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[Intervention Review]

Intravenous fluids for abdominal aortic surgery

Patiparn Toomtong¹, Sirilak Suksompong¹¹Department of Anesthesiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand**Contact address:** Patiparn Toomtong, Department of Anesthesiology, Faculty of Medicine, Siriraj Hospital, Mahidol University, 2 Prannok Road, Siriraj, Bangkok-noi, Bangkok, 10700, Thailand. siptm@mahidol.ac.th.**Editorial group:** Cochrane Vascular Group**Publication status and date:** New search for studies and content updated (no change to conclusions), published in Issue 1, 2010.**Citation:** Toomtong P, Suksompong S. Intravenous fluids for abdominal aortic surgery. *Cochrane Database of Systematic Reviews* 2010, Issue 1. Art. No.: CD000991. DOI: [10.1002/14651858.CD000991.pub2](https://doi.org/10.1002/14651858.CD000991.pub2).

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ABSTRACT

Background

Surgery on the abdominal aorta to treat aneurysms or occlusive disease is a major undertaking which requires intensive physiological support and fluid management. Blood products are often used but the main fluid replacement is with crystalloids or colloids. For years there has been controversy over which fluid is optimal and a number of studies have examined the subject. This is an update of a Cochrane review first published in 2000 and previously updated in 2002.

Objectives

To determine the effectiveness of different non-blood replacement fluids used in abdominal aorta procedures with a view to identifying the optimal fluid for use.

Search methods

The Cochrane Peripheral Vascular Diseases Group searched their Specialised Register (August 2009) and the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2009, Issue 3) for publications describing randomised controlled trials of non-blood replacement fluids in abdominal aortic surgery. In addition, the reference lists from retrieved trials were screened for further information about trials.

Selection criteria

Randomised controlled trials assessing the effects of at least one specific non-blood fluid used for replacement therapy in operations on, and confined to, the abdominal aorta.

Data collection and analysis

Data were extracted and then entered into the Review Manager software where statistical analyses were performed.

Main results

Thirty-eight trials involving 1589 patients were included. Patients undergoing aortic surgery had various physiological parameters measured before and after their operation (these were cardiac, respiratory, haematological, and biochemical). Patients were randomised to a fluid type. This review demonstrated that no single fluid affects any outcome measure significantly more than another fluid across a range of outcomes. The death rate in these studies was 2.45% (39 patients).

Authors' conclusions

Despite the confirmed beneficial effects of colloids in this review, further studies are still required. There are no studies examining the effects of combination fluid therapy. The primary research outcome was death, for which results were limited; therefore, future studies

should pay more attention to short-term outcomes such as minimising the need for allogenic blood transfusion, complications (organ failure), and length of stay in both the intensive care unit and hospital.

PLAIN LANGUAGE SUMMARY

Intravenous fluids for body fluid management during abdominal aortic surgery

There is not enough evidence to show the best fluid replacement to use during and following surgery on the abdominal aorta. Surgery on the abdominal aorta is a major surgical procedure with a mortality of 1.5% in elective patients and up to 5% in emergency surgery. Fluid replacement is needed to replace tissue fluids lost during surgery. Blood products, non-blood products, or combinations including crystalloid solutions and colloids are used. Combination therapy is most common. The review of trials found that although 38 randomised trials involving 1589 patients were identified, there was not enough evidence on the benefits of any particular individual or combination fluid therapy. No single fluid affected any outcome measure significantly more than another fluid across a range of outcomes. The trials used many different fluid replacement comparisons so that few results could be pooled. Important outcomes are the need for allogenic blood transfusion, complications of organ failure, and length of stay in both the intensive care unit and hospital.

BACKGROUND

Description of the condition

Surgery on the abdominal aorta is most commonly performed for the following reasons. Firstly, aneurysm of the abdominal aorta. This has an estimated prevalence of between 2% and 5% in people over 60 years of age, with a male to female ratio of approximately 4:1 (Gratama 2009; Shirani 2009). The prevalence of abdominal aortic aneurysm is higher in people with atherosclerosis, where men over 59 years of age have an abdominal aortic aneurysm prevalence of 11.1%, which is twice as high as for men over 65 years old in the general population. Surgery using an open approach necessitates cross-clamping of the abdominal aorta during graft insertion and anastomosis. The second reason is for atherosclerotic disease. In the USA this affects 10% of the population over the age of 70 years (US Dept of Com 1984). A proportion of these people will require surgery on the abdominal aorta to improve lower limb blood flow.

Surgery which involves cross-clamping of the abdominal aorta results in a reduction in plasma volume that leads to severe hypotensive episodes on releasing the clamp, especially in aneurysm patients. In patients with aorto-occlusive disease the haemodynamic effects from aortic cross-clamping do not cause as much volatility because of the collateral circulation that has formed. Compensatory effects, such as vasoconstriction and an increase in heart rate, can maintain blood pressure for losses of blood up to around 40%, or two litres.

Loss of fluid is due to blood loss at the site of surgery, which averages one to three litres during aneurysm surgery; extracellular losses due to the development of oedema in the tissues as a result of increased microvascular permeability, typically one litre per hour during surgery and continuing into the immediate postoperative period; evaporation from the open peritoneal cavity during the operation. In addition, at clamp release blood is released into a vasodilated ischaemic periphery, which leads to a loss of filling pressure as a result of the loss of afterload resistance. This has the same physiological effect as acutely decreasing the plasma volume. Therefore, there is an apparent reduction in plasma volume at clamp release although the circulating volume has not actually changed.

Description of the intervention

The plasma volume reduction is corrected at the time of surgery and in the early postoperative period with blood products and various crystalloid and colloid solutions. Examples of fluids include 0.9% (normal) saline, 1.8% (hypertonic) saline, starch solutions, gelatins and dextran solutions. There are various factors either in favour of or against each of the individual fluids. These include persistence within the circulatory system, effects on renal function, effects on electrolyte balance, alteration of blood coagulation, changes in plasma oncotic pressure (that is the element of colloid osmotic pressure which is due to the plasma colloids) and risk of development of acute (formerly adult) respiratory distress syndrome (ARDS).

Why it is important to do this review

There has been controversy for many years over which fluid or combination of fluids is preferable for replacement of extracellular losses. A number of studies have examined this subject.

OBJECTIVES

The objective of this review was to compare the physiological effects of different non-blood replacement fluids used in surgery on the abdominal aorta with a view to identifying the optimal fluid for use in such surgery.

METHODS

Criteria for considering studies for this review

Types of studies

The review examined prospective randomised controlled trials of non-blood fluid replacement in patients undergoing abdominal aortic surgery during which the abdominal aorta was cross-clamped as part of the procedure.

Types of participants

Participants in the studies underwent surgery to the abdominal aorta as defined above. The specific nature of the surgery was not a criterion for inclusion in this review, but was commonly for aneurysmal or occlusive disease. Patients having combined thoraco-abdominal procedures that involved surgery on the thoracic aorta were excluded as were patients undergoing any other contemporaneous surgery.

Types of interventions

The intervention was the administration of a non-blood fluid, used with the specific aim of restoring or maintaining extracellular fluid volume. This was given during the operation and in the early postoperative period, that is within the first 24 hours of surgery. Administration of fluid preoperatively was not an included intervention. Fluids included in this review were as follows.

Crystalloids

- Ringer's lactate (RL)
- 5% dextrose in Ringer's lactate (D5-RL)
- 5% dextrose in 0.45% (half normal) saline (D5-NS)
- 5% dextrose in water (D5-W)
- 1.8% (twice normal) saline (2NS)
- Mannitol
- Acetated Ringer's lactate
- Bicarbonated Ringer's lactate

Colloids

- Human albumin solution in Ringer's lactate (HAS-RL)
- Human albumin solution in water (HAS-W)
- 5% dextrose with human albumin solution (D5-HAS)
- Dextran 60 (DEX60)
- Dextran 70 (DEX 70)
- Hetastarch (HETA)
- 6% hydroxyethyl starch (HES)
- Bovine haemoglobin-based oxygen carrier (HBOC-201)
- Hypertonic HES (6% HES, 7.2% NaCl)
- Isotonic HES (6% HES, 0.9% NaCl)
- Hypertonic dextran (7.2% NaCl, 10% dextran)
- Diaspirin crosslink haemoglobin

- Stromal free haemoglobin

Types of outcome measures

Death of the patient within 30 days of the operation, as a dichotomous measure.

Continuous variables were divided into subcategories for clarity (measurement units in brackets).

Cardiac

- Pulmonary artery wedge pressure (mm Hg)
- Central venous pressure (mm Hg)
- Heart rate (bpm)
- Cardiac output (l/min)
- Mean arterial pressure (mm Hg)
- Cardiac index (l/min/m²)
- Systemic vascular resistance (dyne.sec/cm⁵)
- Systemic vascular resistance index (dyne.sec/cm⁵/m²)
- Left ventricular stroke work index (g/m²)
- Mixed venous oxygen saturation (%)
- LiDCO haemodynamic monitoring
- Oesophageal Doppler monitoring

Respiratory

- Oxygen consumption (ml/min)
- Oxygen consumption index (ml/min/m²)
- Oxygen delivery (ml/min)
- Left-right shunt (%)
- Alveolar-arterial oxygen difference (mm Hg)
- Arterial-venous oxygen content difference (ml/dl)

Haematological

- Haemoglobin concentration (g/dl)
- Platelet count (x10⁹/l)
- Prothrombin time (s)
- Partial thromboplastin time (s)
- Activated clotting time (s)

Biochemical

- Serum sodium (mEq/l)
- Serum creatinine (mg/dl)
- Serum lactate (mM)
- Serum albumin (g/dl)
- Plasma glucose (mM)
- Plasma osmolarity (mOsm/l)
- Colloid osmotic pressure (mm Hg)
- Serum oncotic pressure (mm Hg)
- Urine osmolarity (mOsm/l)
- Urinary sodium (mEq/l)

Other

- Intensive care stay
- High dependency unit stay

- Total postoperative stay

It is beyond the scope of this review to discuss the derivation and use of each of these measures. Any reader seeking further information is advised to consult a standard textbook of human physiology. Their specific relevance to the review subject is discussed.

Search methods for identification of studies

Electronic searches

The Cochrane Peripheral Vascular Diseases Group searched their Specialised Register (last searched August 2009) and the Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2009, Issue 3) for publications describing (or which might describe) randomised controlled trials of non-blood replacement fluids in abdominal aortic surgery. See [Appendix 1](#) for details of the search strategy used to search CENTRAL. The Specialised Register is maintained by the Trials Search Co-ordinator and is constructed from weekly electronic searches of MEDLINE, EMBASE, CINAHL, and AMED, and through handsearching relevant journals. The full list of the databases, journals and conference proceedings which have been searched, as well as the search strategies used, are described in the [Specialised Register](#) section of the Cochrane Peripheral Vascular Diseases (PVD) Group module (*The Cochrane Library*).

Searching other resources

The reference lists from retrieved trials were screened for information about additional trials.

Data collection and analysis

Selection of studies

For the update, titles or abstracts of citations retrieved from the literature search were screened by the PVD Group and lists of potential studies for inclusion in the review were sent to the review authors. All studies that were not randomised controlled trials or that clearly did not fit the inclusion criteria were excluded. Where there was uncertainty as to the nature of the trial or randomisation of participants, a letter was sent to the first named author at the institution stated on the paper. The full text of all other citations were reviewed independently by two review authors to assess eligibility.

Data extraction and management

Data were extracted independently by the two authors (PT, SS). For each included study, all data were extracted and recorded by the review author. Information on the demographics of the study and inclusion and exclusion criteria were detailed. Treatment interventions and durations were listed together with details of any control groups and a full list of outcome measures for each study. This is presented in a tabular format in the [Characteristics of included studies](#) table.

RESULTS

Description of studies

See the tables: [Characteristics of included studies](#); [Characteristics of excluded studies](#); [Characteristics of studies awaiting classification](#).

Results of the search

One hundred and sixty-three records were identified from CENTRAL and the PVD Specialised Register. These were screened for relevance on the basis of title and the abstract (see [Figure 1](#)).

Figure 1. Flow-chart of study selection

Figure 1. (Continued)

Included studies

There were 47 reports for 38 included studies. Nineteen of these reports related to 16 studies included in previous versions of this review. Details are given in the [Characteristics of included studies](#) table.

All studies focused on a small group of patients undergoing a specific surgery. The study designs were similar in that all involved the administration of a given fluid during and after an operation, itself a standardised procedure. Patients needing surgical repair for abdominal aortic aneurysm (AAA) tend to have a comparable age range and health status, so it was reasonable to assume that there was clinical homogeneity across these types of included studies. Patients requiring bypass because of aorto-iliac occlusive disease are often younger, with a higher proportion of women, compared to patients requiring surgery for AAA. It was reasonable to assume that there was clinical homogeneity across the included studies involving patients with aorto-iliac occlusive disease. The diversity of fluids used and outcome measures assessed can be seen in the [Characteristics of included studies](#) table. This table includes details of the age of patients, sex ratios, methods of randomisation, interventions, outcome measures and the overall numbers in each study. Each of the trials studied the effects of different solutions on different outcome measures. The [Characteristics of included studies](#) table presents the available data in a concise and comprehensive way and the main results of each trial are summarised with specific reference to the key outcome measures.

The aim of each study was to determine which fluid was optimal for the preoperative and postoperative management of patients. All of the studies used standard protocols for replacing blood lost with 'bank blood'. Replacement of other losses and maintenance of plasma volume has to be tailored to the needs of each individual patient. In order to compare the effects of such fluids a protocol is necessary to ensure that each patient receives their requirement, not more or less. The issue of balanced fluid replacement was addressed in a number of ways, as follows.

Bomberger ([Bomberger 1986](#)) titrated fluid infusion rates to maintain urine output at 50 to 100 ml/hour. Diuretics were administered where patients developed fluid overload, although there was no stated protocol for this.

Eight studies ([Boutros 1979](#); [Virgilio 1979](#); [Shackford 1983](#); [Hankeln 1990](#); [Dawidson 1991](#); [Waters 2001](#); [Bruegger 2005](#); [Soskic 2005](#)) used the preoperative pulmonary artery wedge pressure to define a baseline 'normal' level for each patient, and titrated the fluid infusion to maintain this within defined limits. One study ([Shimada 2005](#)) used the central venous pressure. Three studies ([Virgilio 1979](#); [Shackford 1983](#); [Mahmood 2007](#)) additionally maintained urine output within defined limits.

[Welch 1993](#) examined the effects of isovolemic haemodilution with dextran 70 on renal function. An 'index of renal function' was

determined by expressing mean postoperative creatinine clearance as a fraction of the mean preoperative creatinine clearance.

