World J Surg (2013) 37:1193–1202
DOI 10.1007/s00268-013-1987-8

World Journal of Surgery

Perioperative Fluid Restriction in Major Abdominal Surgery: Systematic Review and Meta-analysis of Randomized, Clinical Trials

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Published online: 6 March 2013
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Abstract

Background Fluid management is a fundamental component of surgical care. Recently, there has been considerable interest in perioperative fluid restriction as a method of facilitating recovery following elective major surgery. A number of randomized trials have addressed the issue in various surgical specialities, and a recent meta-analysis proposed uniform definitions regarding fluid amount as well as examining fluid restriction in patients undergoing colonic resection.

Methods Medline, Embase, trial registries, conference proceedings, and article reference lists were searched to identify randomized, controlled trials of perioperative fluid restriction versus "standard" perioperative fluid management, as per definitions formulated previously. All of the studies involved patients undergoing colonic resection. The primary outcome measure was postoperative morbidity. Secondary endpoints included mortality, renal failure, time to first flatus, and length of hospital stay. A random effects model was applied.

Results Seven randomized, controlled trials with a total of 856 patients investigating standard versus restrictive fluid regimes, as denoted by the definitions, were included. Perioperative fluid restriction had no effect on the risk of postoperative complications (OR 0.49 (95 % confidence interval (CI) 0.2–1.18; $P = 0.101$). There was no detectable effect on death and fluid restriction did not reduce hospital stay (Pooled weighted mean difference −0.25; 95 % CI 0.72–0.21; $P = 0.29$).

Conclusions Perioperative fluid restriction does not significantly reduce the risk of complications following major abdominal surgery. Furthermore, it does not appear to reduce length of hospital stay.

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Introduction

Traditional surgical teaching recommends that a 70-kg male requires 1 l of 0.9 % saline and approximately 2 l of 5 % dextrose per day to maintain homeostasis while oral intake is reduced following surgery [1]. In practice, many patients receive larger volumes as the 3 l of intravenous fluids are supplemented by drug infusions and oral intake [1–3]. Excessive postoperative fluid loading, leading to weight gain, is associated with increased complications and mortality [4, 5]. In patients undergoing colorectal surgery, fluid restriction during the perioperative period is thought to have both general and specific advantages. Limiting administration of fluid in this time period has been shown to be effective with regard to postoperative cardiac and respiratory function [6]. More specifically, fluid excess in the perioperative period can impair anastomotic healing [7]. However, there also is evidence to state that perioperative fluid restriction can impair organ function secondary to hypovolemia [8]. As part of the "Enhanced Recovery After Surgery" concept developed in the past decade, it was proposed that perioperative fluid restriction would reduce postoperative complications and reduce

length of hospital stay. There has been much discussion and debate regarding this vital component. Whilst ERAS programs have been shown to be effective with regard to length of hospital stay [9], individual randomized, controlled trials regarding perioperative fluid restriction have found conflicting results. However, many trials have focused on fluid restriction in patients undergoing generalized abdominal surgery, including, for example, patients undergoing elective abdominal aortic aneurysm repair [10], which has left us with an absence of procedure-specific recommendations with regard to this topic [11, 12]. Furthermore, a wide variation between different RCTs regarding the definition of restrictive, standard, and supplemental fluid regimes has only compounded confusion. Finally, a recent meta-analysis by Rahbari et al. [13] addressed both issues. It included six trials [14–19] that studied the effects of fluid restriction in patients undergoing colorectal resection only as well as formulating uniform definitions for restrictive, standard, and supplemental fluid administration. The results showed that perioperative fluid restriction significantly reduced overall morbidity.

However, a number of randomized, controlled trials with conflicting results have been produced since, therefore, a further systematic review, using similar inclusion criteria as well as definitions for fluid administration as proposed by Rahbari et al. [13] appeared timely.

Methods

Definitions of the terms standard, restrictive, and supplemental fluid restriction

The meta-analysis by Rahbari et al. [13] used current recommendations from the latest edition of the reference anesthesiological textbook, *Miller's Anaesthesia* [20], to standardize the terms standard, restrictive, and supplemental fluid restriction. The definitions used in this meta-analysis are identical to ensure continuity with regard to inclusion of more recent RCTs performed as well as their effect on the results of this meta-analysis. Rahbari et al. [13] proposed that the definition of standard fluid therapy for patients undergoing major bowel resections consisted of the following:

