the volume of IV fluid administered.

Nurses

Results for the nurses-only model are reported in Table 4. Relative to nurses with limited experience (0–5 years), nurses with 6–14 years of experience were more likely to prescribe fluid (OR, 1.40 [95% CI, 1.05–1.88]; $P < 0.05$) and nurses with 15 or more years of experience were less likely to prescribe fluid (OR, 0.74 [95% CI, 0.57–0.96]; $P < 0.05$).

Relative to a stable patient with post-operative sepsis (Category A), nurses were more likely to prescribe fluid to a haemodynamically unstable patient with post-operative sepsis (Category B) (OR, 2.59 [95% CI, 1.45–4.64]; $P < 0.01$) and were less likely to prescribe fluid to a stable patient with TBI (Category A) (OR, 0.61 [95% CI, 0.38–0.96]; $P < 0.05$) and a patient with intracranial hypertension (Category B) (OR, 0.44 [95% CI, 0.28–0.70]; $P < 0.001$).

Relative to saline, nurses were less likely to prescribe synthetic colloids (OR, 0.79 [95% CI, 0.64–0.98]; $P < 0.05$) and blood-derived products (OR, 0.70 [95% CI, 0.58–0.83]; $P < 0.001$). The preference to prescribe buffered salt solution was not significantly different compared with saline (OR, 0.93 [95% CI, 0.76–1.14]; $P = 0.48$).

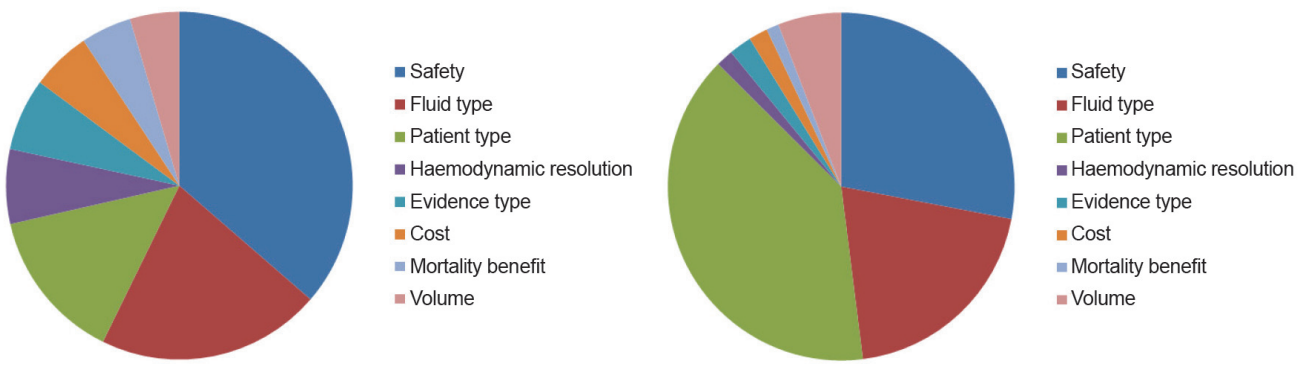
Relative to no safety concerns, nurses were more likely to prescribe fluid with an associated risk of acute renal injury

