Fluid Management During Kidney Transplantation: A Consensus Statement of the Committee on Transplant Anesthesia of the American Society of Anesthesiologists

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Background. Intraoperative fluid management may affect the outcome after kidney transplantation. However, the amount and type of fluid administered, and monitoring techniques vary greatly between institutions and there are limited prospective randomized trials and meta-analyses to guide fluid management in kidney transplant recipients. **Methods.** Members of the American Society of Anesthesiologists (ASA) committee on transplantation reviewed the current literature on the amount and type of fluids (albumin, starches, 0.9% saline, and balanced crystalloid solutions) administered and the different monitors used to assess fluid status, resulting in this consensus statement with recommendations based on the best available evidence. **Results.** Review of the current literature suggests that starch solutions are associated with increased risk of renal injury in randomized trials and should be avoided in kidney donors and recipients. There is no evidence supporting the routine use of albumin solutions in kidney transplants. Balanced crystalloid solutions such as Lactated Ringer are associated with less acidosis and may lead to less hyperkalemia than 0.9% saline solutions. Central venous pressure is only weakly supported as a tool to assess fluid status. **Conclusions.** These recommendations may be useful to anesthesiologists making fluid management decisions during kidney transplantation and facilitate future research on this topic.

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INTRODUCTION

The number of kidney transplants (KTs) in the United States has steadily increased mostly due to an increase of deceased donor transplants, with 23 401 KTs performed in 2019.[1] Outcomes have steadily improved with the incidence of graft failure (6 mo, all-cause) decreasing to 4.8% in 2015 from 7.5% in 2005.[2] Similar improvements in outcome have been observed in Europe.[3]

Intraoperative anesthetic management of kidney transplant patients is a crucial component of overall patient and graft outcome. Although evidence-based standardization of practice improves outcome, there are few guidelines that address intraoperative management of kidney

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transplant patients. Fluid management during the intraoperative period affects hemodynamics and perfusion to the graft immediately following reperfusion and may influence the risk of perioperative cardiac events for this population with preexisting comorbidity. A large variety of technologies to assess for hemodynamic and volume status and fluid responsiveness are used in during KTs often with little evidence to support their utility.

In the absence of sufficient specific guidance in the literature, this consensus statement summarizes the current evidence of different aspects of fluid administration and monitoring during kidney transplantation and provides recommendations based on this evidence. We examined the amount of fluid administration, methods to assess volume status and fluid responsiveness, choice of crystalloid, and role of colloid, specifically considering starch-based options.

MATERIALS AND METHODS

The American Society of Anesthesiologists (ASA) leadership appoints members to the ASA Committee on Transplant Anesthesia with recognized clinical, research, and professional expertise in solid organ transplantation. At the time of writing, the committee was a diverse 18-member committee with academic and private practice representation, charged with providing advice and guidance for issues related to transplant anesthesiology to the medical community and ASA members. This document was developed as part of that mission. While publication of this work product by the ASA Committee on Transplant Anesthesia was approved by ASA leaders with committee oversight, the content has not undergone approval or endorsement by the ASA's Board of Directors or House of Delegates. The latter is a time-consuming process, and therefore, this committee consensus does not represent an ASA Policy, Statement, or Guideline.

Each topic was reviewed by a working group consisting of 2–4 volunteer committee members. Results of each working group was then reviewed, collated, and approved by all authors of this document. Areas where there was insufficient evidence specific to kidney transplantation were noted and summative comments were made based on findings for general surgical or critically ill patients.

Electronic databases (Cochrane Library, including Cochrane Database of Systematic Reviews and Cochrane Central Register of Controlled Trials) and National Library of Medicine (Pubmed.gov) were searched for English-language MesH combinations of adult, renal (kidney) transplant(ation), fluids, crystalloids, colloids, starch, albumin, CVP, monitoring from the earliest detected reports (1987) to February 29, 2020. Reference lists of included manuscripts were reviewed for additional relevant sources and data. We did not include case reports as they provide the lowest level of evidence.

Many of the studies used surrogate markers instead of or in addition to objective outcomes of mortality or graft failure. Graft dysfunction is closely associated with worsened long-term graft survival,[4] and we therefore considered this an important surrogate endpoint. Other outcomes such as change of serum creatinine or urine output may be less relevant to long-term outcome.