> "Administration of 10 ml per kg bodyweight of any colloidal fluid preparation for preblock hydration where applicable; administration of 5–7 ml of any crystalloid solution for compensatory intravascular volume expansion; administration of 4 ml per kg per hour for the first 10 kg, 2 ml per kg per hour for the second 10 kg, and 1 ml per hour for each additional kilogram bodyweight for deficit and maintenance; administration of 4–6 ml per kg bodyweight per hour for loss to the so-called third space; and administration of either 3 ml of any crystalloid solution or 1 ml of any colloidal solution for every millilitre of blood lost. An additional 10 % of the calculated mean is added to the calculated ranges for possible measurement inaccuracies regarding amount of blood lost and fluid administered. Any approach to perioperative fluid therapy resulting in larger amounts of fluid administered, that is larger than the calculated ranges plus 10 %, is considered supplemental. Any approach to perioperative fluid therapy resulting in smaller amounts of fluid administered, that is smaller than the calculated ranges minus 10 %, is considered restrictive."

Table 1 summarizes the components of standard fluid therapy. Table 2 provides a basic example of standard perioperative fluid management of a 60-Kg man undergoing colorectal resection. This table assumes that the patient was fasting for 8 hours preoperatively and that the operation was of 3 h duration. The patient was placed under general anesthetic and intraoperative blood loss set at 400 ml.

Systematic literature search

A systematic literature search of the Embase and Medline databases from 1966 until 2011 as well as the Cochrane Library was conducted using validated methods of the Cochrane Collaboration [21] and the QUOROM [22] statement. The search terms surgery, intravenous fluids, fluid restriction, and fluid management were used in combination with the Boolean operators AND or OR. Two authors (MB and SRW) independently performed electronic searches in December 2011, which included searches of the current controlled trials register (www.controlledtrials.com

Table 1 Fluid management according to current textbook opinion, as per Rahbari et al. [13]

Crystalloid solutions	Crystalloid solutions
Compensatory intravascular volume expansion (with epidural anesthesia) (ml)	Bodyweight (kg) × 10 (ml/kg)
Compensatory intravascular volume expansion (without epidural anesthesia) (ml)	Bodyweight (kg) × 5–7 (ml/kg)
Deficit (ml/h)	(Bodyweight + 40) (kg) × 1 (ml/kg/h)
Maintenance (ml/h)	(Bodyweight + 40) (kg) × 1 (ml/kg/h)
Third space (ml/h)	Bodyweight (kg) × 4–6 (ml/kg/h)
Blood loss (ml)	3:1 (volume:volume)*

*1:1 (volume:volume) for colloidal solutions

Table 2 Example of a standard fluid management regime of a 60-Kg man undergoing colorectal resection

Crystalloid solution	Crystalloid solution	
Compensatory intravascular volume expansion (without epidural anesthesia) (ml)	Bodyweight (kg) × 5–7 (ml/kg) 60 × (5–7) = 300–420 ml	360 ml (average)
Deficit (ml/h)	(Bodyweight + 40) (kg) × 1 (ml/kg/h) (60 + 40) × 1 = 100 ml/h 100 ml/h × 8 h = 800 ml	800 ml
Maintenance (ml/h)	(Bodyweight + 40) (kg) × 1 ml/kg/h (60 + 40) × 1 = 100 ml/h 100 ml/h × 3 h = 300 ml	300 ml
Third space (ml/h)	Bodyweight (kg) × 4–6 (ml/kg/h) 60 (Kg) × 4–6 (ml/kg/h) = 240–360 ml/h 300 ml (average) × 3 h = 900 ml	900 ml (average)
Blood loss (ml/h)	3:1 (volume:volume)* Blood loss = 400 ml Replacement = 400 ml × 3 = 1,200 ml	1,200 ml
Total (ml)		3,560 ml

*1: 1 (volume: volume) for colloidal solutions

) and the Cochrane Database of Controlled Trials. They were supplemented by a hand search of published abstracts from meetings of the Association of Surgeons of Great Britain and Ireland, the Association of Coloproctology of Great Britain and Ireland, the European Association of Coloproctology, Tripartite Colorectal Meeting, and the American Society of Anesthesiology from 1999 to 2011. The reference lists of articles obtained also were searched to identify further relevant citations and the "related articles" function was used to identify similar studies. Finally, experts in the fields were contacted for knowledge of any ongoing studies.

Study selection, data extraction, and quality assessment

Studies were included if they met each of the following criteria: randomized, controlled trial, patients undergoing major abdominal surgery except thoracic esophagectomy and vascular surgery, randomization to intra- and/or postoperative fluid restriction or routine management. Trials that compared endoscopic/laparoscopic techniques or those that investigated the utility of Doppler guided intraoperative fluid management were not eligible. Trials involving patients younger than age 18 years were excluded.