Table 4. Predictors of fluid choice, nurses only

Attribute and attribute level	OR (95% CI)	*P*
Alternative specific constant (reference: no fluid)	4.60 (2.48–8.53)	< 0.0001
Cost, per $1 increase	1.00 (0.99–1.00)	0.531
Patient (reference: sepsis, category A)		
Sepsis, category B	2.59 (1.45–4.64)	0.0013
Traumatic brain injury, category A	0.61 (0.38–0.96)	0.0311
Traumatic brain injury, category B	0.44 (0.28–0.70)	0.0004
Fluid type (reference: normal saline)		
Buffered salt solution	0.93 (0.76–1.14)	0.482
Synthetic colloid	0.79 (0.64–0.98)	0.0321
Blood-derived product	0.70 (0.58–0.83)	0.0001
Haemodynamic resolution time, per min increase	1.00 (0.99–1.00)	0.5964
Level of evidence (reference: observational)		
Randomised controlled trial	1.06 (0.95–1.18)	0.3321
Safety concerns (reference: no safety concerns)		
Acute renal injury	1.58 (1.02–2.44)	0.0409
Coagulopathy	1.00 (0.72–1.40)	0.9833
Metabolic acid–base disorder	0.46 (0.15–1.47)	0.1913
Tissue oedema	0.70 (0.48–1.01)	0.0561
Mortality benefit (reference: no benefit)	0.97 (0.84–1.12)	0.6841
Volume, per mL increase	1.00 (1.00–1.00)	0.1204
Hospital type (reference: tertiary)		
Metropolitan	0.75 (0.52–1.09)	0.1295
Regional/rural	1.40 (0.92–2.14)	0.1145
Professional experience, years (reference: 0–5 years)		
6–14	1.40 (1.05–1.88)	0.0240
≥ 15	0.74 (0.57–0.96)	0.0230

OR = odds ratio.

Figure 2. Relative importance and contribution of attributes to decision utility for doctors (left) and nurses (right)



(OR, 1.58 [95% CI, 1.02–2.44]; $P < 0.05$). The preference to prescribe a fluid to a patient with a risk of coagulopathy (OR, 1.00 [95% CI, 0.72–1.40]; $P = 0.98$), metabolic acid–base disorder (OR, 0.46 [95% CI, 0.15–1.47]; $P = 0.19$) and tissue oedema (OR, 0.70 [95% CI, 0.48–1.01]; $P = 0.06$) was not statistically different compared with a fluid with no safety concerns.

For nurses, the three most important attributes were patient type, pre-specified safety concerns and type of resuscitation fluid (Figure 2). These were followed by the volume of IV fluid administered, the type of evidence, the overall cost of the fluid to the participating hospital, the time to achieve haemodynamic stability and whether or not there was an associated reduction in mortality.

Model fit and calibration

The final adjusted models had pseudo R^2 values of 0.16 for doctors only, 0.14 for nurses only and 0.12 for the full cohort. The ORs for the alternative specific constant covariate in the final adjusted models were doctors, 1.42 (95% CI, 0.88–2.30; $P = 0.15$); nurses, 4.60 (95% CI, 2.48–8.53; $P < 0.0001$); and the full cohort, 2.18 (95% CI, 1.56–3.03; $P < 0.0001$).

Discussion

In this study employing discrete-choice methodology to assess the key drivers of fluid choice, and their relative importance, several themes emerged. Differences were noted in the drivers of fluid choice for doctors and nurses, suggesting that doctor and nurse cohorts use different information when choosing preferred fluids for resuscitation. For doctors, safety concerns, patient type and fluid type were collectively responsible for almost three-quarters of decision making, and volume of IV fluid administered was the only clinical variable not to reach statistical significance as a driver of choice. For nurses, decision making was influenced to a greater extent by the same three attributes, but the order of importance differed, and model results suggest that decision scenarios may not have included all attributes that drive nurse decisions on fluid choice (alternative specific constant, $P < 0.0001$).

Choice experiments (commonly classified as conjoint analysis or DCEs) have been used in psychology and marketing research for over 50 years.[12] The use of this methodology in health care has increased over the past two decades, mostly investigating the trade-off between health outcomes and patient or consumer preferences.[13] To our knowledge, our study is unique in applying DCE methods to understand ICU clinical decision making, recognising that this occurs in a highly complex, heterogeneous, data-driven clinical environment.