[Catoire 1992](#) used preoperative normovolaemic haemodilution (PNH) in order to improve segmental myocardial wall motion in patients undergoing abdominal aortic surgery. Patients were monitored with trans-oesophageal echocardiography. Three studies ([Cheung 2002](#); [Ridler 2003](#); [Wolowczyk 2003](#)) used acute normovolaemic haemodilution in order to study allogenic blood transfusion.

[Nicholson 1996](#) tested the effects of mannitol on renal reperfusion injury during aortic aneurysm surgery in patients undergoing elective repair.

Two studies ([Kasper 1996](#); [Kasper 1998](#)) looked at the effects of a bovine haemoglobin-based oxygen carrier (HBOC-201). After isovolaemic haemodilution with one litre of Ringer's lactate solution, patients were randomised to receive either HBOC-201 or 6% hydroxyethyl starch (HES). [LaMuraglia 2000](#) studied four different doses of HBOC.

[Pull Ter Gunne 1990](#) examined the effects of preoperative 'optimal' hydration, as determined by plotting Starling curves, on haemodynamics during aortic cross-clamping.

[Marik 1997](#) randomised patients undergoing elective abdominal aortic aneurysm repair in order to examine gastric intramucosal pH changes, a surrogate marker of tissue oxygenation, and volume replacement with HES or crystalloids. Intraoperative use of gastric intramucosal pH was also studied by [Rittoo 2002](#).

The aim of the [Ragaller 2000](#) study was to determine whether a reduction in the amount of applied fluid after aortic declamping was possible in order to maintain optimal wedge pressure (PCWP)/cardiac index (CI). The trialists used either hypertonic hydroxyethyl starch (HES 6%, 7.2% NaCl) or isotonic hydroxyethyl starch solution (HES 6%, 0.9% NaCl). The individual optimised PCWP/CI was determined using Frank-Starling curves after induction of anaesthesia and on declamping. [Younes 1988](#) reported changes in haemodynamic parameters (mean arterial pressure, central venous pressure, plasma sodium, serum osmolality, haematocrit, and plasma albumin) after the infusion of 7.5% NaCl compared with giving 0.9% NaCl two minutes before the release of the aortic clamp.

There were studies that randomised patients after they were transferred to the surgical intensive care unit. [Bloomfield 2004](#) studied the effects of diaspirin crosslink haemoglobin on haemodynamics and haemoglobin levels. [Pargger 1998](#) randomised patients to receive fluid management, according to the intragastric mucosal pH; and [Verheij 2006](#) studied four different fluids on haemodynamic and respiratory parameters, in the surgical intensive care unit.

Adjustment of fluid infusion rates to meet predefined criteria introduced a large potential bias into studies where the staff were not blinded to fluid type. This is discussed further under [Risk of bias in included studies](#).

All the studies examined the effects of a given fluid on outcome measures in the immediate postoperative period. Most studies continued to examine effects into the first and second postoperative days. [Shackford 1983](#) presented data until the third postoperative day, although those data were not included in this review. [Godet 2008](#) studied the renal safety parameters (maximum increase in creatinine levels until sixth postoperative day and minimum creatinine clearance), incidence of oliguria, and the adverse events related to renal complications until hospital discharge. Of note was the disparity in choice of outcome measure. For example, two studies ([Boutros 1979](#); [Bomberger 1986](#)) examined the effects of administration of 5% dextrose in 0.45% normal saline and yet the only common outcome measure was pulmonary artery wedge pressure, which was used for fluid titration in the [Boutros 1979](#) study and was therefore not valid. All of the studies referred to one or more outcome measures which were either not included in this review or were presented with insufficient data to permit inclusion. All relevant outcomes and other useful information are presented in the [Characteristics of included studies](#) table.

[Nielsen 1991](#) appeared to present the same data in marginally different formats in four papers. Certain data within these papers, including body weight, age and blood volume, were identical. Further information was sought from the authors but for the purposes of this review the data were amalgamated.

Excluded studies

There were 10 reports for 10 excluded studies, five of which had been excluded in previous versions of the review. Details are given in the [Characteristics of excluded studies](#) table.

Risk of bias in included studies

See [Figure 2](#) and [Figure 3](#). All the included studies randomised participants into treatment groups. Random number tables were used by three studies ([Virgilio 1979](#); [Shackford 1983](#); [Nicholson 1996](#)), deck of cards by two ([Dawidson 1991](#); [Sobczynski 1997](#)) and [Marik 1997](#) used a number generator. Concealment of allocation was described as using sealed envelopes in six studies ([LaMuraglia 2000](#); [Bloomfield 2004](#); [Ridler 2003](#); [Rittoo 2004](#); [Verheij 2006](#); [Godet 2008](#)). It would appear that in all of the studies, patients were randomised consecutively after fulfilling any inclusion criteria. This was essential to reduce bias at the allocation stage.

Figure 2. Methodological quality graph: review authors' judgements about each methodological quality item presented as percentages across all included studies.

Figure 3. Methodological quality summary: review authors' judgements about each methodological quality item for each included study.

	Adequate sequence generation?	Allocation concealment?	Blinding?
Baron 1991	?	?	?
Bloomfield 2004	?	+	-
Bomberger 1986	?	?	-
Boutros 1979	?	?	-
Bruegger 2005	?	?	-
Catoire 1992	?	?	-
Cheung 2002	?	?	-
Dawidson 1991	+	?	?
Degoute 1989	?	?	?
Garrioch 1999	+	?	?
Godet 2008	+	+	?
Gold 1990	?	?	+
Hankeln 1990	?	?	-
Kasper 1996	?	?	-

Figure 3. (Continued)

Kasper 1990	?	?	+
Kasper 1998	?	?	?
LaMuraglia 2000	?	+	-
Mahmood 2007	+	+	-
Marik 1997	+	?	+
Nicholson 1996	+	?	-
Nielsen 1991	?	?	-
Pargger 1998	?	?	+
Pull Ter Gunne 1990	?	?	-
Ragaller 2000	+	?	+
Reiz 1979	?	?	-
Ridler 2003	?	+	-
Rittoo 2002	?	?	-
Rittoo 2004	?	+	-
Shackford 1983	+	?	-
Shimada 2005	?	?	-
Skillman 1975	?	?	-
Sobczynski 1997	+	?	-
Soskic 2005	?	?	-
Verheij 2006	+	+	-
Virgilio 1979	+	?	-

Figure 3. (Continued)

Waters 2001	+	?	+
Welch 1993	?	?	-
Wolowczyk 2003	+	?	-
Younes 1988	?	?	-

Data on inclusion and exclusion criteria are presented in the [Characteristics of included studies](#) table. None of the studies reported any patient exclusions after randomisation, although [Skillman 1975](#) observed that three patients had a deviation from the protocol. Their results were excluded from any analysis but were presented separately within the paper.

The study fluid in each case was a standard fluid used routinely for replacement purposes in major surgical procedures throughout the world. There is no index standard and therefore it was valid to compare any given fluid with one or more other fluids, as in these studies.

All of the continuous outcome measures were calculated or derived from pre-calibrated laboratory or bedside analysers. This minimised error in the measurement of such parameters and eliminated observer bias or the tendency to round off numerical results.

The determination of an appropriate volume when replacing fluids during and after an operation is perhaps more of an art than a science. In an attempt to provide uniformity of treatment, many of the studies identified one of the outcome measures as an indicator of whether intravascular filling was sufficient (in most cases this was the pulmonary artery wedge pressure). Only [Gold 1990](#) blinded the staff who were administering the fluid; therefore all of the other studies had a great potential for bias. Although the measurement of outcome measures was non-biased, there was potential to influence these measures with the volume and type of fluid administered. [Mahmood 2007](#) reported that the statistical analysis performed in their study was carried out blind.

It was likely that the patients in these studies were blinded to the types of fluids given intraoperatively. There were three studies in which the interventions were performed in the surgical intensive care unit but, since these patients were likely to have received postoperative ventilator support with sedation and analgesia during the study period, patients would have been unaware of their fluid infusions. In either case, the outcome measures were unlikely to have been affected by patient awareness of fluid type. Therefore, patient blinding would not have improved the quality of any of these studies.

Effects of interventions

Various outcome measures were assessed; few outcomes were assessed in more than one study. Results were recorded immediately after the operation (up to one hour) and 24 hours postoperatively. The results were presented in two formats.

(1) The key results from individual studies were reported as mean and standard error (SEM). There were four major categories of study fluid comparisons for open abdominal aortic procedures.

1. Comparison between types of crystalloids.
2. Comparison between colloids and crystalloids including hypertonic solutions, or between types of colloids.
3. Haemoglobin derivatives or acute normovolaemic haemodilution in order to minimise allogenic blood transfusions.
4. Intervention in the surgical intensive care unit.

(2) The effects across each of the key outcome areas were summarised. This method of reporting gives a general overview across all of the studies.

(1) Individual studies

1.1 Comparison between types of crystalloid solutions

[Bomberger 1986](#): 5% dextrose in Ringer's lactate (D5-RL), 5% dextrose in 0.45% (half normal) saline (D5-NS).

D5-RL maintained a lower pulmonary artery wedge pressure (7.3 (2.0) mm Hg) compared with D5-NS (11.4 ± 1.9 mm Hg) ($P < 0.05$). Patients receiving D5-NS had a greater decline in sodium (4.5 ± 1.1 mEq/l) than those receiving D5-RL (0.1 ± 0.07 mEq/l) ($P < 0.05$). There was no statistically significant change in serum creatinine levels.

Deaths: D5-RL 3/102; D5-NS 1/80.

[Younes 1988](#): 0.9% normal saline (NS), 7.5% hypertonic saline (HS).

Hypertonic saline (7.5%) administration resulted in a brief higher mean arterial pressure that was statistically significant (at two minutes after declamping) and central venous pressure (at two, four and six minutes after declamping) compared with NS. HS treated patients had less variability in mean arterial pressure (within 10%) than patients receiving NS (up to 25%). There were

no statistically significant changes in serum osmolarity, sodium, haematocrit, or plasma protein. After declamping the aorta, patients given HS received significantly less of both crystalloid solution (698 ± 53 ml versus 811 ± 93 ml) and colloids (210 ml $\pm$ 87 ml versus 466 ± 108 ml) to correct hypotension.

Deaths: none.

Degoute 1989: Ringer's lactate (RL), 5% dextrose in water (D5-W). There was a 20% rise in heart rate after the operation but no statistically significant difference between the groups. Other cardiac parameters: cardiac index, systemic vascular resistance, left ventricular stroke work, intrapulmonary shunt, and oxygen consumption showed no statistically significant differences between the groups.

The arterial blood glucose concentration was 21 ± 6.5 mM in the D5-W group compared with 8.6 ± 2.7 mM in the RL group with correspondingly higher lactate levels (4.15 ± 0.8 mM versus 1.85 ± 0.4 mM).

Deaths: none

Shackford 1983: 1.8% (twice normal) saline (2NS), Ringer's lactate (RL).

Intrapulmonary shunt percentage remained unchanged from the preoperative value in the 2NS group (15%) but increased to 20% in the RL group ($P < 0.05$). There were no other statistically significant differences between the two fluids across the cardiac and respiratory outcome measures. The intraoperative fluid requirement was halved in the 2NS group (4.5 ± 0.3 l versus 9.5 ± 0.8 l) ($P < 0.01$). Serum sodium (151 ± 1 mEq/l) and osmolarity (305 ± 2 mOsm/l) were significantly greater in the 2NS group than the RL group, which were unchanged at 134 ± 2 mEq/l and 280 ± 2 mOsm/l, respectively ($P < 0.001$). Levels with 2NS returned to normal by the third postoperative day.

Deaths: none.

Nicholson 1996: mannitol, saline.

Clinical outcome: the mean intensive care unit (ICU) stay in the mannitol group was 2.1 ± 0.4 days whereas in the control group it was 1.5 ± 0.2 days ($P = 0.43$).

Length of hospital stay: mannitol group 10.6 ± 0.4 days versus control group 10.3 ± 0.6 days ($P = 0.62$).

Renal function: there were no statistically significant changes between the groups.

Renal failure: one in the control group and none in the mannitol group.

No other significant changes were found.

Deaths: two in the mannitol group; and one in the control group.

Waters 2001: Ringer's lactate (RL), 0.9% sodium chloride (NS).

The intraoperative use of sodium bicarbonate was significantly higher in the NS group (40.2 ± 64 ml) compared with 3.8 ± 15.5 ml in RL group; however, the overall use of sodium bicarbonate in the perioperative period was not different. The amounts of allogenic blood transfused and fresh frozen plasma were not different between groups, but the NS group received more platelet transfusion (478 ± 302 ml) than the RL group (223 ± 24 ml) ($P = 0.02$). The time of ventilator support, length of stay in the surgical intensive care unit and in hospital were not different.

Major complications: one patient in the NS group developed sepsis, one patient in each group had an absent pulse of the dorsalis pedis artery, three RL group patients and two NS group patients developed postoperative ileus, two patients had ischaemic bowel,

four RL patients and five NS patients had renal insufficiency, and three patients in each group developed cardiac arrhythmias.

Deaths: RL 1/33; NS 1/33.

Shimada 2005: acetated Ringer's solution (ARL), bicarbonated Ringer's solution (BicRL).

There were no significant differences in haemodynamic outcome between the two types of fluids, amount of fluid replacement, and allogenic blood transfusion. The pH, PaCO₂, and base excess were not different between groups.

Deaths: none.

1.2 Comparison between types of crystalloid and colloid solutions, or between types of colloids

Boutros 1979: 5% dextrose in Ringer's lactate (D5-RL), 5% dextrose in 0.45% (half normal) saline (D5-NS), 5% dextrose with human albumin solution (D5-HAS).

There were no statistically significant differences between any of the three groups. Cardiac output increased postoperatively in all groups (with an increased heart rate).

Serum albumin increased by 20% in the D5-HAS group, but fell by 20% in the other groups. There was no statistically significant change in plasma osmolarity across groups. Urine osmolarity increased in all groups (40% to 60%) but urinary sodium only increased in the D5-NS group, by 100% at 24 hours (there was no mention of the statistical significance between fluid types).

Oxygen consumption increased in all groups by 40% but returned to normal after 24 to 48 hours. Alveolar-arterial oxygen difference increased across the groups by 20% to 40% but the rate of rise was steepest in the D5-RL group.

Creatinine increased in all groups by 20% to 40% but returned to normal within 48 hours.

Deaths: D5-HAS 0/8; D5-NS 1/7; D5-RL 1/9.

Dawidson 1991: dextran 60 (DEX 60), Ringer's lactate (RL).