Abstracts of the citations identified by the search were then scrutinised by two observers (SRW and MB) to determine eligibility for inclusion in the meta-analysis. In situations of uncertainty full papers were obtained. Data from eligible trials were abstracted into a computerized spreadsheet for analysis. Where necessary, trial authors were contacted to provide additional information.

The quality of each trial was assessed using the Jadad scoring system [23]. Items evaluated included size calculation, generation of allocation sequence, allocation concealment, methods of randomization, blinding, and description of protocol deviations, withdrawals, and dropouts.

Definitions of study groups and outcome parameters

Trials were divided into two categories. The first involved RCTs comparing standard fluid amount with restrictive amount. The second involved those comparing standard amount with supplemental fluid. Based on the algorithm by Rahbari et al. [13] detailed above, the "standard" fluid volume for each study group was calculated separately. Depending on the volume actually administered, each study group was classified using the proposed definitions for restrictive and supplemental fluid. Meta-analyses were performed for studies comparing standard with restrictive fluid administration. However, based on the definitions, only two trials were allocated to the second category comparing standard fluid amount with supplemental fluid. It was felt that a meta-analysis of this group would not yield significant results and so this category is not included.

The primary outcome measure for the meta-analysis was the incidence of postoperative morbidity, defined as the number of patients who developed at least one complication after surgery, as per the Rahbari meta-analysis. Secondary outcome measures were length of hospital stay, postoperative renal failure, time to first flatus, and perioperative death.

Data analysis

The statistical analysis was performed using Statsdirect 2.57 (Statsdirect Ltd., Altrincham, UK). Pooled odds ratios were calculated for the effect of fluid restriction on postoperative complications, postoperative renal failure, and perioperative death. Calculations of effect sizes for dichotomous variables are presented as risk ratio with 95 % confidence interval (CI) and for continuous outcomes, such as length of hospital stay, as weighted mean differences. All pooled outcome measures were determined using random-effects models as described by Der Simonian and Laird [24]. Heterogeneity amongst the trials was assessed by Cochran's Q statistic, a null hypothesis test in

which a P value <0.05 indicates the presence of significant heterogeneity. The Egger test was used to assess the funnel plot for significant asymmetry, indicating possible publication or other biases.

Results

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Fig. 1) illustrates the studies identified for inclusion in the final analysis after the initial search.

Nine randomized, controlled trials with a total of 1,144 patients met the eligibility criteria (Fig. 1) [14–19, 25–27]. As mentioned earlier, two of the trials investigating intraoperative fluid management, Holte et al. [18] and Kabon et al. [19], met the definitions denoted standard and supplemental as proposed by Rahbari et al. [13]. On this basis they were not included in the meta-analysis. Therefore, seven randomized, controlled trials with a total of 856 patients investigating standard vs. restrictive fluid regimes, as denoted by the definitions, were included [14–17, 25–27]. Of the 856 patients included, 425 were randomized to fluid restriction. Six of these trials [14–17, 25, 26] were in the published form whilst one was unpublished and available in abstract form [27]. The characteristics of the seven randomized trials for which data were available are summarized in Table 3. The mean Jadad score for the seven RCTs was 3 (range 2–4), indicating moderate methodological quality, as shown in Table 4. Three trials [17, 26, 27] included patients undergoing elective abdominal surgery. The remaining four trials [14–16, 25] included patients with colorectal resections only. Identified studies were conducted in different countries (Denmark, Sweden, Israel, the Netherlands, and the United Kingdom) and were published between 2002 and 2011. All studies reported power calculations, although using different primary endpoints. Notably, sample size varied among the different studies (20 [14] to 240 [27] patients).

Three trials assessed postoperative restriction only [14, 16, 26], one investigated intraoperative restriction only [17], and the remaining three trials assessed both intraoperative and postoperative restriction [15, 25, 27]. Three of the trials relied primarily on intravenous fluids to provide postoperative maintenance [14, 16, 17], whereas three [15, 25, 26] relied on oral intake supplemented as necessary by intravenous fluids. In the seventh trial [27], we were unable to ascertain the role of oral intake in the postoperative period.

Standard versus restrictive fluid administration—meta-analysis

Data on overall morbidity, the primary endpoint, were available from all seven trials. A meta-analysis of these trials did not show a reduced rate of postoperative complications in favor of fluid restriction (odds ratio (OR) 0.49; 95 % CI 0.2–1.18; $P = 0.101$). A Forest Plot of complications is shown in Fig. 2. However, there was evidence of significant heterogeneity amongst the seven trials (Cochran $Q = 34.2$, DF = 6; $P < 0.0001$). The Egger test showed no statistical evidence of bias ($P = 0.25$), but a bias