DCEs have many potential biases related to the misrepresentation of responses, scenario mis-specification and sampling.[14] In our study, we cannot rule out the presence of bias in how scenarios were represented or interpreted, including whether enough information was presented for respondents to make a decision reflective of actual practice. However, to minimise some of these biases, we used a multidisciplinary expert-based, multiple-round consensus process and piloting to ensure clinical relevance and face validity (representativeness) of the clinical scenarios. We also used a pre-determined statistical analysis plan using current, validated statistical methodology.[11]

Our study used a sample of doctors and nurses with varied clinical experience working across tertiary, metropolitan and regional hospitals. We included nurses because they may have a role in choosing resuscitation fluids in Australasian ICUs, although nurses are unlikely to have prescribing rights. We relied on convenience sampling, which may have reduced the external validity of our findings, although the response rate for both groups exceeded 20%. Additionally, we restricted the survey to two clinical scenarios that may be encountered in the ICU, which were constructed to be representative of common clinical decision making using a consensus of expert advice and supported by cross-sectional evidence from 391 ICUs in 24 countries.[8]

Our findings show that ICU doctors consider multiple attributes when contemplating fluid choice. These include attributes of the fluid, such as pre-specified safety concerns, and attributes of the patient, such as diagnosis and illness severity. However, fluid type remains a key independent driver of choice that ranks above patient attributes and individual attributes of the fluid, including time to achieve haemodynamic stability, type of evidence, fluid cost, associated mortality reductions and fluid volume administered. The preference in our sample for balanced salt solutions concurs with two recent cross-sectional studies of fluid resuscitation use in Australia and New Zealand and internationally, and with a retrospective ecological study conducted in Australia and New Zealand.[15-17]

We identified inconsistent findings for doctors and for nurses, particularly for the safety attribute. For both cohorts, there was a trend towards prescribing fluids that carried a risk of acute renal injury compared with other safety attributes. In the context of evidence showing that fluid choice increases the risk of this event,[1-4] it is difficult to know if this finding is real or influenced by bias in the experiment.

Model results for the nurses-only model imply that other unmeasured factors may have had an impact on fluid choice (alternative specific constant, $P < 0.0001$). This is in addition to the divergent findings to the doctors-only model. These may be chance findings or may have been due to nurses'

unfamiliarity with prescribing decisions, as the nurse respondents may not, in practice, have had prescribing rights for IV fluid in hospitals. The nurses-only model results also differed by number of years of experience, with more experienced nurses (15 or more years' experience) less likely to prescribe fluid relative to less experienced nurses, which suggests that clinical experience may lead to more conservative prescribing decisions. Heterogeneity in nursing practice relating to fluid resuscitation has been described in another Australian survey of ICU nurses.[18]

Conclusion

Our results show that safety concerns, patient type and fluid type are collectively responsible for almost three-quarters of doctors' decision making about prescribing resuscitation fluids in the ICU. Nurse decision making is influenced to a greater extent by the same three attributes, with a different order of importance, and other unmeasured attributes may also play a role. The ICU is a high-resource component of health care, but costs of resuscitation fluids appear to play only a minor role in clinical decision making for both groups. This information can be used in designing interventions to encourage evidence-based practice in the prescription of resuscitation fluids.

Competing interests

Colman Taylor is a paid employee of Optum, which provides health economics consulting services for pharmaceutical and medical device companies and the Australian Government. No other conflicts of interest declared.

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Appendix

This appendix was part of the submitted manuscript and has been peer reviewed. It is posted as supplied by the authors.

Supplementary material

List of investigators

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Gosford Hospital	Rob Cameron	**Tauranga Hospital**	Troy Browne
John Hunter Hospital	Miranda Hardie	**Wellington Hospital**	Paul Young
Liverpool Hospital	Sharon Micallef; Anders Aneman	**Western Hospital**	Samantha Bates
Nambour Hospital	Richard Moore	**Westmead Hospital**	Christina Whitehead

Final attributes and levels

Attribute	Attribute level
Patient type	Sepsis category A[1]
	Sepsis category B[1]
	TBI category A[2]
	TBI category B[2]
Cost to hospital for fluid challenge	$0
	$10
	$20
	$30
	$40
Fluid type	Normal saline
	Buffered salt solution
	Synthetic Colloid
	Blood derived product
Haemodynamic resolution time	20 minutes
	40 minutes
	60 minutes
	80 minutes
Type of evidence	Observational
	Randomised Controlled Trial
Safety concerns	No safety concerns
	Acute kidney injury
	Coagulopathy
	Metabolic Acid-base disorder
	Tissue oedema
Demonstrated mortality benefit	No
	Yes
Volume required	200mL
	500mL
	700mL
	1000mL