Cardiac output, pulmonary artery wedge pressure, central venous pressure, mean arterial pressure and albumin concentrations did not show any statistically significant differences between the fluids. There were no statistically significant differences in bleeding time, prothrombin time, partial thromboplastin time, or platelet count.

Deaths: DEX 60 1/10; RL 1/10.

Gold 1990: hetastarch (HETA), 5% dextrose with human albumin solution (D5-HAS).

Platelet count decreased in each group during the operation (263 ± 13 to 193 ± 11 , and 265 ± 16 to $190 \pm 13 \times 10^9/l$, respectively). Bleeding time increased slightly but there were no statistically significant difference between the groups.

Deaths: none.

Hankeln 1990: 10% hydroxyethyl starch, 5% human albumin.

Both patient groups had a higher cardiac index, left ventricular stroke work index, stroke output after infusion, and oxygen availability; however, the pulmonary vascular resistance and haemoglobin decreased in both groups. The 10% hydroxyethyl starch group had a greater improvement in the cardiac index, bigger decrease in PVR, higher rise in left ventricular stroke work index, and a more significant improvement in stroke output; smaller quantities of the volume substitute were required in this group than in the 5% human albumin group.

Deaths: none

Nielsen 1991: human albumin solution in water (HAS-W), 5% dextrose in 0.45% (half normal) saline (D5-NS).

There were no statistically significant differences in sodium concentration or colloid osmotic pressure values between the two groups.

Deaths: none

Skillman 1975: human albumin solution in water (HAS-W), 5% dextrose in Ringer's lactate (D5-RL).

Postoperative albumin levels were increased in the albumin group (4.5 [0.1] g/dl but unchanged in the electrolyte group D5-RL (3.1 [0.2]) g/dl, ($P < 0.01$).

Serum oncotic pressure increased in patients treated with HAS-W (25.7 [1.6] to 27.2 [1.6]) mm Hg but this was not statistically significant.

In the D5-RL group, serum oncotic pressure decreased (26.5 [1.3] to 22.1 [1.4]) mm Hg ($P = 0.05$).

Arterial-alveolar oxygen difference increased without statistical significance in the HAS-W group (48 [13] to 94 [25]) mm Hg, whereas the D5-RL increase was statistically significant (50 [24] to 184 [44]) mm Hg ($P < 0.005$).

Deaths: none

Virgilio 1979: Ringer's lactate (RL), Human albumin solution in Ringer lactate (HAS-RL).

Pulmonary artery wedge pressure was greater in the colloid group postoperatively (14 [1]) mmHg than RL (11 [1]) mm Hg, but this was not significant. However, the difference in cardiac index was significant at (3.9 [0.2]) l/min/m² in HAS-RL compared with (3.1 [0.2]) l/min/m² in RL ($P < 0.01$).

Albumin levels were higher in the albumin treated group (4.5 [0.1]) mg/dl versus (2.4 [0.1]) mg/dl ($P < 0.01$).

Intra-pulmonary shunt increased similarly in both groups (11 [1] to 15 [1])%.

Deaths: RL 1/14; HAS-RL 1/15.

Reiz 1979: isotonic sodium chloride (NS), 5% human albumin.

Following declamping, for mean arterial blood pressure there was a significantly greater decrease in the control group receiving NS (110 ± 23 to 77 ± 21 mm Hg) compared with the albumin group (114 ± 23 to 97 ± 18 mm Hg) ($P < 0.01$). The decrease in left ventricular stroke work index was greater in the control group (42.2 ± 14.7 to 24.1 ± 12.6 g-m/m²) compared with the albumin group (45 ± 14.9 to 39 ± 14.5 g-m/m²) ($P < 0.001$). There were no significant differences in changes of heart rate, SVR, and arterial lactate between groups.

Deaths: none.

Pull Ter Gunne 1990: 'optimal' preoperative hydration with Ringer's lactate and human albumin, no 'optimal' hydration.

Haemodynamics: during aortic clamping the heart rate decreased significantly more in the treatment group. Postclamp wedge pressure (PCWP) and central venous pressure were significantly higher in the treatment group during the whole operation. In the treatment group, creatinine clearance decreased one week after operation.

Renal function: no renal insufficiency of clinical or statistical significance.

No other significant changes were seen between the groups.

Deaths: none.

Marik 1997: gastric intramucosal changes after volume replacement with 6% hydroxyethyl starch (HES), or crystalloids (Ringer's lactate).

One patient in the control group (crystalloid) developed nosocomial pneumonia, another developed non-cardiogenic pulmonary oedema. There were no other serious complications.

Intraoperative fluid balance was significantly better in the control group; there were no differences in the intraoperative blood loss between the groups.

The lowest pH in the HES group was 7.34 ± 0.02 compared with 7.30 ± 0.04 in the crystalloid group. The only variable that influenced the maximal decrease was the type of fluid resuscitation.

There was no significant difference in duration of mechanical ventilation, ICU and hospital stay between the groups.

Deaths: none.

Sobczynski 1997: 7.5% hypertonic saline with 6% hydroxyethyl starch (HTS-HES) compared with 6% HES.

Compared with 6% HES, HTS-HES produced a significant increase in cardiac index (3.6 ± 0.9 versus 3.0 ± 0.8 l/min/m²) ($P < 0.05$) and a significantly higher mean arterial pressure at the end of surgery (103 ± 14 versus 94 ± 14 mm Hg). Oxygen consumption index (VO₂) was significantly higher in the control group of patients, given 6% HES, after infusion and at the end of surgery (102 ± 23 versus 83 ± 25 and 109 ± 31 versus 92 ± 26 ml/min/m², respectively) ($P < 0.05$). Infusion of HTS-HES caused an increase in plasma volume (2.1 ± 0.3 versus 1.9 ± 0.3 l) ($P < 0.05$) and was associated with a significant sodium load (147 ± 4 versus 138 ± 2 mmol/l) ($P < 0.001$) which persisted throughout the early postoperative period.

Twelve patients (48%) in the HTS-HES subgroup were hypokalaemic and needed potassium supplementation intraoperatively. The amount of fluid given intraoperatively was greater in patients given 6% HES (3.8 ± 0.8 versus 2.9 ± 0.3 l) ($P < 0.05$).

Deaths: none.

Ragaller 2000: reduction in fluid, hypertonic hydroxyethyl starch (6% HES, 7.2% NaCl) or isotonic hydroxyethyl starch (6% HES, 0.9% NaCl), during aortic clamping.

Haemodynamics: no significant changes between the groups for postclamp wedge pressure, cardiac index, stroke volume index, mean central venous pressure, oxygen delivery, oxygen consumption.

The optimal postclamp wedge pressure and cardiac output could be attained with significantly less fluid in the the hypertonic HES treatment group (mean 162 ± 111 ml) than the control isotonic HE group (265 ± 108 ml).

Clinical chemistry: sodium concentration increased significantly in the treatment group whereas chloride concentration did not show any significant difference between the groups. There were no significant differences in osmolality, coagulation, haemoglobin, and lactate.

Fluid requirements: urine output and blood loss did not differ.

Three patients developed unspecified serious complications, reported to be unrelated to fluid therapy.

Deaths: one patient (unclear in which group).

Rittoo 2002: hydroxyethyl starch (HES), gelofusine (Gel).

The fall in gastric intramucosal pH (pHi) was significantly greater in the Gel group than for the patients in the HES group at the time of

aortic cross-clamp release (7.29 and 7.33, respectively) ($P = 0.003$). There was a good inverse correlation between the lowest pH and the peak serum interleukin-6. From the multivariate analysis, the type of colloid fluid replacement was the only independent risk factor that influenced the pH. The HES patients required significantly less colloid replacement on the first postoperative day; (3175 ± 175 and 4065 ± 269 ml, respectively) ($P = 0.01$). Deaths: none.

Rittoo 2004: 6% hydroxyethyl starch (HES), or 4% gelofusine (Gel). The $\text{PaO}_2/\text{FiO}_2$ ratio was significantly higher in the HES group compared with the Gel group at all time periods. The decrease in compliance after cross-clamp release was significantly greater in the Gel-treated patients than in the HES treated patients and this persisted throughout the first eight hours after clamp release. There was no significant difference in the mean plasma α_1 -antiprotease $\pm$ elastase complex concentration in the two groups of patients, during surgery and in the first 12 hours after surgery. The peak C-reactive protein was significantly lower in the patients treated with HES ($P < 0.01$). Deaths: none.

Bruegger 2005: haemodynamic data after either hypertonic saline dextran (HSD) or 6% hydroxyethyl starch in normal saline (HES).

The pulmonary artery occlusion pressure (PAOP) was aimed at between eight and 13 mm Hg, and raised to between 15 and 18 mm Hg just before declamping the aorta.

Haemodynamics: the target PAOP was reached throughout the study period in both groups. There was no significant difference between groups in mean arterial pressure, systemic or pulmonary vascular resistance, oxygen consumption, or oxygen delivery. The HSD group required less volume (1.9 l) than the H-NS group (2.7 l) to raise the PAOP to between 15 and 18 mm Hg; it also had a lower positive intraoperative fluid balance (3.6 l and 5.3 l, respectively). Deaths: none.

Mahmood 2007: 6% hydroxyethyl starch with a mean molecular weight of 200 kDa and a degree of hydroxyethyl substitution of 0.62 (HES 200/0.62), 6% hydroxyethyl starch with a mean molecular weight of 130 kDa and a degree of hydroxyethyl substitution of 0.4% HES (130/0.4), 4% gelatin.

The amount of colloids to maintain haemodynamics in the intensive care unit were not different; however, the gelatin group received less crystalloids than the HES 130/0.4 group ($P = 0.01$). Serum urea was significantly lower in the HES 130/0.4 group compared with the gelatin group on postoperative days two to five, while the HES 200/0.62 had significantly lower serum urea on postoperative day two compared with the gelatin group. The serum creatinine levels were significantly lower in the HES 130/0.4 group compared with the gelatin group on postoperative days one, two, and five. The indexes for renal injury (urinary α_1 -microglobulin and urinary IgG) were significantly lower in the starch group compared with the gelatin group.

Major complications: for HES 200/0.62 two patients required relaparotomy for bleeding, one patient required relaparotomy for colitis, one required embolectomy, and one had massive intraoperative bleeding; for HES 130/0.4 one required relaparotomy for bleeding; for gelatin two required further vascular bypass, one developed acute renal failure, two had cardiac complications (myocardial infarction, cardiac failure), and one had multiorgan failure.

Deaths: HES 200/0.62 1/21; HES 130/0.4 1/21; gelatin 6/20.

Soskic 2005: 0.9% normal saline (NS), 7.2% sodium chloride with 10% dextran (DEX).

In both groups there was an increase in cardiac output; however, the DEX group had a significant increase in cardiac output (NS: 4.98 ± 2.06 l/min to 5.99 ± 3.02 l/min; DEX: 5.67 ± 2.95 to 7.05 ± 3.39 l/min, $P = 0.004$). In the NS group the central venous pressure and diastolic pulmonary artery pressure were decreased (6.84 ± 2.73 to 6.45 ± 2.5 mm Hg; 12.65 ± 4.28 to 11.85 ± 3.91 mm Hg, respectively); both were increased in the DEX group (8.75 ± 3.67 to 9.3 ± 2.77 mm Hg, $P = 0.022$; 15.92 ± 5.61 to 16.65 ± 6.53 mm Hg, $P = 0.021$, respectively). The NS group required more crystalloids in the first 24 hours after declamping compared with the DEX group ($P < 0.001$), and more human albumin was given in the NS group ($P = 0.001$). The mixed venous oxygen saturation and oxygen delivery were increased in the DEX group (73.3 ± 7.33 to $74.95 \pm 6.19\%$, $P = 0.001$; 684.44 ± 244.34 to 1362.45 ± 2351.01 ml/min, $P = 0.016$, respectively) but lowered in the NS group (65.35 ± 10.39 to $62.65 \pm 10.42\%$; 668.2 ± 382.12 to 651.7 ± 313.98 ml/min, respectively). The oxygen tension gradient between alveoli and arterial blood increased in the NS group but decreased in the DEX group ($P = 0.05$). Deaths: not mentioned.

Godet 2008: 6% hydroxyethyl starch (HES 130000/0.4), 3% modified gelatin (Plasmion®).

Both groups had comparable urine output outcomes (total urine output for six days, mean urine output/kg body weight). Allogenic blood transfusion was required in 22/32 HES patients and 30/33 gelatin patients. Vasopressor infusion was required in 21 HES patients and 20 gelatin patients. Non-inferiority of HES versus gelatin for a clinically significant increase in creatinine was shown by the intention-to-treat analysis. No statistically significant difference was found in the secondary renal safety parameters (creatinine clearance). No differences were observed between treatment groups for any haemodynamic parameter at any time point. The frequency of patients with intraoperative hypotensive episodes, as a potential risk factor for postoperative complications, were similar between groups. There were no relevant differences between the treatment groups regarding coagulation parameters. Haematology parameters, clinical chemistry, and urinalysis were also comparable between groups.

Deaths: two patients per treatment group.

1.3 The haemoglobin derivatives and acute normovolaemic haemodilution to minimise allogenic blood transfusion.

Baron 1991: acute normovolaemic haemodilution with 6% hydroxyethyl starch (HES) or albumin 4%.

Blood gas (oxygen) and plasma levels of hormones were comparable between groups. As the decrease in blood cell volume was exactly compensated by the increase in plasma volume, in both groups, no significant change in total blood volume was observed. No significant changes in mean arterial and right atrial pressures were observed in either group. In the HES group, a significant increase of pulmonary capillary wedge pressure was noted 120 min after haemodilution. After haemodilution systemic oxygen transport did not significantly vary until 24 h in relation to the increased cardiac index, despite a significant decrease in arterial oxygen content. An increase in O_2 extraction was observed after

the exchange but no further increase was observed until 24 h. No significant changes were detected in either global

O₂ consumption or lactate concentration. Plasma renin activity fell in both groups while atrial natriuretic factor increased, with a peak value at 2 h.

Deaths: none.

Catoire 1992: preoperative normovolaemic haemodilution (PNH) with dextran 60, no PNH.

Haemodynamics: no significant differences between the two groups were found.

Blood loss was significantly higher in the treatment group (PNH with dextran 60).

Deaths: none

Welch 1993: haemodilution with dextran 70 in saline, no haemodilution.

No complications attributable to haemodilution were reported.

No statistically significant differences were found between the treatment and control groups with respect to left ventricular stroke work index, cardiac output, or renal artery blood flow. Mean preoperative creatinine clearance levels were similar in both groups but this value was significantly lower in the control group after the operation; this was reflected in the index of renal function which was significantly lower in the control group ($P < 0.01$).