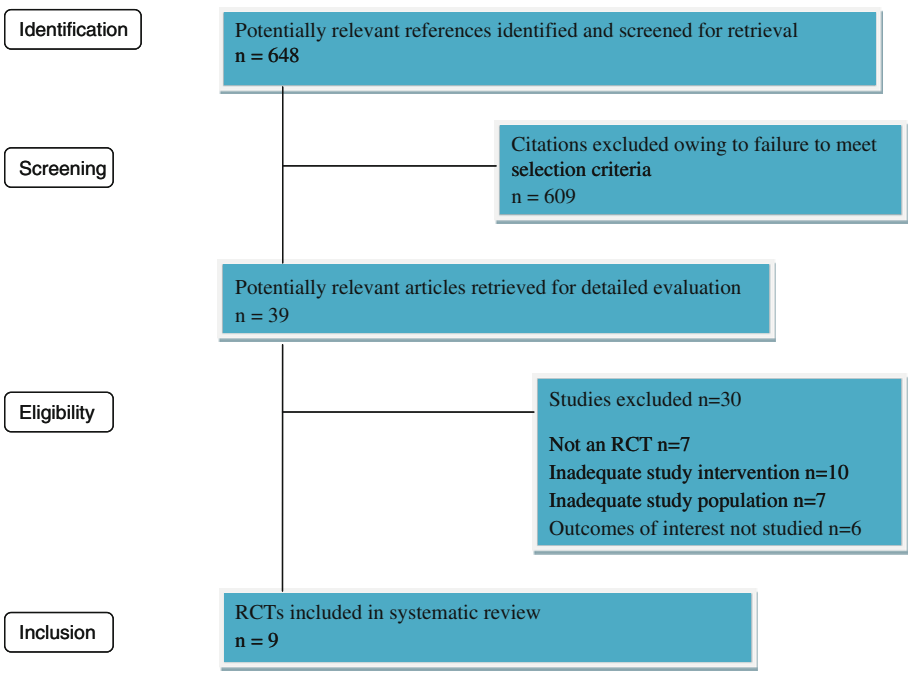


Fig. 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement summarizing search for and selection of studies. *RCT* randomized controlled trial

Table 3 Characteristics of included trials

	Lobo et al. [14]	Brandstrup et al. [15]	Nisanevich et al. [17]	Mackay et al. [16]
Sample size	20	141	152	80
Primary outcome measure	Solid-phase and liquid-phase gastric emptying times	Complications	Complications and postoperative death	Hospital stay
Surgery type	Elective colectomy	Elective colorectal resection	Elective intra-abdominal gastrointestinal resections	Elective colorectal resection with primary anastomosis
Intraoperative restriction	No	Yes	Yes	Yes
Postoperative restriction	Yes	Yes	No	Yes
Purgative bowel preparation	Some	Unclear	All	No
IV fluid with bowel preparation	N/A	Unclear	Yes	N/A
Epidural use	No	Yes	Yes	No
Volume preloading before epidural	N/A	Yes	No	N/A
Early feeding	No	Yes	No	Yes
Early mobilization	No	No	No	Yes

	Nordling et al. [25]	Kalyan et al. [27]	Vermeulen et al. [26]
Sample size	161	240	62
Primary outcome measure	Postoperative hospital stay	Complications	Postoperative hospital stay
Surgery type	Elective colorectal surgery	Upper GIT resections/colorectal resections	Major abdominal surgery
Intraoperative restriction	Yes	Yes	No
Postoperative restriction	Yes	Yes	Yes
Purgative bowel preparation	N/A	N/A	Yes
IV fluid with bowel preparation	N/A	N/A	No
Epidural use	Yes	N/A	Yes
Volume preloading before epidural	Yes	N/A	No
Early feeding	Yes	N/A	Yes
Early mobilization	Yes	N/A	Unclear

N/A not available

assessment plot was asymmetrical on visual inspection (Fig. 3). In three of the trials, complications were classified as major and minor [15, 25, 26]. Major complications included cardiac, such as myocardial infarction and arrhythmias, respiratory, such as pulmonary edema, respiratory tract infection, and ARDS, abdominal, such as anastomotic leakage and peritonitis, and general, such as sepsis, thromboembolism, and hemorrhage. Minor complications included wound infection, wound dehiscence, and vomiting, as well as mild electrolyte abnormalities. From available data, the most common major cardiac, respiratory, and abdominal complications were arrhythmia, respiratory tract infection, and anastomotic leak respectively. The most common general complication was hemorrhage.