Evidence levels and recommendations are based on the Grading of Recommendations Assessment, Development and Evaluation (GRADE) working group[5] (Table S1, **SDC, http://links.lww.com/TP/C73**). The existing evidence was ranked based on the present literature into high (A), moderate (B), low (C), and very low (D) quality. A large number of randomized trials with the same outcome or systematic reviews were in general considered high quality, whereas observational studies, especially retrospective observational studies were considered low or very low quality. The strength of a recommendation (strong [1] and weak [2] in favor and strong [4] and weak [3] against an intervention) was based on the quality of the existing evidence. Strong recommendations were made when there was consistent agreement and the benefits clearly outweighed the risks (or the risks outweigh any potential benefit when recommending against an intervention). Weak recommendations were assigned when evidence was lower quality and the risk–benefit balance would favor individualized (and patient-centered) decisions.

RESULTS

Amount of Fluid Administration and Monitoring of Volume Status

Amount of Fluid Administration and CVP

Fluid administration during kidney transplantation is thought to affect the graft outcome. Traditionally, more fluid than in nontransplant surgery was considered beneficial to maximize cardiac output and renal perfusion. Studies through the 1990s advocated for maximum volume infusion during kidney transplantation to the point of no response.[6-8] These studies led to the long-held belief that large amounts of fluid administration are beneficial in kidney transplantation. In these studies, central venous pressure (CVP) was frequently used to determine adequate intraoperative fluid resuscitation, although in non–kidney transplant populations, static CVP measurements do not correlate well with fluid status or volume-responsiveness.[9-12] Studies using CVP to guide fluid management in kidney transplantation have been inconsistent with different thresholds and times of measurement.[13,14]

Two retrospective studies found that emergence CVP <8 mm Hg (155 patients, donation after death by neurological criteria [DDNC], odds ratio [OR] 3.53 [1.63–7.63])[15] and lowest intraoperative CVP <6 mm Hg (177 patients, donation after circulatory death, OR 3.1 [1.4–7.1], $P = 0.007$)[16] were significant predictors of delayed graft function or primary nonfunction, respectively. More recently though a large retrospective study of 1966 patients found that mean CVP ≥11 mm Hg was predictive of chronic graft dysfunction ($P < 0.001$) and volume administration >2500 mL was an independent risk factor associated with graft failure.[17] In a small, prospective study in living-donor kidney transplant (LDKT) recipients (40 patients), aggressive infusion of fluid to elevate the target CVP to 15 mm Hg *during graft ischemia* from a baseline of 5 mm Hg was associated with better graft function, fewer vasopressors, diuretics, and postoperative tissue edema compared to a constant infusion rate group ($P < 0.03$), even though final fluid totals were similar.[18] In a retrospective study of LDKT recipients (100 patients), the authors suggest that a CVP at reperfusion of 12 mm Hg was a factor associated with good early graft function, although the fall in creatinine trends was not

significant.[19] Finally, 3 retrospective studies (77 deceased donor transplants recipients,[20] 84 out of a cohort of 290 with a CVP measure LDKT,[21] 149 patients mixed deceased and LDKT22) found no effect of specific CVP measures on graft outcome. In aggregate, there were no robust data indicating harm with CVP use as a guide if the mean CVP was maintained >5–8 mm Hg without overt fluid overload (CVP > 11 mm Hg), with higher temporary values at the time of reperfusion.

Monitoring of Volume Status: Mean Arterial Pressure and Other Modalities

Mean arterial pressure (MAP) has been advocated as a measure for resuscitation during kidney transplantation but is not a reflection solely of fluid management. Retrospective studies referenced above for CVP findings determined different targets and thresholds: average systolic BP < 110 mm Hg was associated with more primary nonfunction (177 patients, donation after circulatory death grafts, OR 2.6 [1.1–5.9], $P = 0.03$)[16] and mean MAP >93 mm Hg (1966 patients) was associated with better graft outcomes ($P = 0.04$).[17] Although the authors of another retrospective study proposed maintaining MAP > 100 mm Hg (95 LDKT patients, addition of dopamine as needed), these trends were not significant.[19] Mean perioperative MAP <70 mm Hg (149 patients with deceased and living-donor donation) was associated with delayed graft function ($P = 0.005$).[22]

Other modalities for measuring intravascular volume and adequacy of fluid resuscitation include stroke volume or pulse pressure variation, esophageal Doppler, and plethysmography pulse variability. Large prospective trials with these techniques in kidney transplantation have yet to be performed.