Deaths: none.

Kasper 1996: bovine haemoglobin-based oxygen carrier (HBOC-201), 6% hydroxyethyl starch (HES).

In the treatment group there was a 49% decrease in mean arterial pressure, a 69% increase in systemic vascular resistance index, and a 25% decrease in cardiac index.

One patient in the HES group required thrombectomy of the right femoral artery; the clinical course was uneventful for the other patients.

No side effects were caused by HBOC-201 infusion (for example anaphylaxis, ECG changes, haemoglobinuria, oliguria).

Deaths: none.

Kasper 1998: haemodilution with Ringer's lactate solution then either haemoglobin-based oxygen carrying solutions (HBOC) in two different doses, or 6% hydroxyethyl starch (HES).

Haemodilution with HBOC maintained the arterial oxygen content at levels higher than haemodilution with hydroxyethyl starch. The advantage of a greater oxygen-carrying capacity was offset by an increase in systemic vascular resistance index, with a resulting net decrease in both cardiac index and oxygen delivery index; the oxygen consumption index was maintained by an increase in oxygen extraction ratio. In terms of haemodynamics and oxygen transport, haemodilution with bovine haemoglobin provided no apparent benefit over haemodilution with hydroxyethyl starch in the doses used.

Deaths: none.

Garrioch 1999: diaspirin cross-linked haemoglobin (DCLHb), Ringer's lactate solution.

After the infusion of DCLHb increased mean arterial pressure and systemic vascular resistance index were significantly different from the baseline values. The duration of the significant increase in systemic vascular resistance index with infusion of DCLHb was dose dependent, the higher the dose the longer period of increased

systemic vascular resistance index when compared to the control group. The DCLHb treated group was not different from the control group when the total amount of fluids and allogenic blood transfusions were considered. All patients required vasopressors however the cumulative doses of ephedrine ($P = 0.023$) and methoxamine ($P = 0.045$) were significantly lower in the DCLHb group compared to control. About half of the patients required blood transfusion.

Deaths: none.

LaMuraglia 2000: haemoglobin-base oxygen-carrying solutions (HBOC), no HBOC.

All patients required at least one allogenic blood transfusion In the control group while 13 of 48 patients (27%, 95% confidence interval (CI) 15% to 42%) in the HBOC group did not require any allogenic blood transfusions. However, HBOC transfusion did not reduce the median allogenic blood transfusion requirement. Patients from the HBOC group reported a 15% increase in mean arterial pressure and a three-fold peak increase in serum urea nitrogen concentration, which were significantly higher than the control patients.

Major complications: two patients from each group developed stroke; ventricular arrhythmias in one control and two HBOC patients; heart failure in three control patients and one HBOC patient; peripheral ischaemia in one patient from each group; venous thrombosis in one control and two HBOC patients; haemorrhage in one control patient and three HBOC patients; and one control patient developed acute renal failure.

Deaths: HBOC 3/48, control 2/24.

Cheung 2002: routine acute normovolaemic haemodilution (rANH), supplemented (sANH) acute normovolaemic haemodilution with polymerized stromal-free haemoglobin (Poly-SFH-P).

More autologous units of blood were collected prior to skin incision in the sANH group (5.6 ± 0.17 units) than in the rANH group (2.8 ± 0.23 units) ($P < 0.001$). Total haemoglobin was comparable between groups (sANH: 8.4 ± 0.11 , rANH: 8.6 ± 0.8). However, the requirements for allogenic blood transfusion were not different between groups: sANH 2.36 ± 1.29 units intraoperatively, 0.42 ± 0.9 units postoperatively; rANH 2.1 ± 0.7 units intraoperatively, 0.7 ± 1.3 units postoperatively.

Hospital length of stay and serious adverse complications were not different between groups.

Deaths: none.

Wolowczyk 2003: acute normovolaemic haemodilution (ANH), no ANH.

The ANH group received significantly more replacement fluid at the time of aortic cross-clamping (ANH median 3500 ml, control group median 2000 ml; $P < 0.001$) however the overall intraoperative fluid amount was comparable. The amount of blood loss and requirements for allogenic blood transfusion were not different between groups.

Major complications: in the ANH group two patients had myocardial infarction, one had left ventricular failure; in the control group one patient had respiratory failure, one acute renal failure, and two patients had left ventricular failure.

Deaths: ANH group 1/16, control group 2/16.

Ridler 2003: acute normovolaemic haemodilution (ANH), no ANH.

There were no differences in intraoperative transfusion (two ANH patients: five units of blood; two control patients: three units of blood), postoperative transfusion (eight ANH patients: 24 units of

blood; seven control patients: 19 units of blood) or blood products used. The ANH patients had significantly shorter length of hospital stay: eight days (range 5 to 34 days); control patients: 11 days (range 7 to 23 days) ($P = 0.037$).

Two patients developed myocardial ischaemia, one for each group. The ANH patient was referred to coronary grafting instead of abdominal aortic aneurysm repair.

Deaths: one in the ANH group.

When the results of [Ridler 2003](#) and [Wolowczyk 2003](#) were combined to study the effects of acute normovolaemic haemodilution on death, no difference was found between the intervention and the control groups ([Figure 4](#)). No difference was found between groups when the studies by [Ridler 2003](#) and [Wolowczyk 2003](#) were pooled to study the secondary outcome of avoidance of intraoperative allogenic blood transfusion after acute normovolaemic haemodilution ([Figure 5](#)).

Figure 4. Forest plot of comparison: Acute normovolaemic haemodilution (ANH) versus no ANH, Outcome: 1.1 Death.

Figure 5. Forest plot of comparison: Acute normovolaemic haemodilution (ANH) versus no ANH, Outcome: 1.2 Avoidance of intraoperative allogenic blood transfusion.

1.4 Interventions in the surgical intensive care unit (SICU)

[Pargger 1998](#): protocol guided fluid replacement by the gastric mucosal pH (pHi), or control patients where pHi was blinded to physicians in the SICU.

A pHi of less than 7.32 led to a higher risk of complications in the SICU and, if it persisted for more than 10 hours, complications were more likely ($P < 0.001$). Raising the pHi did not result in improved outcomes. The amount of fluid replacement in the SICU, the time of ventilation support, SICU and hospital length of stay were comparable between groups.

Major complications: In the SICU, one patient in the protocol guided group developed myocardial infarction, one patient intra-abdominal bleeding, and one patient multiorgan failure; two patients in the control group had cardiac failure, one sepsis, and one intra-abdominal bleeding. In the ward, for the protocol guided group one patient developed anastomosis leakage, one sepsis, one ileus, and one pneumonia; in the control group one patient had sepsis, one massive pulmonary embolism, and two patients had cardiac failure.

Deaths: protocol guided 1/29, control 2/26.

[Bloomfield 2004](#): plasma haemoglobin, haemodynamic data in the SICU after repair of abdominal aortic aneurysm with either diaspirin cross-linked haemoglobin (DCLHb) 50 mg/kg, or an equal volume of hetastarch (HES).

Haemodynamics: cardiac output in the HES group was 6.18 ± 0.54 compared to 5.34 ± 7.92 in the DCLHb group. Mean pulmonary artery wedge pressure was lower in the HES group (22.8 ± 2.86 mm Hg) compared with the DCLHb group (26.4 ± 3.18 mm Hg). One patient in the DCLHb group developed acute myocardial infarction and there was one patient in the HES group who had elevated liver enzymes.

Deaths: none.

[Verheij 2006](#): 0.9% normal saline (NS), 4% gelatin, 6% hydroxyethyl starch (HES), 5% albumin.

All fluid types induced lower haemoglobin levels or haematocrits, the lactate levels were slightly lower in all groups. NS, gelatin, and HES induced lower serum albumin levels. All colloid types had higher colloid osmotic pressures, while the NS group had a slightly lower colloid osmotic pressure. After fluid loading, all types of fluids had higher oxygen delivery, oxygen consumption, and oxygen extraction ratios. The PvO_2 , PaO_2 , and $\text{PaO}_2/\text{FiO}_2$ increased in all groups. In the patients who received colloids, a small elevation

of the lung injury score was noted and it was associated with a decrease in total respiratory compliance.

Deaths: none.

(2) Outcome measure groups (descriptive data only, extracted and summarised from all of the trials)

Cardiac

Heart rate showed an increase postoperatively. Pulmonary artery wedge pressure did not change with any fluid but central venous pressure was elevated in two measured groups (3 cm at one hour in the Ringer's lactate group and 1.7 cm in the dextran 60 group). Several of the studies stated that central venous or pulmonary artery wedge pressures were used to assess fluid infusion volumes and were, therefore, maintained within a narrow range, it was likely that similar titration of fluid volume to maintain central venous or pulmonary artery wedge pressures was used in the studies where it was not stated. A rise of 2 to 3 cm H₂O in central venous pressure is unlikely to be of clinical significance. Mean arterial pressure remained stable in all groups, whereas cardiac output increased across the board over the 24 hours following surgery although it was unchanged immediately postoperatively. Systemic vascular resistance decreased postoperatively as is expected with rewarming of the patient and with maintained cardiac filling pressures (titrated to pulmonary artery wedge pressure). This explains the increase in cardiac output.

The mean arterial pressure and systemic vascular resistance index could be increased by the infusion of fluids that contained haemoglobin derivatives. The measurement of intragastric mucosal pH (pHi) has shown that patients with a lower pHi in the intensive care unit require more colloid infusion for replacement, and may be used for early detection of immediate complications in the surgical intensive care unit. Mixed venous saturation was utilised to assess intraoperative tissue perfusion and it was better in patients who received colloid compared to those with 0.9% saline.

Respiratory

Most parameters varied little between fluid types. Oxygen consumption increased markedly after the operation, and especially so at 24 hours in those receiving 5% dextrose in 0.45% saline or 5% dextrose in Ringer's lactate (49, 50 ml/min respectively). With less than 10 patients in each group this may be a non-significant difference. Left-right shunt tended to increase by 4% to 8% during the 24 hours after surgery. Arterial-alveolar oxygen difference increased with time for the three fluids where this was measured, 92.5 mm Hg in patients receiving 5% dextrose in Ringer's lactate, 66 mm Hg in those receiving 5% dextrose in 0.45% saline, and 23 mm Hg in patients receiving 5% dextrose in albumin. There were no clinically significant changes in venous-arterial oxygen difference. The oxygen tension gradient was higher with the infusion of normal saline while it was lower when hypertonic dextran was given. When lung compliance was measured after the administration of fluids, the colloid types (gelatin, hydroxyethyl starch, and albumin) were associated with a reduction in lung compliance compared with normal saline.

Haematology

Platelet count was reduced in all studies (70 to 146 x 10⁹/l). This is a physiological response to any surgery or insult and is to be expected. Platelets transfusion may be more likely when normal

saline is chosen as a main crystalloid fluid compared to Ringer's lactate. The haemoglobin concentration remained unchanged. Coagulation times were prolonged by a few seconds immediately postoperatively but appeared to be returning towards normal after 24 hours.

Biochemistry

Serum sodium increased in patients receiving hypertonic saline, by 14 mEq/l at the end of the operation, but in all other patients it fell by 2 to 4 mEq/l. Urinary sodium decreased by 49 mEq/l in those patients receiving 5% dextrose in 0.45% saline but increased by 202 mEq/l in patients receiving 5% dextrose in Ringer's lactate. Plasma glucose levels increased by 9.3 mmol/l in patients receiving 5% dextrose. Serum lactate increased but this was to be expected as lactate is produced during the oxidation of glucose and the anaerobic glycolysis of glycogen. Cross-clamping of the aorta with subsequent reduced oxygen delivery to the legs leads to a decrease in the uptake of lactate by the already paralysed skeletal muscle.

Albumin levels showed a small, non-significant increase in studies where albumin was given and a small decrease where it was not. Colloid osmotic pressure decreased by 7 to 8 mm Hg where patients were given hypertonic saline and Ringer's lactate but remained unchanged in those given human albumin in Ringer's lactate. Serum oncotic pressure followed a similar pattern. Plasma osmolarity decreased with 5% dextrose in albumin or 5% dextrose in 0.45% saline and human albumin solution but increased (26 mOsm/l) in the early postoperative period in patients given hypertonic saline. Urine osmolarity increased in all patients in the first 48 hours postoperatively, 251 to 254 mOsm/l in the crystalloid patients and 149 mOsm/l in the colloid patients.

Other

Intensive care stay length of stay and total hospital stay were reported in nine studies ([Dawidson 1991](#); [Kasper 1996](#); [Nicholson 1996](#); [Marik 1997](#); [Pargger 1998](#); [Waters 2001](#); [Cheung 2002](#); [Ridler 2003](#); [Wolowczyk 2003](#)). There were two reports that showed the differences between the average length of hospital stay. In [Dawidson 1991](#) hospital length of stay for the DEX-60 group was significantly less (11 days) than for the Ringer's lactate group (17 days). In ([Ridler 2003](#)) the patients who had intraoperative acute normovolaemic haemodilution had significantly shorter lengths of hospital stay than the control patients (8 versus 11 days; $P = 0.037$). No significant difference was found between fluids in either study. The average ICU length of stay was approximately one to four days following the procedure and the average hospital stay was from 6 to 18 days.

Mortality

The death rate within 30 days across the studies was 2.8% (39 deaths). This was lower than the 5% reported in the literature ([Galland 1998](#)).

DISCUSSION

Summary of main results

No overwhelming evidence was found in favour of or against the preferential use of any type of replacement fluid.

Overall completeness and applicability of evidence

One of the major drawbacks of the reviewed literature is that the individual studies involved very small numbers of patients and each study considered only a limited number of outcome measures. Several of the studies failed to fully discuss their protocols, for example the use of diuretics to prevent fluid overload (Bomberger 1986). Nor did they explain how the amount of fluids required was determined. For this review, it has been assumed that management was based on central venous and pulmonary artery wedge pressures as is standard procedure in intensive care units. There was little mention of weight gain after the operation, or the time required for weight to return to normal. This measure would be confounded somewhat by the hypercatabolic state after major abdominal surgery and variability in the use of supplementary nutrition. There was only one report about fluid responsiveness and tissue perfusion, by the value of mixed venous oxygenation (Soskic 2005); and two reports about the value of intragastric mucosal pH (Pargger 1998; Rittou 2002). Future studies, both in the operating theatres and intensive care area, may focus on this area. The central venous saturation may be examined instead of the mixed venous saturation in the era of less pulmonary artery catheter insertion. In modern society, cost data are important, although the cost of a few litres of fluid is likely to be insignificant compared with a day or two on an intensive care unit. However, a delay in discharge from intensive care would have significant cost implications.