All seven trials reported mortality [14–17, 25–27]. Eight deaths were reported in the standard fluid group, whereas four were reported in the restrictive group. The random effects model yielded no statistically significant reduction in perioperative mortality between the two groups (OR 0.63; 95 % CI 0.2–1.91; $P = 0.41$; Fig. 4), but the fixed effects model did (OR 0.250158; 95 % CI 0.05–0.93; $P = 0.03$; Fig. 5). There was no evidence of heterogeneity (Cochran $Q = 1.79$, DF = 6; $P = 0.94$) amongst the trials regarding death in the postoperative period and an Egger test revealed no statistical bias ($P = 0.69$).

Only six of the trials reported data on perioperative renal failure [14–17, 25, 26]. Data regarding renal failure could not be obtained from the seventh trial [27]. Only one patient developed postoperative renal failure in the

Table 4 Quality assessment of included trials

	Lobo et al. [14]	Brandstrup et al. [15]	Nisanevich et al. [17]	Mackay et al. [16]
Power calculation	Yes	Yes	Yes	Yes
Inclusion/exclusion criteria specified	Yes	Yes	Yes	Yes
Placebo-controlled	Yes	Yes	Yes	Yes
Blinding	No	Yes	Yes	Yes
Randomization process explained	Yes	Yes	Yes	Yes
Loss to follow-up reported	No	Yes	Yes	Yes
Intention to treat analysis	Yes	Yes	Yes	Yes
Significant baseline differences	No	Yes	No	No
Jadad score	2	4	3	4

	Nordling et al. [25]	Kalyan et al. [27]	Vermeulen et al. [26]
Power calculation	Yes	Yes	Yes
Inclusion/exclusion criteria specified	Yes	No	Yes
Placebo-controlled	Yes	Yes	Yes
Blinding	Yes	Yes	Yes
Randomisation process explained	Yes	N/A	Yes
Loss to follow-up reported	No	N/A	Yes
Intention to treat analysis	No	N/A	Yes
Significant baseline differences	No	X	X
Jadad score	2	2	4

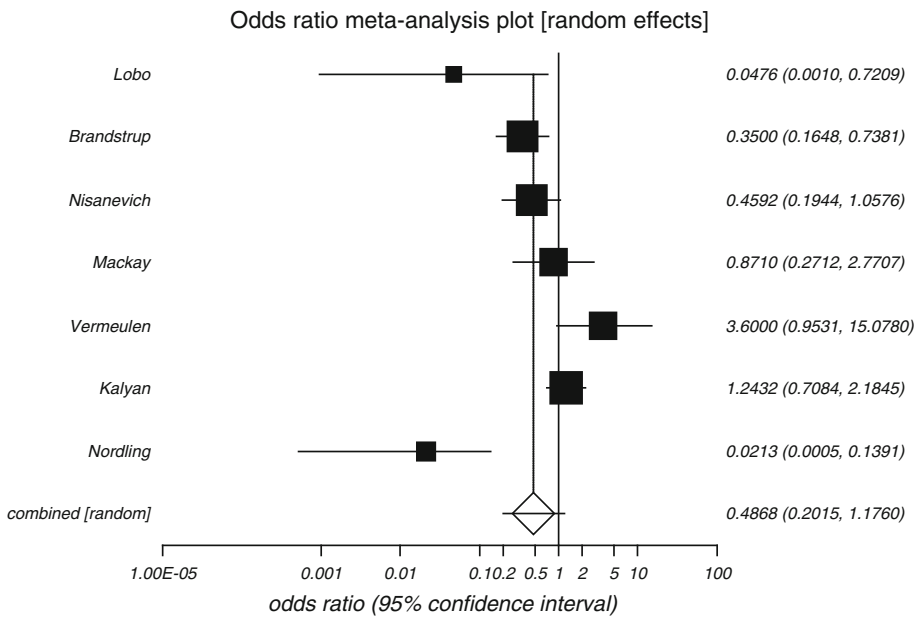


Fig. 2 Forest plot of postoperative complications amongst the seven trials included

standard group compared with three patients in the restrictive group. Perioperative fluid restriction had no significant effect on perioperative renal failure.

Data with respect to length of hospital stay was available from five of the seven trials [14, 16, 17, 26, 27]. Length of hospital stay in the sixth trial [25] was presented as median (range) and so not suitable for pooled analyses. Data regarding length of hospital stay could not be obtained for the seventh trial [15]. Two of the trials [16, 27] found no difference in length of hospital stay between the two groups, whereas two other trials [14, 17] found that fluid restriction decreased the length of hospital stay.