1. Category A had a lower severity of illness compared to category B that was haemodynamically less stable characterised by increasing inotrope/vasopressor requirements (see Table 1)
2. Category A had a lower severity of illness compared to category B that had increasing intracranial pressure (see Table 1)

Experimental design

	BLOCK 1		**BLOCK 2**		**BLOCK 3**		**BLOCK 4**	
	BLOCK 1 Question 1 (Scenario 5)		**BLOCK 2 Question 1 (Scenario 1)**		**BLOCK 3 Question 1 (Scenario 4)**		**BLOCK 4 Question 1 (Scenario 6)**	
	Fluid A	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**
Type of patient	Post-op sepsis – category A		Post-op sepsis – category B		Post-op sepsis – category A		Trauma with TBI – category A	
Fluid type	Normal Saline	Synthetic Colloid	Normal Saline	Synthetic Colloid	Blood derived product	Normal Saline	Blood derived product	Normal Saline
Haemodynamic resolution time	40 minutes	40 minutes	20 minutes	80 minutes	20 minutes	80 minutes	40 minutes	20 minutes
Type of evidence	RCT	Observational	Observational	RCT	Observational	Observational	Observational	RCT
Safety concerns	Yes - Increased risk of coagulopathy	Yes - Increased risk of acute renal replacement therapy	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)	No safety concerns	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)	No safety concerns	No safety concerns	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)
Demonstrated Mortality benefit	No	No	Yes	No	No	No	No	Yes
Volume required	700mL	700mL	200mL	200mL	500mL	500mL	700mL	200mL
Cost to hospital for fluid challenge	$40	$10	$40	$0	$0	$40	$10	$0
For this patient, which fluid would you choose?	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B
	BLOCK 1 Question 2 (Scenario 10)		**BLOCK 2 Question 2 (Scenario 2)**		**BLOCK 3 Question 2 (Scenario 13)**		**BLOCK 4 Question 2 (Scenario 7)**	
	Fluid A	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**
Type of patient	Post-op sepsis – category A		Trauma with TBI – category A		Post-op sepsis – category B		Post-op sepsis – category B	
Fluid type	Buffered salt solution	Normal Saline	Synthetic Colloid	Buffered salt solution	Buffered salt solution	Synthetic Colloid	Blood derived product	Buffered salt solution
Haemodynamic resolution time	80 minutes	40 minutes	60 minutes	20 minutes	20 minutes	80 minutes	60 minutes	20 minutes
Type of evidence	Observational	Observational	RCT	RCT	Observational	RCT	RCT	Observational
Safety concerns	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)	Yes - Increased risk of acute renal replacement therapy	Yes - Increased risk of acute renal replacement therapy	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes - Increased risk of acute renal replacement therapy	Yes - Increased risk of acute renal replacement therapy	Yes - Increased risk of coagulopathy
Demonstrated Mortality benefit	Yes	Yes	Yes	Yes	No	Yes	Yes	No
Volume required	500mL	700mL	1000mL	200mL	500mL	1000mL	1000mL	500mL
Cost to hospital for fluid challenge	$10	$10	$20	$40	$40	$10	$20	$40
For this patient, which fluid would you choose?	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B
	BLOCK 1 Question 3 (Scenario 11)		**BLOCK 2 Question 3 (Scenario 3)**		**BLOCK 3 Question 3 (Scenario 15)**		**BLOCK 4 Question 3 (Scenario 8)**	
	Fluid A	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**
Type of patient	Trauma with TBI – category B		Post-op sepsis – category A		Post-op sepsis – category A		Trauma with TBI – category A	
Fluid type	Synthetic Colloid	Synthetic Colloid	Blood derived product	Buffered salt solution	Synthetic Colloid	Normal Saline	Buffered salt solution	Blood derived product