The data available on non-blood fluid replacement in aortic surgery over a range of outcome measures does not show a significant benefit for any one fluid. There are certainly changes in electrolyte and protein concentrations and minor changes in haematological parameters but these are corrected by the body in a short period of time. Postoperative lung function, however, does appear to be affected significantly by the fluid type used, as shown by the arterial-alveolar oxygen difference measurements. The arterial-alveolar oxygen difference is a reflection of the distance between the alveolar lumen and the capillary blood stream. This is increased as the volume of interstitial water increases, leading to pulmonary oedema. In general the lungs are well protected from oedema formation, even with a reducing colloid osmotic pressure in the plasma. The interstitial fluid protein concentration in the lungs is as high as 70% to 80% of that in the plasma (Zarins 1978) so that the colloid osmotic pressure gradient is small. Any leakage of protein into the interstitium is, therefore, less significant than in the peripheral tissues. Formation of oedema is more proportionally related to the hydrostatic pressure.

Lung function was measured in the studies by examining the arterio-alveolar oxygen difference, as an indication of excess interstitial water increasing diffusion distance. However, there is evidence that this can be affected by changes in cardiac output as much as by changes in pulmonary function (Shapiro 1977). It was proposed (Virgilio 1979) that the higher arterio-alveolar difference in the crystalloid group represented an underfilling of the vascular system because of a decreased cardiac output, and not an increase in interstitial lung water. Correction of the filling deficit would abolish the differences between these patients and those receiving colloids. Furthermore, the authors proposed that the colloid osmotic pressure was of little significance provided that pulmonary artery wedge pressure was within normal range.

Therefore, colloids or crystalloids were of equal value provided that pulmonary artery wedge pressure was maintained.

In colloid fluid infusion interventions, patients who receive intraoperative colloid may require less overall fluid replacement compared with patients who do not receive such fluids. The lower fluid requirement would affect the patients' clinical pathways in the perioperative period, both in the surgical ICU and the convalescence period. However, the link with less fluid replacement and the shorter duration of ICU length of stay cannot be confirmed from this review. This possible outcome requires further study. The effect of hypertonic solutions (both hypertonic saline and hypertonic hyperoncotic) results in less fluid requirement during the intraoperative period. In this review the combined effect was not studied because the study designs were so different.

Mortality did not differ between patients who received acute normovolaemic haemodilution and those in the control group who did not, however the pooled effect was only from two studies. The beneficial effect of avoiding allogenic transfusion after acute normovolaemic haemodilution cannot be confirmed in this review because of the limited data available.

Thus, with all fluids there was an alteration of physiological parameters after the operation. This happened regardless of which fluid was used. The aim of all the investigators was to determine which fluid would minimise that disruption. The body has a remarkable ability to maintain homeostasis and we do not know to what extent certain physiological changes are less harmful than others. Indeed, suppression of some of the changes may in fact be harmful where those changes are part of a normal response to the trauma of surgery and are required to ensure healing and regeneration. Until there is a more thorough understanding of such matters, it will be difficult to express a benefit of one fluid over another; all that clinicians can do is observe and report what they see. The total amount of fluids required to maintain stable haemodynamics both intraoperatively, especially at the time of aortic cross-clamp release, and in the surgical ICU have been reported to be less in patients receiving colloids compared to crystalloids. This was reported in only 10% of patients in this review. It may not improve patient outcomes since the ventilator support time and surgical ICU length of stay did not differ with the types of fluids given. Besides, the colloid type may affect respiratory compliance more than crystalloid fluids.

Although we found no overwhelming evidence in favour of the preferential use of any one type of fluid, concerns regarding individual fluids, such as an observed excess mortality in patients given albumin (Alderson 2004), are likely to result in a change in patterns of use.

AUTHORS' CONCLUSIONS

Implications for practice

Surgery on the aorta is a major undertaking and requires specialised anaesthetic and surgical staff to optimise patient outcomes. There has been much controversy over the most appropriate single or combination fluid to use to minimise morbidity and mortality. Numerous studies have been performed but with little co-ordination. There remains insufficient evidence to draw any firm conclusions and until studies with a suitable

statistical power are planned and underway that situation is unlikely to change.

There is no evidence here of the effects of combination fluid therapy, that is colloid and crystalloid combined. This is the management of choice (anecdotally) of most anaesthetists and perhaps, with the lack of evidence for any specific advantage to either alone, the most rational.

Implications for research

This review demonstrates the urgent need for greater co-ordination in medical research with more emphasis on research based on existing evidence and designed appropriately to maximise the efficient use of scarce resources. This review covers work produced over a period of 30 to 40 years. Despite hundreds of 'man' years of research, no definite benefit of one fluid over another is seen from the included studies. Fluid management in open aortic surgery can be adapted and varied by anaesthetic staff. It is possible that many choices of fluid supplementation for these high risk patients are available. Further studies in the near future need very well planned and clear objectives in order to obtain important results or create a paradigm shift. In the field of a restrictive fluid regimen using hypertonic saline or colloid solution more information on patient safety is needed.

Many aspects of patient care and management during aortic surgery have changed since many of the studies were carried out, especially within the last 10 years. There have been changes in anaesthetic drugs and techniques with increasing use of adjunctive epidural anaesthesia. Surgical techniques are developing, especially with the increasing use of endovascular

approaches to aneurysm repair, with much less physiological insult to the patient. Future researchers may find it is more difficult to recruit surgical patients into their studies.

The choice of fluid for a given patient can only be based on the evidence available, and the best evidence comes from randomised controlled trials. However, it is currently impossible to measure the clinical significance of the changes seen in the many outcome measures that have been assessed. It will only be through the collection of prospective observational data on the many thousands of aneurysm operations that take place each year that greater understanding will be gained of the importance of any physiological changes. Armed with this knowledge, future researchers will be able to design randomised controlled trials to specifically examine those outcome measures of clinical and physiological importance. Future research may focus on short-term patient outcomes as the primary research outcomes. These include major complications in organ systems, myocardial injury, acute renal failure, the alleviation of requirements for vasopressors, shorter duration of ventilation support, lower allogenic blood transfusion requirements in the immediate perioperative period, and economical issues especially time in the surgical ICU and hospital. As the need for evidence in surgery grows ever stronger the development of large prospective multi-centred studies will enable current practices to be justified.

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* Indicates the major publication for the study

CHARACTERISTICS OF STUDIES
Characteristics of included studies [ordered by study ID]

Baron 1991

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 18</p> <p>Inclusion criteria: patients scheduled for elective abdominal aortic surgery . The haematocrit levels in each patient were above 33%.</p> <p>Exclusion criteria: contraindications for normovolaemic haemodilution: unstable angina, congestive heart failure, cardiac arrhythmias, uncontrolled hypertension, LV ejection fraction < 40%, major respiratory and renal diseases, coagulopathy, taking β-adrenergic antagonists or digitalis. Allergy to plasma substitution.</p>
Interventions	<p>Treatment A: 6% low molecular weight hydroxyethyl starch for normovolaemic haemodilution.</p> <p>Treatment B: albumin 4%.</p>
Outcomes	<p>Haemodynamic parameters: arterial blood pressure, heart rate, RA pressure, PCWP, CO, CI, PaO₂, PvO₂, SaO₂, SvO₂, SVR, CaO₂, CvO₂, DO₂, VO₂</p> <p>Plasma lactate, protein, hormones: ADH, plasma renin activity, adrenaline, noradrenaline, atrial natri-uretic factor</p> <p>Blood volume measurements</p>

Intravenous fluids for abdominal aortic surgery (Review)

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Baron 1991 (Continued)

Notes The ANH was performed until the haematocrit of 28-30 % was achieved. The colloid replacement was 1.2 ml per each ml of blood withdrawn, and each patient received another 500 ml of colloid from 30 minutes to 3 hours after the exchange.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Patients were randomised, method not stated.
Allocation concealment?	Unclear risk	Not mentioned.
Blinding? All outcomes	Unclear risk	Not mentioned.

Bloomfield 2004

Methods	Study design: randomised controlled trial.
Participants	Number: 10 Inclusion criteria: repair of abdominal aortic aneurysm. Exclusion criteria: pregnant, history of renal disease, liver disease, coagulopathy, hypertension (BP > 160/100 mmHg), or cardiac arrest.
Interventions	Treatment A: diaspirin cross-linked haemoglobin 50 mg/kg. Treatment B: an equal volume of hetastarch.
Outcomes	Plasma haemoglobin, haemodynamic data, cardiac output at two hours, platelet counts (at 24 hours)
Notes	Patients were randomised to receive either diaspirin crosslinked haemoglobin 50 mg/kg or an equal volume of hetastarch in the surgical intensive care unit. All fluids were infused for more than 30 minutes through a 20 µm blood filter.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described. 10 patients were randomised in the surgical intensive care unit after repair of abdominal aortic aneurysm.
Allocation concealment?	Low risk	Sealed envelopes.
Blinding? All outcomes	High risk	There was no blinding the staff administering the fluid. There is no statement that results analysis was carried out blind.

Bomberger 1986

Methods	Study design: randomised controlled trial.
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Intravenous fluids for abdominal aortic surgery (Review)

Bomberger 1986 (Continued)

Participants	<p>Number:182</p> <p>Inclusion criteria: primary inclusion criterion was surgery involving the abdominal aorta (with cross-clamping).</p> <p>Exclusion criteria: There were no stated exclusion criteria.</p>
Interventions	<p>Treatment A: 5% dextrose in Ringer's lactate solution.</p> <p>Treatment B: 5% dextrose in 0.45% normal saline solution.</p>
Outcomes	<p>Death within 30 days of operation.</p> <p>A number of other parameters were measured immediately before the operation and at 48 hours post-operatively: serum creatinine; serum sodium; pulmonary artery wedge pressure. These were all included in this review.</p> <p>Additional outcome measures not included in the review were serum potassium and urine output (no preoperative levels recorded); weight gain (not meaningful unless linked with a number of other factors such as renal and cardiac function).</p>
Notes	<p>Patients were randomised to receive either 5% dextrose in Ringer's lactate solution or 5% dextrose in 0.45% normal saline solution. This was administered postoperatively for 48 hours at a rate titrated to maintain a urine output of 50-100 ml/hour. Diuretics were administered where there was felt to be fluid overload.</p> <p>Additional information, to clarify some of the queries alluded to in the comments above, was been sought from the authors.</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described. 182 patients were randomised, divided into two groups with a mean age of 63 years.
Allocation concealment?	Unclear risk	Not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Boutros 1979

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 24</p> <p>Age: mean age was 62 years.</p> <p>Sex: male:female ratio of 15:9.</p> <p>Inclusion criteria: Each was to undergo a major abdominal aortic procedure.</p> <p>Exclusion criteria: No exclusion criteria were stated.</p>
Interventions	<p>Treatment A: 5% dextrose in water plus salt-poor albumin.</p> <p>Treatment B: 5% dextrose in 0.45% sodium chloride solution.</p> <p>Treatment C: 5% dextrose in Ringer's lactate solution.</p>

Intravenous fluids for abdominal aortic surgery (Review)

Boutros 1979 (Continued)

The allocated fluid was administered for 48 hours postoperatively. The rate of fluid infusion was adjusted to maintain the pulmonary artery wedge pressure at the preoperative level for each patient. All patients were given 5% dextrose in Ringer's lactate solution during the operation.

Outcomes	<p>Death within 30 days of operation.</p> <p>Measured within one hour, at 24 hours and at 48 hours postoperative were: heart rate; cardiac output; oxygen consumption; arterio-venous oxygen content difference; left-right shunt; alveolar-arterial oxygen content difference; serum albumin; haemoglobin; urinary sodium; plasma osmolarity; urinary osmolarity.</p> <p>Measured but not included in this review were: mean arterial pressure and peripheral resistance (no postoperative values given); pulmonary artery wedge pressure (used to determine fluid requirement and therefore not an outcome).</p>
Notes	<p>Data on postoperative values were presented graphically in this paper with no stated standard error of the mean for each outcome. Preoperative measurements were quoted with standard errors and therefore the review authors estimated the standard error for each outcome as a percentage of the result based on the percentage error reported for the preoperative value. Whilst this can only give an approximate value, these measurements are based on machine-generated figures which can be assumed (with modern engineering tolerances) to run repeatedly within their standard error, and therefore are valid for these comparisons. The use of one of the study fluids in all cases during the operation tends to reduce the credibility of any subsequent results.</p>

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Bruegger 2005

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 28</p> <p>Inclusion criteria: abdominal aortic aneurysm surgery.</p> <p>Exclusion criteria: serum creatinine > 2 mg/dl, congestive heart failure, brain infarction during the last 6 months, contraindication to the administration of hydroxyethyl starch or dextran, and classified as ASA physical status IV. Suprarenal clamping during the intraoperative period and extension of aneurysm to iliac arteries were also excluded.</p>
Interventions	<p>Treatment A: the HSD group received 250 ml of hypertonic saline dextran (7.5% sodium chloride and 6% dextran 70), Treatment B: the H-NS group received 250 ml of 6% hydroxyethyl starch in normal saline within 20 minutes via a central venous catheter during clamping.</p> <p>After declamping until 2 hours after the procedure the HSD group received normal saline and 6% Dextran 60, while the H-NS group continued to receive normal saline and hydroxyethyl starch. The pulmonary artery occlusion pressures (PAOP) were aimed to be between 8 mmHg and 13 mmHg and raised to between 15 mmHg and 18 mmHg just before declamping the aorta.</p>
Outcomes	The target PAOP was reached in both groups throughout the study period. Mean arterial pressure, systemic or pulmonary vascular resistance, oxygen consumption or oxygen delivery. The HSD group re-

Intravenous fluids for abdominal aortic surgery (Review)

Bruegger 2005 (Continued)

quired less volume (1.9 l) than the H-NS group (2.7 l) to raise the PAOP to a value between 15 mmHg and 18 mmHg and had less positive intraoperative fluid balance; 3.6 l and 5.3 l, respectively.

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Catoire 1992

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 20</p> <p>Sex: male.</p> <p>Age: mean age in PNH group 67 years, control group 66 years.</p> <p>Weight: mean weight PNH group 87 kg, control group 76 kg.</p> <p>Inclusion criteria: carotid artery disease undergoing abdominal aortic surgery.</p> <p>Exclusion criteria: absence of CAD, haematocrit of less than 36%, or a recent history of congestive heart failure.</p>
Interventions	<p>Treatment: preoperative normovolaemic haemodilution (PNH) with dextran 60.</p> <p>Control: no PNH.</p>
Outcomes	Blood loss.
Notes	PNH group blood losses were significantly greater than no PNH group ($P < 0.05$).