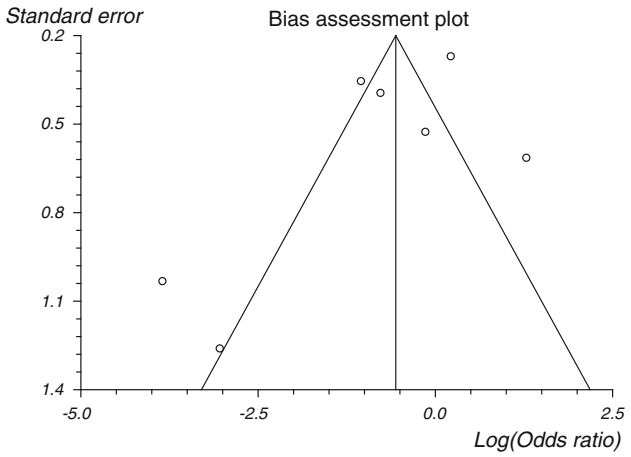


Fig. 3 Bias assessment plot of the seven trials included

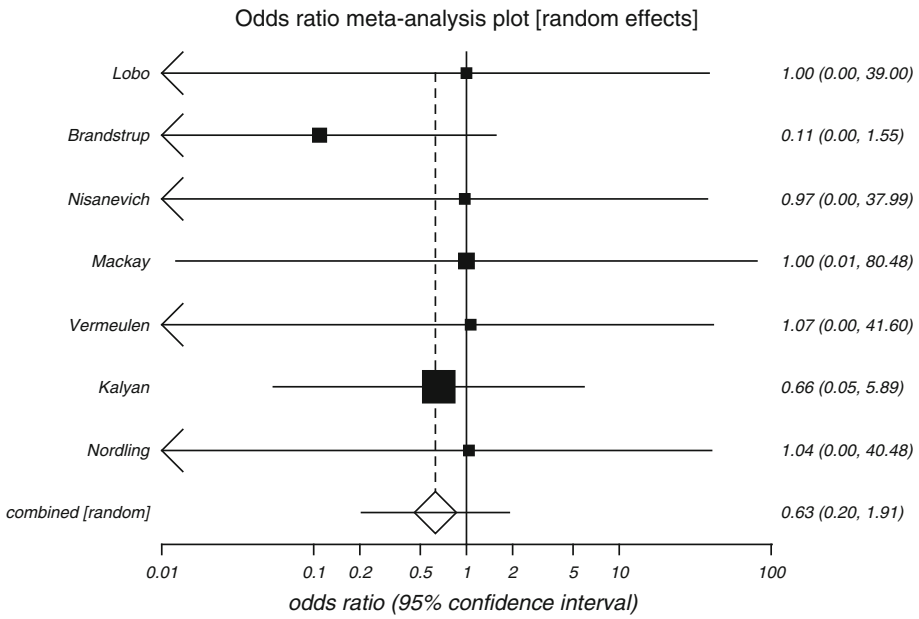
Interestingly the fifth trial, by Vermeulen et al. [26], found that fluid restriction increased length of hospital stay. Meta-analysis on data regarding the length of hospital stay yielded no statistically significant difference (pooled weighted mean difference −0.25; 95 % CI 0.72–0.21; $P = 0.29$) between the two groups. However Cochran's Q statistic showed significant heterogeneity between the trials (Cochran $Q = 23.88$, DF = 4; $P < 0.0001$). There was no significant bias ($P = 0.36$). A Forest Plot of the five trials with regard to length of hospital stay is shown in Fig. 6. Time to first flatus was only reported in four trials [14, 16, 17, 26]. Meta-analysis of the data found no statistically significant difference between the two groups (pooled weighted mean difference −0.416365; 95 % CI −0.985521–0.152791; $P = 0.1516$).

Discussion

The meta-analysis performed by Rahbari et al. [13] and published in the *British Journal of Surgery* in 2008 was the first to propose uniform definitions for the terms standard, restrictive, and supplemental fluid administration in the perioperative period. This proposal followed more than a decade of RCTs, debate and confusion regarding the impact of fluid restriction on postoperative morbidity. Thus, the model of standardized definitions was put in place for one simple reason in that, as per Rahbari et al. [13], it "dispenses with the many terms that have been used arbitrarily in the past to refer to different amounts of intravenous fluid therapy." The definitions were derived from the most renowned reference textbook available, *Miller's Anesthesia* [20], and resemble intravenous fluid therapy regimes used in common practice. The meta-analysis by Rahbari et al. [13] yielded a statistically significant reduction of postoperative morbidity in favour of fluid restriction. Restrictive fluid administration involving six patients was required to prevent one complication.

It is worth noting that a more recent meta-analysis by Varadhan et al. [28] also proposed slightly different definitions to classify trials included. For this meta-analysis, patients who received between 1.75 and 2.5 l of fluid per day were considered to be in a state of "fluid balance" and those that more or less than this to be in a state of "fluid imbalance." This meta-analysis showed that those who were in a state of fluid balance had 59 % fewer complications and a 3.4-day shorter length of hospital stay (Fig. 6) than those who were in a state of fluid imbalance.