In a retrospective report, stroke volume variation of 6% was an equivalent guide to volume management compared to a CVP of 8 mm Hg (635 recipients).[23] In a small prospective observational study (31 recipients of LDKT), stroke volume variation was a better predictor of preload (measured by right ventricular end diastolic volume, $r^2 = 0.48$) compared to pressure-based indices (CVP, $r^2 = 0.19$; pulmonary artery diastolic pressure, $r^2 = 0.33$).[24] A prospective, nonrandomized report of esophageal Doppler monitoring for kidney transplantation (110 patients, LDKT) found that graft function was similar compared to patients with CVP monitoring (104 recipients), although transesophageal Doppler monitored patients received less fluid and had fewer fluid overload-related complications.[25]

In a prospective, observational study of deceased donor transplant recipients (40 recipients of deceased donor grafts), the dynamic change in amplitude of the pulse oximeter during a respiratory cycle (Pleth variability index—PVi^R) correlated poorly with CVP values and a higher value (>9%, $P = 0.02$) before reperfusion was the only predictor of delayed immediate graft function in multivariate analysis.[26]

A recent review of fluid assessment in kidney transplant echoes the overall low quality of evidence and need for robust, prospective evaluation, including dynamic parameters which have physiologic appeal in patients with end-stage renal disease. It further emphasizes that the ideal amount of fluid for each individual patient is difficult to assess and in the absence of better prospective trials, unrestrained fluid administration to the level of fluid unresponsiveness may be harmful.[27]

Relevant studies are summarized in Tables S2A and B, **SDC**, http://links.lww.com/TP/C73.

Conclusion

- There is low-quality evidence for larger volume fluid administration targeting a higher CVP during kidney transplantation (GRADE low-quality evidence, weak recommendation).
- Use of CVP as a guide to fluid administration is weakly supported (GRADE low-quality evidence, weak recommendation).
- Accelerated fluid administration during graft ischemia rather than constant infusion may lead to improved graft function (GRADE, moderate-quality evidence, weak recommendation).
- Although not specific to fluid volume, avoidance of intraoperative hypotension with different thresholds supports improved graft function (GRADE moderate-quality evidence, weak recommendation).
- Reports of stroke volume variation, esophageal Doppler and PViR to guide fluid administration are promising but limited (GRADE low-quality evidence, weak recommendation).

Colloids and Type of Crystalloid for Fluid Administration

The ideal type and composition of intraoperative fluid to support allograft function is controversial. Early bias toward use of colloid has been tempered by recent data indicating no significant difference in the outcome compared with crystalloid solutions in most reports in kidney transplant recipients. However, differences among crystalloid solutions are pertinent and may contribute to outcome. This section also addresses albumin as a commonly used colloid with starch molecules reviewed separately.

Albumin

Albumin's theoretical advantages result in continued advocacy for use in renal transplant recipients, including increased plasma oncotic pressure, antioxidant properties, enhanced protein transport, anti-inflammatory properties, and buffering capacity.[28] This contrasts with rapid equilibrium of crystalloid solutions within the extravascular space, with increased risk for pulmonary and interstitial edema, and decreased tissue perfusion.[29] Potential risks associated with albumin include increased cost, availability, potential disease transmission, and immunogenicity. Albumin use in nonrenal transplant patients has not been associated with improved outcomes.[30-32]

In kidney transplantation, early studies supported albumin use. In a retrospective analysis (438 deceased donor recipients), infusion of albumin at 1.2–1.6 g/kg weight improved immediate allograft function and decreased delayed graft failure and primary nonfunction.[33] The authors hypothesized that albumin effectively expanded intravascular volume, reduced hypoxic injury, and preserved renal tissue.[33,34]

Later studies indicate no difference in the outcome with albumin. In a prospective randomized trial of 20% human albumin + 0.9% saline versus 0.9 % saline alone in LDKT recipients, there were no differences in the graft outcome.[35] A similar study (80 LDKT recipients), also using 20% albumin, also found no differences in graft function, although no patient had delayed graft function requiring dialysis.[36]

A recent study evaluated kidneys from deceased donors (after neurological death) who received colloid (primarily gelatin [68%], less frequently albumin [17%], and starch [17%]) with crystalloid compared to crystalloid alone (data for 143/181 transplanted kidneys from 100 donors). In the delayed graft function group (40), more patients received crystalloid alone ($P = 0.005$) and this remained an independent risk factor for delayed graft function in multivariate analysis (OR 2.95, $P = 0.034$). More patients with preserved early graft function (103) had received gelatin ($P = 0.041$) than albumin ($P = 0.997$) or starch ($P = 0.716$).[37] Relevant studies are summarized in Table S3, **SDC,** http://links.lww.com/TP/C73.