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Cheung 2002

Methods	Study design: randomised controlled trial.
Participants	Number: 28 patients. Inclusion criteria: infrarenal AAA repair.
Interventions	Treatment A: routine acute normovolaemic haemodilution (rANH). Treatment B: supplemented (sANH) acute normovolaemic haemodilution with polymerized stromal-free haemoglobin (Poly-SFH-P).
Outcomes	Autologous units of blood collected, haemoglobin after acute normovolemic haemodilution, the overall use of allogenic transfusions, hospital length of stay, number of serious adverse events, and deaths.
Notes	Acute normovolemic haemodilution before skin incision until 3000 ml of blood was collected or the total haemoglobin was below 9 g/dl. In the sANH group Poly-SFH-P was administered instead of colloid if the haemoglobin was below 9 g/dl, Poly-SFH-P was administered up to a maximal dose of 3000 ml to the sANH group for the replacement of intraoperative blood loss.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Dawidson 1991

Methods	Study design: randomised controlled trial.
Participants	Number: 20 Age: Mean age was 64 years. Sex: male:female ratio of 13:72. Inclusion criteria: elective abdominal aortic reconstructive surgery. Exclusion criteria: No exclusion criteria were detailed in the paper.
Interventions	Treatment A: Ringer's lactate solution. Treatment B: 3% dextran-60. Patients were randomised to receive either Ringer's lactate solution or 3% dextran-60 during the operation and in the first 24 hours postoperatively. The rate of fluid infusion was adjusted to maintain the pulmonary artery wedge pressure at or above 10 mmHg for each patient with a urine output of greater than 30 ml/hour.
Outcomes	Death within 30 days of operation. Measured within one hour and at 24 hours postoperative were: central venous pressure; mean arterial pressure; systemic vascular resistance; serum albumin; serum creatinine; platelet count; prothrombin time; activated partial thromboplastin time.

Dawidson 1991 (Continued)

Measured but not included in this review were: blood and plasma volume, red blood cell volume and dextran distribution (not useful for this review). Urine output and pulmonary artery wedge pressures were recorded but were used to titrate fluid infusion rates and are therefore not outcomes.

Notes	Four patients in the Ringer's lactate group were given fresh frozen plasma to expand their plasma volume. This will have affected the coagulation parameters measured; however without the raw data, the results cannot be excluded from the calculations. The review authors have therefore included the results as published, although the above detail should be borne in mind when interpreting the data.
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Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised using a playing card drawn from "...a previously prepared deck". This is likely to represent true randomisation but clarification has been sought from the authors.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Unclear risk	There was a partial blinding of the surgeons administering the fluid in that blood volume and plasma volume measurements were concealed to prevent adjustment of the infusion rates. There is no statement that results analysis was carried out blind.

Degoute 1989

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 20</p> <p>Age: mean age was 62 years.</p> <p>Sex: male:female ratio of 3:1.</p> <p>Inclusion criteria: each was to undergo infrarenal aortic surgery. Patients were of ASA grade 2 or 3 and in "good nutritional condition".</p> <p>Exclusion criteria: diabetes, "low cardiac output syndrome", or on beta adrenoreceptor blocking drugs.</p>
Interventions	<p>Treatment A: Ringer's lactate solution during the operation.</p> <p>Treatment B: 5% dextrose in water during the operation.</p>
Outcomes	<p>Death within 30 days of operation.</p> <p>Measured within one hour of the operation ending: heart rate; pulmonary artery wedge pressure; mean arterial pressure; cardiac index; systemic vascular resistance index; left ventricular stroke work index; arterial lactate; arterial glucose; left-right shunt; oxygen consumption.</p>
Notes	This study did not continue into the postoperative period. There was no specified protocol for determining fluid infusion rate. Note the use of "index" measurements in this study. i.e. the individual results are divided by the body surface area in square metres.

Risk of bias

Bias	Authors' judgement	Support for judgement
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Degoute 1989 (Continued)

Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Unclear risk	There is no statement that results analysis was carried out blind.

Garrioch 1999

Methods	Study design: randomised controlled trial.
Participants	Number: 34 patients, 2 were excluded due to operation changed. Sex: 24 male, 8 female. Inclusion criteria: undergoing elective repair of infrarenal aortic aneurysm.
Interventions	Treatment A: diaspirin crosslinked (DCLHb) haemoglobin. 5 patients (4 male/1 female) received DCLHb 50 mg/kg, 6 patients (3 male/3 female) received DCLHb 100 mg/kg, and 5 patients (4 male/1 female) received DCLHb 200 mg/kg. Treatment B: Ringer' s lactate (16 patients).
Outcomes	Haemodynamic data, oxygen delivery, oxygen consumption, and requirement of vasoconstrictor to correct hypotension.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Randomisation was performed by the hospital pharmacy department.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Unclear risk	The anaesthesia staff who administered the fluid were not blinded to the type of fluid, but were blinded to the doses of fluid studied, There was no statement that results analysis was carried out blind.

Godet 2008

Methods	Study design: randomised controlled trial.
Participants	Number: 65 Inclusion criteria: scheduled for abdominal aortic surgery. Baseline renal function was impaired in all patients (creatinine clearance (CrCl) < 80 ml/min). Exclusion criteria: endovascular aortic surgery, preoperative serum creatinine > 250 µmol/l, dialysis, anuria and post-transplant status. Patients with a history or present diagnosis of severe hepatic insufficiency or coagulation disorders were also excluded.

Intravenous fluids for abdominal aortic surgery (Review)

Godet 2008 (Continued)

Interventions	Treatment A: 6% HES 130/0.4 for perioperative volume substitution. Treatment B: 3% gelatin solution for perioperative volume substitution. The daily dose limitation for HES was 50 ml/kg body weight.	
Outcomes	Renal safety parameters: peak increase in serum creatinine, minimum postoperative CrCl, the incidence of oliguria (urine output < 500 ml/day), and adverse events associated with the renal system until hospital discharge. The adverse events included were itching/pruritus, haematology (haemoglobin, haematocrit, erythrocytes, leucocytes), clinical chemistry (sodium, potassium, calcium, alkaline phosphatase, total bilirubin, albumin, creatinine, urea, aspartate aminotransferase, alanine aminotransferase, a-amylase, coagulation parameters (Quick's test, activated partial thromboplastin time , platelets), urinalysis parameters, haemodynamic parameters (pulse, systolic blood pressure, diastolic blood pressure, mean arterial pressure, CVP) and fluid balance were descriptively analysed by time point.	
Notes	Sample size calculation was based on the primary renal safety parameter. Differences between the treatment groups up to 17.68 µmol/l (0.2 mg/dl) were regarded as clinically not relevant.	
Risk of bias		
Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised by the use of computer-generated randomisation block.
Allocation concealment?	Low risk	Sealed envelope which would be opened at the time the patient entered an induction room.
Blinding? All outcomes	Unclear risk	The blinding for staff administering the fluid was not mentioned. There was no statement that the results analysis was carried out blind.

Gold 1990

Methods	Study design: randomised controlled trial.
Participants	Number: 40 Age: Mean age was 69 years. Sex: male:female ratio of 37:3. Inclusion criteria: elective abdominal aortic aneurysm repair. Exclusion criteria: No exclusion criteria were detailed in the paper.
Interventions	Treatment A: 5% human albumin solution (1g/kg) during the operation. Treatment B: 6% hetastarch (1g/kg) during the operation.
Outcomes	Death within 30 days of operation. Measured within 1 hour postoperative: platelet count; activated clotting time; prothrombin time; partial thromboplastin time.
Notes	
Risk of bias	

Intravenous fluids for abdominal aortic surgery (Review)

Gold 1990 (Continued)

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Low risk	The staff administering the fluid were blinded by covering the solution with foil. There is no statement that the results analysis was carried out blind.

Hankeln 1990

Methods	Study design: randomised controlled trial.	
Participants	Number: 40 Inclusion criteria: abdominal aortic aneurysm repair.	
Interventions	Treatment A: 10% hydroxyethyl starch. Treatment B: 5% human albumin.	
Outcomes	The cardiac index, left ventricular stroke work index, stroke volume, pulmonary vascular resistance, and oxygen transport parameters.	
Notes	Patients, whose expected hemodynamic instability during surgery necessitated invasive monitoring (Swan-Ganz catheter) and arterial pressure monitoring the hemodynamic and oxygen transport parameters in conditions of hypervolemic haemodilution were investigated in randomised tests. After insertion of a radial arterial catheter and Swan-Ganz catheter via the internal jugular vein, one of the two volume substitutes (10% hydroxyethyl starch or 5% human albumin) selected at random was infused in quantities of 125 ml/5 min and the hemodynamic changes were measured after infusion of 500 ml and finally after a wedge pressure of 18 mmHg was reached.	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that result analysis was carried out blind.

Kasper 1996

Methods	Study design: randomised controlled trial.	
Participants	Number: 13 Sex: 10 male, 3 female. Age: mean age 60±8 years HBOC-201; 60±6 years HES group.	

Intravenous fluids for abdominal aortic surgery (Review)

Kasper 1996 (Continued)

Weight: mean weight: 83±8 kg HBOC-201 group, 83±12 kg HES group.

Inclusion criteria: elective abdominal aortic surgery.

Exclusion criteria: poorly controlled hypertension, unstable angina pectoris, history of myocardial infarction within the last 6 months, congestive heart failure (NYHA III or IV), Hb concentration less than 11.0g/dl, renal insufficiency (creatinine more than 1.5 mg/dl) and history of allergic reactions.

Interventions	Treatment A: 3 ml/kg of haemoglobin-based oxygen carrier (HBOC-201). Treatment B: 3 ml/kg of 6% hydroxyethyl starch (HES).
Outcomes	Heart rate, mean arterial pressure, right arterial pressure, mean pulmonary artery pressure, pulmonary artery occlusion pressure, cardiac index, pulmonary vascular resistance index.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Kasper 1998

Methods	Study design: randomised controlled trial.
Participants	Number: 24 Inclusion criteria: elective abdominal aortic surgery. Exclusion criteria: poorly controlled hypertension (systolic BP > 180 mmHg or diastolic BP > 100 mmHg with medication), unstable angina pectoris, history of myocardial infarction within 6 months, congestive heart failure, impaired renal function (creatinine > 1.5 mg/ml), and history of allergic reactions.
Interventions	Study A Treatment A: 6.9 ml/kg of haemoglobin-based oxygen carrier (HBOC-201). Treatment B: 6.9 ml/kg of 6% hydroxyethyl starch (HES). Study B Treatment A: 9.2 ml/kg of haemoglobin-based oxygen carrier (HBOC-201). Treatment B: 9.2 ml/kg of 6% hydroxyethyl starch (HES).
Outcomes	Heart rate, mean arterial pressure, cardiac output, oxygen content, oxygen extraction, and systemic and pulmonary vascular resistance.
Notes	Study A was performed before the study B because the ethics committee insisted the safety of the smaller dose of HBOC-201 be proven before proceeding with the larger dose.

Kasper 1998 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Unclear risk	There were no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

LaMuraglia 2000

Methods	Study design: randomised, multicentre, controlled trial.
Participants	<p>Number: 72</p> <p>Inclusion criteria: patients undergoing infrarenal abdominal aortic reconstruction for aneurysmal or occlusive disease. The patients had to meet perioperative criteria:</p> <ol style="list-style-type: none"> 1. the initial transfusion episode occurred in the interval between the initiation of the operation and the discharge from the postsurgical intensive care unit; 2. the haemoglobin concentration was 6.5 to 9.0 g/dl or the haematocrit level was 19% to 27%; 3. all available autologous blood transfusion had been infused; and 4. a transfusion had been prescribed. <p>Exclusion criteria: patients undergoing emergency surgery, extended suprarenal clamping, or planned concomitant renal or visceral reconstruction, had a creatinine > 2.0 mg/dl, uncontrolled hypertension, a known left ventricular ejection fraction less than 30%, active infection or sepsis, unstable medical disease (ASA IV or V classification), or had a history of allergy or intolerance to bovine products.</p>
Interventions	<p>Treatment A: 48 patients received a maximum of four doses of HBOC (first dose 60 g in 500 ml and three subsequent doses of 30 g in 250 ml).</p> <p>Treatment B: 24 patients received four allogenic RBC transfusions within 96 hours after the initial transfusion decision.</p> <p>After 96 hours or four transfusions, which ever occurred first, all subsequent transfusions in either treatment group consisted of allogenic RBCs.</p>
Outcomes	<p>Death within 30 days of operations.</p> <p>Haemodynamic measurements, arterial blood gas, haematocrit or haemoglobin concentrations.</p>
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Low risk	Sealed envelope.

LaMuraglia 2000 (Continued)

Blinding? All outcomes	High risk	The physicians administering the fluid were not blinded. There is no statement that the results analysis was carried out blind.
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Mahmood 2007

Methods	<p>Study design: randomised controlled trial.</p> <p>Patients were randomised by blocks of six using a random number table to allow equivalence in each group and the sealed envelopes were opened in the morning of surgery to either the 6% hydroxyethyl starch (200/0.62), 6% hydroxyethyl starch (130/0.4), or 4% gelatin. The physicians administering the fluid were not blinded. The results analysis was carried out blind.</p>	
Participants	<p>Number: 62</p> <p>Inclusion criteria: patients undergoing elective infrarenal abdominal aortic reconstruction.</p> <p>Exclusion criteria: patients with preoperative serum creatinine of more than 177 micromol/l, and a left ventricular ejection fraction less than 40%, patients with juxtarenal aneurysms and post-renal transplant patient.</p> <p>Patients undergoing elective infrarenal abdominal aortic reconstruction were recruited to the study. 21 patients in the HES 200/0.62 group, 21 patients in the HES 130/0.4 group, and 20 patients in the gelatin group were included. Preoperative serum creatinine of more than 177 micromol/l, and a left ventricular ejection fraction less than 40%, patients with juxtarenal aneurysms and post-renal transplant patients were excluded from the study.</p>	
Interventions	<p>Treatment A: 21 patients in the HES 200/0.62 group.</p> <p>Treatment B: 21 patients in the HES 130/0.4 group.</p> <p>Treatment C: 20 patients in the gelatin group.</p> <p>All patients received 15ml/kg 0.9% normal saline (NSS) 8 hours before surgery. Immediately after anaesthesia induction all patients received 15 ml/kg of 0.9% NSS over 1 hour followed by a maintenance 3 ml/kg/h during surgery. After anaesthesia induction and preparation for surgery had been completed, a bolus of 3ml/kg of the study colloid was infused. After surgery, crystalloid infusion was maintained at 2ml/kg/h and increased to maintain a urine output greater than 0.5 ml/kg/h.</p>	
Outcomes	<p>Serum creatinine concentration and serum urea were used for markers of glomerular filtration and general hydration. More specific markers of glomerular and tubular injury were urinary immunoglobulin G: creatinine and alfa1-microglobulin: creatinine respectively.</p>	
Notes		

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised by blocks of six using a random number table.
Allocation concealment?	Low risk	Sealed envelopes.
Blinding? All outcomes	High risk	Physicians administering the fluid were not blinded. The results analysis was carried out blind.