Fig. 4 Forest plot of perioperative mortality amongst the seven trials—random effects



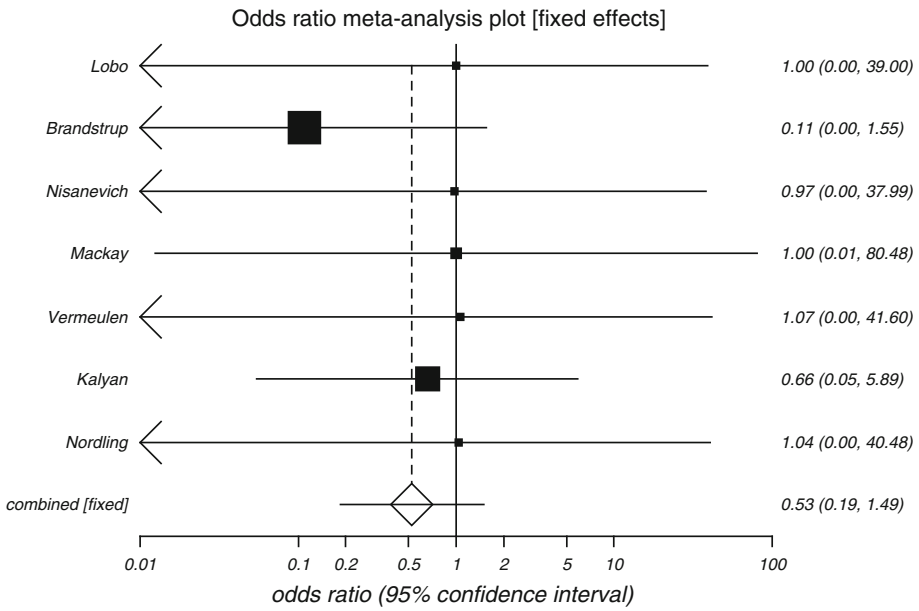


Fig. 5 Forest plot of perioperative mortality amongst the seven trials—fixed effects

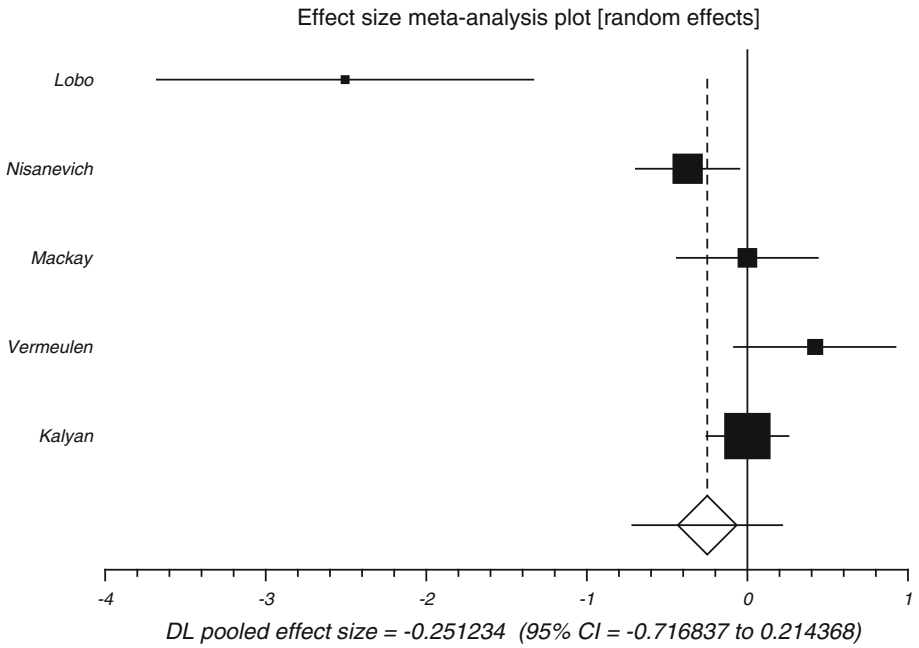


Fig. 6 Forest plot of length of hospital stay amongst the five trials

Our meta-analysis follows on from Rahbari's meta-analysis [13] and uses the same definitions to classify recent RCTs examining perioperative fluid restriction. We have added three RCTs—two published [25, 26] and one unpublished [27] but available in abstract form. Once classified all of these trials were placed in the standard vs. restrictive group. With regard to this group, our meta-analysis suggested that routine perioperative fluid restriction, as per the standardised definitions, did not result in a decrease in postoperative morbidity. There appears to be some benefit in perioperative fluid restriction with regard to mortality, but there is no difference between the two groups when one considers postoperative renal failure or length of hospital stay.