Conclusion

- Recent available evidence suggests that there is no advantage of albumin over crystalloid alone in kidney transplantation and use should be selective rather than per protocol (GRADE moderate-quality evidence, low-level recommendation).

Type of Crystalloid

Traditionally, 0.9% saline was considered the fluid of choice during kidney transplantation. In a 2002 survey, 83% of transplant centers used 0.9% saline in over 90% of KTs. This preference was based on the belief that potassium-containing solutions could potentially aggravate hyperkalemia.[38]

Non–kidney Transplant Evidence

Studies in non–kidney transplant general surgical, vascular and gynecological patients show that patients who received 0.9% saline developed hyperchloremic metabolic acidosis compared to balanced electrolyte solutions.[39-41] These findings are anticipated with calculation of the strong ion difference, SID = Na + K + Mg + Ca – Cl – lactate,[42] when a supraphysiological concentration of chloride is administered.[43] Hyperchloremic metabolic acidosis leads to shifting of potassium outside the cell, potentially causing hyperkalemia.[44]

A chochrane meta-analysis that included 13 trials with a total of 706 participants comparing perioperative use of buffered versus nonbuffered solution found no difference in mortality but increased metabolic disturbances with use of nonbuffered solutions (most commonly, 0.9% saline).[45] Recent studies in patients with sepsis[46] and critical illness[47] found increased mortality and acute kidney injury with 0.9% saline compared to balanced electrolyte solutions.

Evidence in Kidney Transplantation

In kidney transplantation, substantial randomized controlled data exist for the effect of different crystalloid solutions on acid–base balance, hyperkalemia, hemodynamic stability, need for postoperative renal replacement therapy, and graft survival.[48-59]

In a prospective randomized study (51 deceased donor KTs), there were no differences in overall potassium levels between 0.9% saline and Lactated Ringers (LR) groups. However, 19% patients in the 0.9% saline group versus none in the LR group had potassium concentrations >6 mEq/L requiring treatment for hyperkalemia ($P = 0.05$). Eight (31%) patients in the 0.9% saline group versus zero (0%) patients in the LR group were treated for metabolic acidosis ($P = 0.004$).[48] The study was terminated early because of safety concerns with higher rate of hyperkalemia in the 0.9% saline group.

A similar randomized study found that potassium concentrations in patients undergoing LDKT receiving LR decreased by 0.5 mEq/L during surgery compared to an increase by 0.5 mEq/L in patients receiving 0.9% saline ($P < 0.001$). Two patients in the LR group developed graft thrombosis, a finding that was not replicated in any other study.[49] In a 3-way randomized study (90 patients undergoing LDKT, 0.9% saline, LR or Plasma-Lyte), there was no difference in potassium levels between groups but patients receiving 0.9% saline had greater acidosis ($P < 0.05$). Patients receiving LR had higher arterial lactate levels at the end of surgery compared to 0.9% saline or Plasma-Lyte ($P < 0.05$).[50] In a prospective study only reported as a letter to the editor (74 patients undergoing LDKT), those receiving LR had lower potassium concentrations ($P < 0.05$) and higher pH ($P < 0.05$) than the 0.9% saline group.[51] In a small prospective study (60 patients undergoing LDKT), those receiving 0.9% saline had lower pH without significant change in potassium concentrations compared to Plasma-Lyte.[52] In a prospective study (150 patients undergoing deceased donor transplants), those receiving 0.9% saline had greater base deficit ($P < 0.001$) and catecholamine requirement ($P = 0.03$) compared to a balanced crystalloid solution group.[53] The increased vasopressor requirement was confirmed in subanalysis.[54]