Haemodynamic resolution time	40 minutes	60 minutes	60 minutes	20 minutes	20 minutes	80 minutes	80 minutes	60 minutes
Type of evidence	Observational	RCT	Observational	RCT	Observational	Observational	Observational	RCT
Safety concerns	Yes - Increased risk of coagulopathy	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes - Increased risk of coagulopathy	No safety concerns	Yes - Increased risk of acute renal replacement therapy	Yes - Increased risk of coagulopathy	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)
Demonstrated Mortality benefit	No	Yes	No	No	Yes	No	Yes	Yes
Volume required	200mL	1000mL	700mL	500mL	200mL	200mL	500mL	700mL
Cost to hospital for fluid challenge	$0	$20	$10	$0	$40	$0	$0	$20
For this patient, which fluid would you choose?	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B
	BLOCK 1 Question 4 (Scenario 12)		**BLOCK 2 Question 4 (Scenario 18)**		**BLOCK 3 Question 4 (Scenario 17)**		**BLOCK 4 Question 4 (Scenario 9)**	
	Fluid A	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**
Type of patient	Trauma with TBI – category B		Trauma with TBI – category A		Trauma with TBI – category B		Trauma with TBI – category B	
Fluid type	Normal Saline	Blood derived product	Normal Saline	Buffered salt solution	Buffered salt solution	Normal Saline	Synthetic Colloid	Blood derived product
Haemodynamic resolution time	60 minutes	60 minutes	40 minutes	40 minutes	80 minutes	20 minutes	80 minutes	60 minutes
Type of evidence	RCT	RCT	RCT	Observational	RCT	Observational	RCT	RCT
Safety concerns	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)	Yes - Increased risk of coagulopathy	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic acidosis/alkalosis)	No safety concerns	Yes - Increased risk of acute renal replacement therapy	Yes- Increased risk of tissue oedema (e.g. pulmonary, cerebral, or skin)
Demonstrated Mortality benefit	Yes	Yes	No	No	No	No	Yes	Yes
Volume required	1000mL	1000mL	700mL	700mL	200mL	500mL	1000mL	1000mL
Cost to hospital for fluid challenge	$20	$40	$10	$10	$40	$0	$20	$20
For this patient, which fluid would you choose?	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B
	BLOCK 1 Question 5 (Scenario 16)		**BLOCK 2 Question 5 (Scenario 19)**		**BLOCK 3 Question 5 (Scenario 20)**		**BLOCK 4 Question 5 (Scenario 14)**	
	Fluid A	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**	**Fluid A**	**Fluid B**
Type of patient	Trauma with TBI – category B		Trauma with TBI – category A		Post-op sepsis – category B		Post-op sepsis – category B	
Fluid type	Synthetic Colloid	Buffered salt solution	Buffered salt solution	Blood derived product	Blood derived product	Synthetic Colloid	Normal Saline	Blood derived product
Haemodynamic resolution time	80 minutes	40 minutes	20 minutes	80 minutes	40 minutes	60 minutes	60 minutes	40 minutes
Type of evidence	RCT	Observational	Observational	Observational	RCT	RCT	RCT	Observational
Safety concerns	Yes - Increased risk of acute renal replacement therapy	No safety concerns	No safety concerns	Yes - Increased risk of coagulopathy	No safety concerns	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic	Yes - increased risk of metabolic acid-base disorder (e.g. Metabolic	Yes - Increased risk of coagulopathy

						acidosis/alkalosis)	acidosis/alkalosis)	
Demonstrated Mortality benefit	Yes	Yes	No	No	Yes	Yes	No	No
Volume required	1000mL	500mL	500mL	200mL	200mL	1000mL	700mL	700mL
Cost to hospital for fluid challenge	$20	$10	$0	$40	$0	$20	$10	$20
For this patient, which fluid would you choose?	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B	Fluid A	Fluid B

Final model
The final model was a mixed (random parameters) logit model as described below.