The other group included in the Rahbari et al. [13] meta-analysis that examined standard vs. supplemental fluid restriction was not included in this meta-analysis because no other studies could be found that added to this group. The original meta-analysis that included trials by Holte et al. [18] and Kabon et al. [19] showed no statistically significant difference between the two study groups.

Currently meta-analysis provides the highest level of evidence when summarising the most recent randomized, controlled trials that concerns a specific topic. Our meta-analysis

aims to provide the most up-to-date summary of randomized, controlled trials regarding perioperative fluid restriction. However, there are limitations. A prominent advantage of the meta-analysis performed by Rahbari et al. [13] was that it set a cutoff value of 50% for the proportion of patients who had colorectal surgery in each trial. As a result, they formulated procedure-specific recommendations for patients undergoing colorectal surgery. Whilst we have removed this cutoff value from our inclusion criteria, we believe our meta-analysis remains procedure specific for colorectal surgery. The vast majority of patients from two of the three new trials included underwent colorectal resection [25, 27]. The third trial added by Vermeulen et al. [26] does include patients who underwent colorectal surgery, but the majority of patients in this trial underwent upper GI surgery. However, when one considers the entire group of patients across the seven trials included, it is clear that colorectal resection accounts for the vast majority of surgeries involved.

Furthermore, the trial by Rahbari et al. [13] included two studies [14, 16] that looked at perioperative fluid restriction in the postoperative period only. The rationale behind the inclusion of the studies was explained by the fact that the intervention and control treatments (involving fluid volume and concentration of sodium) in these two studies were almost identical. Furthermore, these treatments were in accordance with postoperative fluid amounts considered restrictive and standard at the authors' institution. We have included one further trial, by Vermeulen et al. [26], which looks at perioperative fluid restriction in the postoperative period only. Notably the fluid amounts and sodium concentrations differ from the two studies mentioned previously. Stratified analyses of studies on fluid amount were not performed for timing of study intervention and this may account for the clinical heterogeneity observed in our meta-analysis.

Six [14–17, 25, 26] of the seven trials included in the meta-analysis had stringent exclusion criteria. Exclusion criteria in the different trials included a history of renal impairment, cardiac failure, diabetes mellitus, hepatic dysfunction, ascites, peritoneal metastases, poor mobility, anemia, medication affecting gastrointestinal function, coagulopathy, psychiatric illness, or inflammatory bowel disease. Thus, the trials were conducted on relatively healthy populations of surgical patients. More than 65 % of participants were ASA class I or II patients. Rigorous exclusion criteria minimized the potential confounding effect of comorbidities in these small trials. However, it also means that the results of the trials, and consequently the meta-analysis, should not be generalized to patients with multiple comorbidities, although there were a minority of ASA class III patients involved. Therefore, our data suggest that fluid restriction does not reduce the risk of complications in otherwise fit patients.

It is worth noting that RCTs regarding perioperative fluid restriction in other areas of surgery also have been produced. As mentioned previously, a study by McArdle et al. [10] examined perioperative fluid restriction in patients undergoing elective abdominal aortic aneurysm repair. Further similar studies are required so that procedure-specific recommendations for individual surgeries, such as elective AAA repair, can be made.

The ERAS program proposed that perioperative fluid restriction reduced postoperative morbidity as well as length of hospital stay. This proposal was confirmed by the meta-analysis performed by Rahbari et al. [13]. Whilst the findings from Rahbari et al.'s meta-analysis and this meta-analysis with regard to secondary endpoints, such as length of hospital stay, are similar, there is an obvious difference in the primary endpoint, postoperative morbidity. This meta-analysis includes the largest randomized, controlled trials performed to date examining the role of perioperative fluid restriction. The addition of these trials provides the most recent and, more importantly, the most substantial evidence that fluid restriction does not favorably affect outcome in patients undergoing elective colonic resection. It is possible that fluid restriction underestimates loss to the so-called "third space" and that such a loss may need to be replaced more aggressively in the perioperative period. Furthermore, increased cardiac complications as well as an increased need for vasopressor support amongst fluid restricted patients may account for the results of this meta-analysis.

In conclusion, meta-analysis of the currently available data suggests that perioperative fluid restriction in fit patients does not reduce the risk of postoperative complications. The effects on death and renal failure require further investigation with larger studies. As studies regarding the issue of fluid restriction continue to be performed, it is necessary that uniform definitions, as proposed by Rahbari et al. [13], be applied to ensure continuity when these studies are compared and analyzed.

Acknowledgments This article received no funding

Disclosures The authors declare that there are no conflicts of interest.

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