These 6 studies comprised a Cochrane meta-analysis which concluded no aggregate difference in graft loss or potassium concentrations, but a higher pH in the balanced electrolyte solution group compared to 0.9% saline (mean difference 0.7, confidence interval [CI] 0.05-0.09).[55] Subsequent to the meta-analysis, a prospective study (49 patients) found higher potassium concentrations ($P = 0.009$), more frequent treatment of hyperkalemia ($P = 0.004$), and greater acidosis ($P = 0.05$) in the 0.9% saline group compared to Plasma-Lyte.[56] In a retrospective observational study with unequal groups (97 patients), those receiving 0.9% saline had increased potassium concentrations ($P = 0.002$), acidosis ($P < 0.045$) and postoperative renal replacement therapy than those receiving Plasma-Lyte.[57] Another retrospective, observational study of 359 patients undergoing deceased donor KTs receiving 0.9% saline per institutional protocol found no effect on graft function, despite 11% developing hyperchloremic acidosis.[58] In a large retrospective study of LDKT, increasing proportion of intraoperative fluid (20%) as 0.9% saline lead to increase in potassium concentrations at 24 h ($P = 0.026$).[59]

A large randomized pragmatic study of 0.9% saline versus Plasma-Lyte in deceased donor kidney transplantation (Better Evidence for Selecting Transplant fluids) trial is currently underway (Clinical trials identifier NCT03829488) and may add conclusive outcome evidence for future practice. In agreement with these findings, a recent review supports aggregate findings favoring balanced crystalloid solutions over 0.9% saline.[60]

Conclusion

Balanced crystalloid solutions are associated with a better metabolic profile and equal, if not lower potassium levels compared to 0.9 % saline for perioperative management of KTs and are therefore preferred (GRADE moderate-quality of evidence, strong recommendation).

Use of Starches in Kidney Transplantation

In non–kidney transplant populations, use of hydroxyethyl starch (HES) solutions of variable molecular weight (MW), molar substitution and C_2/C_6 substitution ratios has been variably associated with adverse effects in critically ill and septic patients, including renal and hepatic dysfunction and coagulopathy.[61,62]

HES and Renal Function

Multiple prospective studies and meta-analyses in critically ill patients describe renal complications (renal failure, renal replacement therapy, mortality) as more frequent adverse events associated with HES administration.[63-67] Although these have not been uniformly reproduced in the perioperative setting, marketing authorization of starch solutions, particularly in critically ill patients with sepsis, has been restricted.

Although not well understood, proposed mechanisms of injury may be relevant to a kidney transplant cohort. There is evidence of direct uptake of HES by renal tissue leading to osmotic nephrosis, cytoplasmic vacuolization, tubular swelling and obstruction, although tubular vacuolization is not HES-specific.[68]

HES in Kidney Donors

Early small studies identified graft loss in transplanted deceased donor kidneys when donors were administered HES.[69,70] Subsequent studies in deceased donors (no available studies in living donors) have been reported. In a retrospective report of 262 DDNC donors, administration of >1500 mL HES was 1 risk factor for delayed graft function for >6 d.[71] In a large retrospective study (986 kidneys from 529 DDNC donors), 42% of donors received HES which was associated with increased incidence of delayed graft function ($P < 0.001$) and was an independent predictor of delayed function (OR 1.41 [1.02–1.95]).[72] As anticipated from pharmacokinetic principles, MW starch with lower molar substitution (HES 130/0.4) was less nephrotoxic compared to higher molar substitution (HES 200/0.6) in a retrospective study of 115 transplanted kidneys from 64 DDNC donors. Serum creatinine levels at 1 mo ($P < 0.005$) and 1 y ($P = 0.05$) were better in the low starch MW recipients.[73] In a letter to the editor, the authors confirmed sustained lower creatinine up to 7 y in the low MW starch group.[74]

HES in Kidney Transplant Recipients

There are less data for use of HES solutions in kidney transplant recipients. In a small prospective study of 80 m LDKT recipients with use of low MW HES compared to a gelatin-based solution, there was no difference in short-term outcomes, with marginally quicker recovery of blood urea nitrogen in the HES group.[75] In another retrospective study of low MW HES (113 subjects deceased and LDKT), there were no differences in short-term graft outcome compared to balanced crystalloid solutions.[76]

Conclusion

- Based on the current literature, kidney donor HES exposure is associated with increased risk of delayed graft function (GRADE low-quality evidence, strong recommendation against use).
- Low MW HES administration to recipients has not demonstrated short-term adverse effects (GRADE low-quality of evidence, weak recommendation of support). However, given small sample sizes, limitations in study design and current marketing restrictions against HES use in patients with preexisting renal disease, it appears prudent to avoid use of HES in kidney transplant recipients (**Tables S4A and B, SDC,** http://links.lww.com/TP/C73).