Marik 1997

Methods	Study design: randomised controlled trial. Patients were randomised by random number generator. The anaesthesia staff, intensive care staff, and surgical residents treating the patients were blinded to pH measurements. There was no statement that results analysis was carried out blind.
Participants	Number: 30 (15 in each group) Sex: 18 male, 12 female. Age: mean age 66±9 years. Inclusion criteria: patients undergoing elective abdominal aortic aneurysm repair.
Interventions	Treatment A: intraoperative and postoperative fluid replacement with hydroxyethyl starch. Treatment B: intraoperative and postoperative fluid replacement with crystalloids.
Outcomes	Hemodynamic, oxygenation and gastric intramucosal pH changes.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised by random number generator.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Low risk	The anaesthesia staff, intensive care staff and surgical residents treating the patients were blinded to pH measurements. There was no statement that results analysis was carried out blind.

Nicholson 1996

Methods	Study design; randomised controlled trial.
Participants	Number: 28 Sex: 15 patients in mannitol group (13 male, 2 female); 13 patients in saline group (11 male, 2 female). Age: Mean age in mannitol group 68 (65-72) and in control group 71 (68-75) years. Inclusion criteria: elective aortic aneurysm repair.
Interventions	Treatment: mannitol 0.3g/kg. Control: an equivalent volume of normal saline.
Outcomes	Blood urea, serum creatinine, creatinine clearance.
Notes	

Risk of bias

Nicholson 1996 (Continued)

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised by random number tables.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Nielsen 1991

Methods	Study design: randomised controlled trial.	
Participants	Number: 26 Sex: 20 male, 6 female. Age: Mean age was 57 years. Inclusion criteria : scheduled for reconstructive surgery on the abdominal aorta and/or its branches.	
Interventions	Treatment A: 20% human albumin solution (1g/kg on day 1 and 0.25g/kg for each subsequent day). Treatment B: 5% dextrose in 0.45% normal saline.	
Outcomes	Death within 30 days of operation. Serum sodium; plasma osmolality were measured at 24 and 48 hours postoperatively. Measured in the study but not included in this review were: body weight; fluid balance; sodium balance; glomerular filtration rate.	
Notes	The two 1985 studies include the same data and have the same text in the "methods" section. The 1989 study forms a major part of the 1991 study along with the 1985 study.	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that the results analysis was carried out blind.

Pargger 1998

Methods	Study design: randomised controlled trial.	
Participants	Number: 55 Inclusion criteria: elective repair of infrarenal abdominal aortic aneurysms.	

Pargger 1998 (Continued)

Interventions	<p>Treatment A: 29 patients of pHi guided therapy group with a pHi of lower than 7.32 were treated by means of a prospective protocol in order to increase their pHi to 7.32 or more.</p> <p>Control: the pHi values were obtained as in the treatment group, attending physicians were blinded for pHi values and treatment performed according to usual guidelines.</p>
Outcomes	<p>Death within 30 days of surgery.</p> <p>Measurements of gastric intramucosal pH, pHi, hospital stay, total fluids in surgical ICU, requirement of vasoactive agents.</p>
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Low risk	The staff in the surgical intensive care unit were blind to the gastric intramucosal pH (pHi) values of the patients in control group and treatment was performed according to the usual clinical guidelines. There was no statement that the results analysis was carried out blind.

Pull Ter Gunne 1990

Methods	Study design: randomised controlled trial.
Participants	<p>Number 30</p> <p>Inclusion criteria: elective resection of abdominal aortic aneurysm.</p>
Interventions	<p>Treatment: preoperative hydration with Ringer's lactate and human albumin 20%.</p> <p>Control: no preoperative hydration.</p>
Outcomes	Heart rate, mean arterial pressure, central venous pressure, precapillary wedge pressure, cardiac output, creatinine clearance, cardiac index, systemic vascular resistance index.
Notes	Four patients were excluded, leaving 26 patients, 13 in each group.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Ragaller 2000

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 32</p> <p>Age: Mean age 68.4±8.5 years in the h-HES group, 63.5±6.6 years in the i-HES group.</p> <p>Weight: Mean weight 77.1±11.8 kg in the h-HES group; 76.6±10.2 kg in the i-HES group.</p> <p>Inclusion criteria: high risk patients undergoing elective abdominal aortic aneurysm resection.</p> <p>Exclusion criteria: ASA > 3, congestive heart failure NYHA IV, decompensated renal failure, serum creatinine > 2.0 mg/dl, myocardial infarction in the past 6 months, drug abuse, pregnancy.</p> <p>Treatment A: 16 patients, 14 male, 2 female received hypertonic HES (h-HES).</p> <p>Treatment B: 13 patients, 12 male, 1 female received isotonic HES (i-HES).</p>
Interventions	Hypertonic, isooncotic hydroxyethyl starch (h-HES) or isotonic, isooncotic hydroxyethyl starch (i-HES).
Outcomes	Mean arterial pressure, mean pulmonary artery pressure, central venous pressure, pulmonary capillary wedge pressure, cardiac output, systemic vascular resistance index, pulmonary vascular resistance, cardiac index, stroke volume index, oxygen delivery, oxygen consumption.

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised in blocks.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Low risk	Double blind study.

Reiz 1979

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 19</p> <p>Age: Mean age was 67 years.</p> <p>Sex: 13 male, 6 female.</p> <p>Inclusion criteria: either elective abdominal aortic aneurysm repair (2 patients in control and 1 patient in study group) or fusiform aorto-iliac atherosclerotic aneurysm (7 patients in control and 9 patients in study group).</p> <p>Exclusion criteria: no exclusion criteria were detailed in the paper.</p> <p>All patients were catheterised with a 7F balloon-tipped thermodilution catheter into the pulmonary artery and invasive blood pressure monitoring of the non-dominant arm.</p>

Reiz 1979 (Continued)

Interventions	<p>Treatment: 10 patients were given the same treatment as the control patients until 10 minute prior to the declamping when a rapid infusion of 5% human plasma albumin was started in order to achieve a mPAOP around 17 mmHg immediately before declamping.</p> <p>Control: The 9 patients in control group were given an isotonic sodium chloride glucose infusion to maintain a stable mean pulmonary artery occlusion pressure (mPAOP) of 10 mmHg prior to the declamping the aorta or any of the common iliac arteries.</p>
Outcomes	Mean arterial pressure after declamping; left ventricular stroke work index; death.
Notes	A decrease in mean arterial pressure after declamping was significantly less in study group compared to control group ($P<0.05$). The decrease in left ventricular stroke work index was significantly less in the study group than in control group ($P<0.001$). There was one death in the control group.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Ridler 2003

Methods	<p>Study design: randomised controlled trial.</p> <p>acute normovolaemic haemodilution (ANH) or no ANH. The staff performing the ANH were not blinded. There is no statement that the results analysis was carried out blind.</p>
Participants	<p>Number: 63</p> <p>Inclusion criteria: elective repair of abdominal aortic aneurysms.</p>
Interventions	<p>Treatment: intraoperative acute normovolaemic haemodilution.</p> <p>Control: no acute normovolaemic haemodilution.</p>
Outcomes	<p>Death within 30 days.</p> <p>Intraoperative and postoperative transfusion, hospital stay.</p>
Notes	One patient had myocardial ischaemia after acute normovolaemic haemodilution, abdominal aortic aneurysm repair was abandoned.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Low risk	Sealed envelope.

Ridler 2003 (Continued)

Blinding? All outcomes	High risk	The staff performing the ANH were not blinded. There is no statement that the results analysis was carried out blind.
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Ritto 2002

Methods	Study design: randomised controlled trial.
Participants	Number: 22 Inclusion criteria A: elective abdominal aortic aneurysm resection. 10 patients received gelofusine; 12 patients received hydroxyethyl starch (eloHAES).
Interventions	Treatment: 6% hetastarch (1g/kg) during the operation. Control: 5% human albumin solution (1g/kg).
Outcomes	Gastric intramucosal pH, total colloid replacement.
Notes	Gastric intramucosal pH (pHi) was monitored intraoperatively.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Ritto 2004

Methods	Study design: randomised controlled trial.
Participants	Number: 40 Inclusion criteria: elective repair of abdominal aortic aneurysm surgery. Exclusion criteria: ejection fraction of < 40%, poor pulmonary function ($\text{PaO}_2 < 8.9 \text{ kPa}$), microalbuminuria (albumin excretion rates of 20-200 $\mu\text{g}/\text{min}$), and a creatinine level of > 150 $\mu\text{mol}/\text{l}$.
Interventions	Treatment: intraoperative replacement of 6% hydroxyethyl starch. Control: 4% gelofusine for colloid volume replacement; to obtain a stable heart rate, central venous pressure of 8-10 cmH_2O , a steady mean arterial pressure and a urine output of > 40 ml/h .
Outcomes	$\text{PaO}_2/\text{FiO}_2$ ratio, respiratory compliance, non-cardiogenic pulmonary oedema, plasma elastase, microalbuminuria, and plasma oncotic pressure.
Notes	

Rittoo 2004 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Low risk	Sealed envelopes.
Blinding? All outcomes	High risk	There were no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Shackford 1983

Methods	Study design: randomised controlled trial.	
Participants	Number: 58 Age: mean age was 61 years. Sex: 52 male, 9 female. Inclusion criteria: elective major aortic reconstruction. Exclusion criteria: no exclusion criteria were stated.	
Interventions	Treatment A: hypertonic saline solution. Treatment B: Ringer's lactate solution; to maintain pulmonary artery wedge pressure and central venous pressure within 3 mmHg of the pre-operative value.	
Outcomes	Death within 30 days of operation. Measured within one hour and at 24 and 48 hours postoperatively were: serum sodium; serum creatinine; serum osmolarity; colloid osmotic pressure; left-right shunt; cardiac index. Measured, but not included in this review, were: urine osmolarity; urine electrolytes; creatinine clearance; oxygen delivery; serum lactate; left and right ventricular stroke work indices; functional residual capacity; arterial oxygen and carbon dioxide levels; pulmonary artery wedge pressure (used to determine infusion rates). Data on many of the outcome measures were collected, and are presented in the paper for 72 hours postoperatively.	
Notes		

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Random numbers.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Shimada 2005

Methods	Study design: randomised controlled trial.
Participants	Number: 20 Inclusion criteria; elective surgery on infrarenal aortic aneurysms. Exclusion criteria: severe hepatic, renal, pulmonary dysfunction, congestive heart failure, or ASA physical status IV.
Interventions	Treatment A: intraoperative replacement of bicarbonated Ringer's solution. Treatment B: acetated Ringer's solution. The fluid replacement rate was adjusted to maintain the CVP between 6 and 12 mmHg using colloid and each crystalloid fluid. Dopamine was administered when systolic BP was below 80 mmHg.
Outcomes	Death within 30 days. Volume of crystalloid and colloid infusion, blood transfusion, arterial blood gas analyses.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There were no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Skillman 1975

Methods	Study design: randomised controlled trial.
Participants	Number:16 Age: mean age was 62 years. Sex: 16 male, 5 female. Inclusion criteria: surgery on the abdominal aorta. Exclusion criteria: no exclusion criteria were stated.
Interventions	Treatment A: 25% human albumin solution (1g/kg). Treatment B: 5% dextrose in Ringer's lactate solution. At the end of the operation, after analysis of the outcome measures, albumin was given to both groups of patients for a further 24 hours. The ventilator was adjusted to give a PaCO ₂ of 40 mmHg during analysis of each outcome measure.
Outcomes	Death within 30 days of operation.

Skillman 1975 (Continued)

Measured within one hour of operation were: serum oncotic pressure; serum albumin; alveolar-arterial oxygen content difference.
Measured but not included in this review were: plasma volume; circulating albumin mass; creatinine clearance (not useful for this review); change in body weight; sodium intake (preoperative values not recorded).

Notes
The administration of a study fluid to both groups after the operation invalidates any comparison and thus these results have been discarded. Results from the end of the operation are still valid and are therefore included in this review. Three patients were excluded from the data analysis due to an error in administered lactate dose, but the data from these patients are presented (for information only) in the published paper.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Sobczynski 1997

Methods	Study design; randomised controlled trial.
Participants	Number: 50 Age: 40-68 years. Inclusion criteria: ASA Grade III undergoing elective abdominal aortic reconstruction. Exclusion criteria: congestive heart failure (defined as NYHA Grades III and IV), renal and hepatic failure, and any kind of neurological disorder.
Interventions	After general anaesthesia, administered: Treatment A: 5 ml/kg of a 7.5% NaCl/6% HES 200/05 solution (HTS-HES group). Treatment B: the same volume of 6% HES 200/05 solution. The solutions were given immediately after aortic crossclamping release in a 5-minute duration. Ringer's solution and packed red blood cells were administered throughout the intraoperative period in both groups of patients to maintain the pulmonary artery wedge pressure above 10 mmHg and the haemoglobin level above 10 g/dl. During the first 24 hours after the operation each patient received 2000 ml of 5% glucose solution while Ringer's solution was used to maintain filling pressures at the pre-operative level.
Outcomes	The haemodynamic variables: mean arterial pressure (MAP), pulmonary artery wedge pressure (PAWP), cardiac output, and cardiac index (CI). Haematocrit (Hct), oxygen partial pressures and saturations in arterial and mixed venous blood (PaO ₂ , SaO ₂ , PvO ₂ , SvO ₂), plasma sodium (Na) and potassium (K), plasma volume, plasma osmolality. The following derived parameters were calculated: left ventricular stroke work index (LVSWI), pulmonary vascular

Sobczynski 1997 (Continued)

resistance index (PVRI), systemic vascular resistance index (SVRI), oxygen delivery (DO_2), oxygen consumption (VO_2) and oxygen extraction ratio (OER). The variables were measured the day before surgery (T1), after induction of anaesthesia (T2), immediately after infusion of study fluid (T3), immediately after the end of the surgical procedure (T4) and 24 hours after surgery (T5).

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised by a card draw prior to surgery.
Allocation concealment?	Unclear risk	The concealment was not mentioned in the method.
Blinding? All outcomes	High risk	The staff administering the fluid were not blinded, the result analyses were not performed blind.