$U(A / B) = \sigma + \beta_1 \text{fluid type} + \beta_2 \text{time to haemodynamic resolution} + \beta_3 \text{level of evidence} + \beta_4 \text{safety} + \beta_4 \text{moratlity} + \beta_5 \text{volume} + \beta_6 \text{cost} + \beta_7 \text{patient} + \varepsilon$

$U(\text{no treatment}) = 0.$

Where $\beta_{1\text{-}7}$ represents the parameter estimates of the respective attributes and denotes the relative contribution to treatment choice when statistically significant ($P<0.05$). σ is the alternative specific constant and captures the preference of fluid over no fluid, and ε denotes the random error term associated with each choice set and accounts for the unobserved preference variation. A higher utility indicates preference for fluid. With the exception of cost, haemodynamic resolution time, and fluid volume, all attributes were effects coded and interpreted relative to the base category

Reference categories for variables in final model

Attribute	Attribute level
Patient	**Sepsis, category A (reference)**
	Sepsis, category B
	TBI, category A
	TBI, category B
Cost to hospital for fluid challenge	***Analysed as continuous variable***
Fluid type	**Normal saline (reference)**
	Buffered salt solution
	Synthetic Colloid
	Blood derived product
	Randomised Controlled Trial
Haemodynamic resolution time	***Analysed as continuous variable***
Level of evidence	**Observational (reference)**
	RCT
Safety concerns	**No safety concerns (reference)**
	Acute renal injury
	Coagulopathy
	Metabolic Acid-base disorder
	Tissue oedema
Demonstrated mortality benefit	**No (reference)**
	Yes
Volume required	***Analysed as continuous variable***
Hospital type	**Tertiary (reference)**
	Metro
	Regional/rural
Professional experience	**0-5 years (reference)**
	6-14 years
	15 years plus

Doctors unadjusted results

Table S1. Unadjusted results for doctors only model

Attribute	Attribute level	OR	OR 95%CI lower	OR 95%CI Upper	P
Alternative specific constant (reference, no fluid)		1.33	0.84	2.12	0.2220
Cost*	*per $1 increase*	0.99	0.99	0.99	0.0002
Patient (sepsis, category A reference)					
	Sepsis, Cat. B	1.86	1.39	2.47	<0.0001
	TBI, Cat. A	1.09	1.76	0.81	0.5664
	TBI, Cat. B	0.56	0.42	0.75	0.0001
Fluid type (reference, Normal saline)					
	Buffered salt solution	2.32	1.87	2.87	<0.0001
	Synthetic Colloid	0.38	0.30	0.48	<0.0001
	Blood derived product	0.71	0.59	0.85	0.0002
Haemodynamic resolution time	per minute increase	0.99	0.98	0.99	0.0001
Level of evidence (observational, reference)					
	Randomised Controlled Trial	1.34	1.19	1.50	<0.0001
Safety concerns (No safety concerns, reference)					
	Acute renal injury	1.28	0.84	1.95	0.2466
	Coagulopathy	1.10	0.81	1.50	0.5330
	Metabolic Acid-base disorder	0.13	0.04	0.38	0.0002
	Tissue oedema	1.61	1.13	2.30	0.0087
Mortality benefit (no, reference)		1.23	1.07	1.41	0.0031
Volume	per mL increase	1.00	1.00	1.00	0.0537

Nurses unadjusted results

Table S2. Unadjusted results for nurses only model

Attribute	Attribute level	OR	OR 95%CI lower	OR 95%CI Upper	P
Alternative specific constant (reference, no fluid)		4.25	2.37	7.61	<0.0001
Cost	per $1 increase	1.00	0.99	1.00	0.5289
Patient (sepsis, category A reference)					
	Sepsis, Cat.B	2.52	1.41	1.41	0.0017
	TBI, Cat. A	0.60	0.38	0.95	0.0290
	TBI, Cat. B	0.45	0.29	0.71	0.0005
Fluid type (reference, Normal saline)					
	Buffered salt solution	0.93	0.76	1.13	0.4779
	Synthetic Colloid	0.79	0.64	0.98	0.0347
	Blood derived product	0.70	0.58	0.83	0.0001
Haemodynamic resolution time	per minute increase	1.00	0.99	1.00	0.5737
Level of evidence (observational, reference)					
	Randomised Controlled Trial	1.06	0.95	1.18	0.3250
Safety concerns (No safety concerns, reference)					
	Acute renal injury	1.57	1.02	2.43	0.0409
	Coagulopathy	1.01	0.72	1.40	0.9688
	Metabolic Acid-base disorder	0.46	0.15	1.46	0.1878
	Tissue oedema	0.70	0.49	1.01	0.0588
Mortality benefit (no, reference)		0.97	0.84	1.12	0.6821
Volume	per mL increase	1.00	1.00	1.00	0.1186