Fluid Management in Living-donor Kidney Transplantation

Incidence of delayed graft function and graft failure is lower in recipients of living donors kidneys because of shorter graft cold ischemia time[77] and a lower burden of pretransplant dialysis and cardiac morbidity.[78]

Because of limited aggregate data, we were unable to directly compare evidence for fluid management strategies for living versus deceased donor kidney recipients, although there may be a lower incidence of recipient comorbidity with shorter duration of dialysis. Aggressive fluid loading may be less concerning in a cohort with a lower incidence of pulmonary hypertension and cardiovascular disease. In the absence of comparative data, the approach to fluid management in living-donor kidney transplantation should follow similar principles as outlined earlier.

DISCUSSION

In the absence of robust, high-quality data to guide choices for intraoperative fluid management and monitoring, members of the Committee on Transplant Anesthesia of the ASA reviewed available data to develop a consensus approach to assist anesthesiologists who care for renal transplant recipients. Inherent limitations of retrospective or small prospective studies with variable interventions and measured outcomes do not allow for stronger conclusions in the form of a guideline. In addition, the risk of publication bias given the limited aggregate data is acknowledged.

Based on our review of the data, we conclude that:

- Large volume administration to the level of volume unresponsiveness is not recommended. This is contrary to early studies and emphasizes that likely an individualized approach may be best to balance fluid administration to maintain renal perfusion and possible complications of fluid overload. The best modality to assess fluid status, however, is also controversial
- There is only weak evidence to support use of static CVP to assess fluid status in kidney transplantation: CVP has been traditionally used despite good evidence (from nonkidney transplant) literature that there is little if any correlation between fluid status and responsiveness and CVP. CVP has been used as an endpoint for fluid administration in most, especially older studies of fluid administration for KTs.
- There are insufficient data for dynamic monitors of fluid response (stroke volume variation, esophageal doppler, and pleth variability) to make more than a weak recommendation. Many of these monitors may be better suited than CVP to assess fluid status in non–kidney transplant studies, but there is too little evidence in the kidney transplant literature to support 1 method over another.
- There is no apparent advantage of albumin over crystalloid use. There is no good evidence supporting the routine use of albumin despite some smaller positive studies.

TABLE 1.
Summary of conclusions

Recommendation	Background	Center for Evidence-Based Medicine		GRADE system	
		Level of evidence	Grade of recommendation	Level of evidence	Grade of recommendation
General large volume fluid administration or "high CVP" is not recommended	Not sufficient and only weak evidence to support generally large volume fluid administration or aim for high CVP (level III–IV evidence)	3–4	C	B	2
There is probably no benefit for routine use of albumin over crystalloids	KT: No benefit in 2 RCTs (level I B) Non-KT: No benefit in large, multicenter RCTs (level I A)	1B–1A	B	A	4
Balanced crystalloid solution are at least equal if not better than 0.9% saline	KT: Balanced crystalloid solutions are associated with a better metabolic profile and equal if not lower potassium levels compared to 0.9% saline	1A	A	A	1
Use of starches is not recommended	KT: Worse renal outcomes with starches (II B) Non-KT: Strong evidence of worse outcomes in multiple RCTs (I A)	2B–1A	A	A	4
Central venous pressure is not a useful endpoint for fluid administration	Non-KT: Systematic review of 24 studies assessing CVP as a monitor for volume status found "a very poor relationship between CVP and blood volume" (IA)	1A	A	A	4

CVP, central venous pressure; GRADE, Grading of Recommendations Assessment, Development and Evaluation; KT, kidney transplant.

- Balanced crystalloid solutions have a better metabolic profile than 0.9% saline and are preferred. Many fear that potassium-containing valanced solution may worsen hyperkalemia; however, this fear is unfounded and there is very good evidence that 0.9% saline causes more metabolic disarray. "Normal saline" is not normal.
- Starch-based colloids should be avoided in kidney donors and although data are limited for low MW compounds, prudence given reported renal effects of HES suggests that HES be avoided in kidney recipients. Most studies in non–kidney transplant patients have demonstrated nephrotoxic effects of starches and there is very little if any benefit with the use of starches to outweigh the potential for harming the graft even with low MW starches.

These recommendations are summarized in Table 1. In conclusion, we have reviewed the inhomogeneous, potentially biased data for fluid management strategies for patients undergoing renal transplantation and have synthesized the quality of evidence and strength of recommendation to assist clinical practice. Robust prospective evaluations are required to further direct management.

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