Soskic 2005

Methods	Study design: randomised controlled trial.
Participants	Number: 40 Inclusion criteria: reconstruction of the abdominal aorta. Exclusion criteria: preoperative creatinine level over 130 micromol/l and an ejection fraction of less than 40%.
Interventions	Treatment: 20 patients received a small volume (4 ml/kg) of hypertonic, hyperoncotic solution (7.2% NaCl/10% dextran). Control: 20 patients received 0.9% NaCl infusion.
Outcomes	Cardiac output, haemodynamic data, the amount of crystalloids and human albumin during 24 hours after removal of the aortic crossclamp. Oxygen delivery, venous oxygen saturation, tissue perfusion.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Verheij 2006

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 68</p> <p>Inclusion criteria: 40 patients who were to undergo cardiac procedures, 28 major vascular procedures and 18 patients reconstruction of the abdominal aorta. The inclusion criteria, judged when the patients arrived at the ICU, were presumed hypovolaemia, defined as systolic BP < 110 mmHg and pulmonary capillary wedge pressure at or below 10 mmHg or CVP at or below 8 mmHg.</p> <p>Exclusion criteria: age of more than 75 years or known anaphylactoid reactions to colloids.</p>
Interventions	<p>Treatment A: 0.9% NaCl, 4% gelofusine.</p> <p>Treatment B: 6% hydroxyethylstarch (MW 200,000, substitution 0.45-0.55).</p> <p>Treatment C: 5% human albumin.</p> <p>Fluids were given during 90 min on the basis of the response within predefined pressure limits of PCWP or CVP. Boluses of maximum 200 ml were given per 10 min.</p>
Outcomes	Measures at 90 minutes of fluid replacement: cardiac output, intrathoracic blood volume, extravascular lung water, pulmonary leak index, global end-diastolic volume index, global ejection fraction, left ventricular stroke work index, stroke volume index.
Notes	The data of the patients included in this study was provided by the authors.

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Hospital pharmacy.
Allocation concealment?	Low risk	Sealed envelope.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Virgilio 1979

Methods	Study design: randomised controlled trial.
Participants	<p>Number: 29</p> <p>Age: mean age was 58 years.</p> <p>Inclusion criteria: aortic reconstructive surgery.</p>
Interventions	<p>Treatment A: Ringer's lactate solution.</p> <p>Treatment B: 5% human albumin in Ringer's lactate solution;</p> <p>during operation and for the first 24 hours postoperative. The rate of fluid infusion was adjusted to maintain the pulmonary artery wedge pressure within 5 mmHg of the preoperative level for each patient and cardiac output equal to or greater than the preoperative value with a urine output of greater than 50 ml/hour.</p>
Outcomes	Death within 30 days of operation.

Virgilio 1979 (Continued)

Measured within one hour and at 28 and 48 hours postoperatively were: left-right shunt; serum albumin; colloid osmotic pressure.
Measured but not included in this review were: sodium intake and output; fluid balance. Cardiac index, urine output and pulmonary artery wedge pressure were used to adjust fluid infusion rates.

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Random numbers.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Waters 2001

Methods	Study design: randomised controlled trial.
Participants	Number: 66 Inclusion criteria: open aortic aneurysm repair. Exclusion criteria: a history of abnormal renal function or serum blood urea nitrogen > 25mg/dl or creatinine > 1.4 mg/dl, with abnormal chloride levels (<97 or >105 mEq/l), or pre-existing acid-base abnormalities by base excess (>2 or <-2 mEq/l) and PCO ₂ (<35 or > 45mmHg).
Interventions	Treatment A: intraoperative administration of lactated Ringer's solution. Treatment B: intraoperative administration of 0.9% normal saline; to maintain pulmonary arterial occlusion pressure or central venous pressure within 10% of the baseline preoperative value. Colloid was restricted to periods of acute blood loss after aortic clamping or declamping. Sodium bicarbonate was restricted to patients with base excess < -5 mEq/l.
Outcomes	Death within 30 days. Total crystalloid replacement volume, blood transfusion, coagulation, arterial blood gas, and electrolytes.

Notes

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Random number generator.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	Low risk	Anaesthesia and critical care providers were blinded by covering the labels of the solutions.

Intravenous fluids for abdominal aortic surgery (Review)

Welch 1993

Methods	Study design: randomised controlled trial.
Participants	Number: 39 Age: mean age of haemodilution group 59.25 (43-77) years; control group 60.9 (44-75) years. Inclusion criteria: patients undergoing elective infrarenal aortic operation, 9 for aneurysm and 30 for occlusive disease.
Interventions	Treatment: acute preoperative isovolaemic haemodilution with dextran 70, 20 patients (9 male, 11 females) received haemodilution. Control: no haemodilution, 19 patients (14 males, 5 females).
Outcomes	Mean postoperative creatinine clearance as a fraction of mean preoperative creatinine clearance. Cardiac output.
Notes	

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that results analysis was carried out blind.

Wolowczyk 2003

Methods	Study design: randomised controlled trial.
Participants	Number: 47 Inclusion criteria: elective open AAA repair. Exclusion criteria: patients with preoperative haemoglobin < 12.0 g/l, moderate to severe left ventricular failure with ejection fraction < 30%, poor exercise tolerance, severe ischaemic heart disease in the form of severe or unstable angina and/ or myocardial infarct within six months, evidence of critical stenosis of left main coronary artery, aortic stenosis, untreated systemic hypertension, liver disease and coagulopathy, impaired renal function, and sickle cell disease.
Interventions	Treatment: acute normovolaemic haemodilution (ANH), 15 g/kg of blood, with hydroxyethyl starch. Control: no ANH.
Outcomes	Amount of replacement fluid volume, perioperative haemoglobin.
Notes	4 patients were excluded and 7 patients did not consent. 36 patients were randomised into either acute normovolaemic haemodilution (ANH) or control group. Two ANH patients were further excluded due to poor cardiac reserve after induction of general anaesthesia. The study was not performed on an intention-to-treat basis.

Wolowczyk 2003 (Continued)

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Low risk	Patients were randomised using computer-generated randomisation programme in blocks of four.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There was no statement that results analysis was carried out blind.

Younes 1988

Methods	Study design: randomised controlled trial.	
Participants	Number: 31 Sex: 24 males, 7 females. Inclusion criteria: elective abdominal aortic surgery.	
Interventions	Treatment A: 7.5% hypertonic sodium chloride (2400 mOsm/l) (18 patients). Treatment B: 0.9% sodium chloride (13 patients). The amount of 4 ml/kg body weight was infused within 15 minutes, the fluid infusion was started 2 minutes before the release of aortic clamp.	
Outcomes	Mean arterial pressure, central venous pressure, serum osmolarity, plasma sodium, haematocrit, plasma protein.	
Notes		

Risk of bias

Bias	Authors' judgement	Support for judgement
Adequate sequence generation?	Unclear risk	Random allocation reported but the method of randomisation was not described.
Allocation concealment?	Unclear risk	Method not stated.
Blinding? All outcomes	High risk	There was no blinding of the staff administering the fluid. There is no statement that result analysis was carried out blind.

cardiac index (CI), cardiac output (CO), haematocrit (Hct), left ventricular stroke work index (LVSWI), mean arterial pressure (MAP), oxygen consumption (VO₂), oxygen delivery (DO₂), oxygen extraction ratio (OER), oxygen partial pressures (PaO₂), pulmonary artery wedge pressure (PAWP), plasma sodium (Na), potassium (K), pulmonary vascular resistance index (PVRI), pulmonary capillary wedge pressure (PCWP), right atrial pressure (RA), systemic vascular resistance index (SVRI)

Characteristics of excluded studies [ordered by study ID]

Study	Reason for exclusion
Albrecht 1995	This study examined patients before surgery and before induction of anaesthesia.
Auler 1987	This was not a randomised controlled trial. Ten patients were studied; the first five were allocated to receive hypertonic saline and the second five to receive isotonic saline. The study was open with no attempt at allocation concealment. Only three of the ten cases involved intra-abdominal surgery alone, the remainder included surgery on the thoracic aorta.
Clagett 1999	This prospective randomised trial used the intraoperative cell salvage during aortic surgery.
Croft 1992	This randomised study appeared to be of high quality, but there were no details of standard errors of the means quoted and many of the results were presented in a graphical format which precluded accurate reporting. This study was excluded on these grounds.
Luck 1965	The intervention was to administer a small volume of Mannitol with a view to improving renal blood flow and glomerular filtration rather than as a non-blood fluid replacement. There was no evidence that this study was randomised.
Merkulov 2004	The study focused on the differences in red blood cell transfusion between intraoperative haemodilution and preoperative autologous donation with intraoperative cell salvage.
Sumi 2008	Intervention of drug trial human atrial natriuretic peptide not a fluid.
Ueda 1998	Patients were not randomised in this study.
von Sommoggy 1990	This study randomised patients with aortofemoral bifurcation bypass to receive fresh frozen plasma and human albumin for one group, while the other group received hydroxyethyl starch.
Wong 2002	This prospective randomised clinical trial addressed the transfusion strategy in aortic surgery.

Characteristics of studies awaiting assessment *[ordered by study ID]*

[Mannova 2007](#)

Methods	Randomised controlled trial.
Participants	50 patients admitted for elective AAA repair.
Interventions	Acute normovolaemic haemodilution
Outcomes	Haemodynamic changes
Notes	Czech paper requires translation

[Naumenko 2005](#)

Methods	Transfusion of the allogenic components of blood was made in the both groups according to the indications. It was shown that using the solution of high molecular hydroxyethyl starch promoted the elevated level of the delivery and consumption of oxygen as compared with the standard infusion-transfusion therapy which is explained by the predominantly hemodynamic component of the oxygen transport.
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Naumenko 2005 (Continued)

Participants	71 patients with obliterating atherosclerosis of the lower extremities with chronic ischemia. Planned operations of aorto-bifemoral shunts were made.
Interventions	Patients of the first group (n=43) were treated by infusion therapy including solutions of colloids and crystalloids. In the second group a solution of high molecular hydroxyethyl starch was used in addition to colloids and crystalloids.
Outcomes	Oxygen-transport function of blood were studied before initial narcosis.
Notes	Russian paper requires translation.

cardiac index (CI), cardiac output (CO), haematocrit (Hct), left ventricular stroke work index (LVSWI), mean arterial pressure (MAP), oxygen consumption (VO₂), oxygen delivery (DO₂), oxygen extraction ratio (OER), oxygen partial pressures (PaO₂), pulmonary artery wedge pressure (PAWP), plasma sodium (Na), potassium (K), pulmonary vascular resistance index (PVRI), pulmonary capillary wedge pressure (PCWP), right atrial pressure (RA), systemic vascular resistance index (SVRI)

DATA AND ANALYSES

Comparison 1. Acute normovolaemic haemodilution (ANH) versus no ANH

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Death	2	95	Odds Ratio (M-H, Fixed, 95% CI)	0.99 [0.16, 6.03]
2 Avoidance of allogenic blood transfusion	2	96	Odds Ratio (M-H, Fixed, 95% CI)	0.76 [0.32, 1.80]

Analysis 1.1. Comparison 1 Acute normovolaemic haemodilution (ANH) versus no ANH, Outcome 1 Death.

Analysis 1.2. Comparison 1 Acute normovolaemic haemodilution (ANH) versus no ANH, Outcome 2 Avoidance of allogenic blood transfusion. **Comparison 2. Colloids versus crystalloids**

Outcome or subgroup title	No. of studies	No. of participants	Statistical method	Effect size
1 Total IV fluids	5	145	Mean Difference (IV, Fixed, 95% CI)	-0.95 [-1.27, -0.63]
1.1 Total intraoperative fluid	3	87	Mean Difference (IV, Fixed, 95% CI)	-0.85 [-1.20, -0.50]
1.2 Intraoperative positive fluid balance	2	58	Mean Difference (IV, Fixed, 95% CI)	-1.43 [-2.20, -0.66]

Analysis 2.1. Comparison 2 Colloids versus crystalloids, Outcome 1 Total IV fluids.

APPENDICES

Appendix 1. Search strategy for CENTRAL 2009 update

#1	MeSH descriptor Aortic Aneurysm explode all trees	625
#2	(aneur* or abdomin*) near3 aort*	1156
#3	MeSH descriptor Aorta, Abdominal explode all trees	283
#4	MeSH descriptor Fluid Therapy explode all trees	895
#5	MeSH descriptor Infusions, Intravenous explode all trees	0
#6	MeSH descriptor Lactic Acid explode all trees	1311
#7	MeSH descriptor Glucose explode all trees	9619
#8	MeSH descriptor Saline Solution, Hypertonic explode all trees	272
#9	MeSH descriptor Mannitol explode all trees	311
#10	MeSH descriptor Albumins explode all trees	2956
#11	MeSH descriptor Dextrans explode all trees	444
#12	MeSH descriptor Hetastarch explode all trees	345
#13	lactate* or dextrose* or glucose* or fluid* or saline* or mannitol* or albumin* or dextran* or hetastarch or (bovine next h?emoglobin next based oxygen) or HBOC or hydroxyethyl-starch or HES	46280
#14	MeSH descriptor Isotonic Solutions, this term only	513
#15	MeSH descriptor Plasma Substitutes explode all trees	1046
#16	(#4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15)	48174
#17	(#1 OR #2 OR #3)	1161
#18	(#16 AND #17)	163

WHAT'S NEW

Date	Event	Description
10 September 2009	New citation required but conclusions have not changed	New authors for the updated review.

Date	Event	Description
10 September 2009	New search has been performed	Twenty-two additional studies have been included in the review and five additional studies excluded. Two studies have been added to 'Studies awaiting classification'.

HISTORY

Protocol first published: Issue 1, 1998

Review first published: Issue 4, 2000

Date	Event	Description
18 August 2008	Amended	Converted to new review format.
16 July 2002	New citation required but conclusions have not changed	Change in author. Substantive amendment

CONTRIBUTIONS OF AUTHORS

Patiparn Toomtong selected trials for inclusion, assessed methodological quality of trials, extracted data, amended text for update of review. Sirilak Suksompong assessed methodological quality of trials and extracted data.

DECLARATIONS OF INTEREST

There is no known conflict of interest.

SOURCES OF SUPPORT

Internal sources

- No sources of support supplied

External sources

- Chief Scientist Office, Scottish Government Health Directorates, The Scottish Government, UK.

INDEX TERMS

Medical Subject Headings (MeSH)

*Fluid Therapy; Aorta, Abdominal [*surgery]; Aortic Aneurysm, Abdominal [surgery]; Arteriosclerosis [surgery]; Blood Loss, Surgical; Colloids; Randomized Controlled Trials as Topic; Solutions [therapeutic use]

MeSH check words

Humans