Full cohort results

Table S3. Unadjusted results for the full cohort

Attribute	attribute level	OR	OR 95%CI lower	OR 95%CI Upper	P
Alternative specific constant (reference, no fluid)		1.94	1.42	2.66	<0.0001
Cost	per $1 increase	0.99	0.99	1.00	0.0018
Patient (sepsis, category A reference)					
	Sepsis, Cat. B	1.66	1.33	2.07	<0.0001
	TBI, Cat. A	1.02	0.83	1.26	0.8312
	TBI, Cat. B	0.65	0.53	0.79	<0.0001
Fluid type (reference, Normal saline)					
	Buffered salt solution	1.44	1.25	1.65	<0.0001
	Synthetic Colloid	0.58	0.50	0.67	<0.0001
	Blood derived product	0.72	0.64	0.81	<0.0001
Haemodynamic resolution time	per minute increase	0.99	0.99	1.00	0.0004
Level of evidence (observational, reference)					
	Randomised Controlled Trial	1.17	1.09	1.27	<0.0001
Safety concerns (No safety concerns, reference)					
	Acute renal injury	1.50	1.13	2.00	0.0057
	Coagulopathy	1.13	0.91	1.41	0.2552
	Metabolic Acid-base disorder	0.22	0.11	0.48	0.0001
	Tissue oedema	1.11	0.87	1.42	0.4190
Mortality benefit (no, reference)		1.08	0.98	1.19	0.1140
Volume	per mL increase	1.00	1.00	1.00	0.8251

Table S4. Adjusted results for the full cohort

Attribute	Attribute level	OR	OR 95%CI lower	OR 95%CI Upper	P
Alternative specific constant (reference, no fluid)		2.18	1.56	3.03	<0.0001
Cost	per $1 increase	0.99	0.99	1.00	0.0023
Patient (sepsis, category A reference)					
	Sepsis, Cat. B	1.69	1.35	2.11	<0.0001
	TBI, Cat. A	1.02	0.82	1.26	0.8604
	TBI, Cat. B	0.63	0.51	0.77	<0.0001
Fluid type (reference, Normal saline)					
	Buffered salt solution	1.43	1.25	1.65	<0.0001
	Synthetic Colloid	0.57	0.49	0.66	<0.0001
	Blood derived product	0.73	0.64	0.82	<0.0001
Haemodynamic resolution time	per minute increase	0.99	0.99	1.00	0.0008
Level of evidence (observational, reference)					
	Randomised Controlled Trial	1.17	1.09	1.27	0.0001
Safety concerns (No safety concerns, reference)					
	Acute renal injury	1.50	1.12	2.00	0.0066
	Coagulopathy	1.11	0.90	1.39	0.3287
	Metabolic Acid-base disorder	0.23	0.11	0.50	0.0002
	Tissue oedema	1.10	0.86	1.41	0.4618
Mortality benefit (no, reference)		1.08	0.98	1.19	0.1313
Volume	*per mL increase*	1.00	1.00	1.00	0.8820
Hospital type (Tertiary, reference)					
	Metro	0.92	0.75	1.14	0.4482
	Regional/rural	1.24	0.98	1.57	0.0791
Professional experience (0-5 years, reference)					
	6-14 years	1.02	0.87	1.20	0.8044
	15years plus	0.86	0.73	1.01	0.0722
Doctor (nurse, reference)		0.75	0.67	0.85	<0.0001