# CHAPTER 2
# Carrying out the transplant

## CHAPTER 2.1 Anaesthesiological and perioperative management

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### Introduction

Anaesthesia care not only ensures insensitivity and unawareness during surgery, but, even importantly, also involves the monitoring and support of vital organ functions. Reduced physiological reserve has significant implications for anaesthetic management. As the systemic effects of end-stage renal disease impair the function of multiple organs, a comprehensive preoperative assessment – focusing on evaluation of metabolic changes and assessment of end-organ damage – is crucial for determining perioperative risks.[1] A thorough preoperative work-up, including the optimisation of fluid status, electrolyte balance, lung function and cardiovascular status, can help reduce perioperative complications. Table 1 outlines the pathophysiological changes in each organ system and the recommended preoperative tests and preparations.

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**Table 1** Preoperative assessment in pediatric kidney transplantation: tests and considerations

| Organ system | Encountered problems | Preoperative Tests | Preoperative preparation |
|---|---|---|---|
| Pulmonary function | Pulmonary edema<br>Lung fibrosis<br>Obstructive and/or restrictive lung function | Lung function tests | Perioperative bronchodilator therapy when indicated |
| Cardiac function | Hypertension<br>Left ventricular hypertrophy, diastolic dysfunction, structural lesions | Blood pressure<br>Cardiac ultrasound | Anti-hypertensive medication usually stopped on day before surgery, to prevent intra-operative hypotension |
| Neurologic Development | Cognitive impairment<br>Uremic neurotoxicity | | |
| Electrolytes | Hyperphosphatemia<br>Hypocalcemia<br>Hypomagnesemia<br>Hyperkalemia<br>Acidemia | Serum electrolyte analysis<br>Blood gas analysis | Diet, Cation exchangers, Phosphate binders, Calcium, Magnesium supplements; all stopped on day of surgery<br>Sodium bicarbonate; continued until surgery |

Table 1. *(continued)*

| Organ system | Encountered problems | Preoperative Tests | Preoperative preparation |
|---|---|---|---|
| Fluids and feeding | Residual diuresis or anuria<br>Fluid restriction<br>Malnutrition, feeding difficulties | Glucose (in)tolerance | Gastric tube for feeding and medication<br>Fluid restriction<br>Glucose containing fluids when at risk for hypoglycemia |
| General evaluation | Urologic impairment, risk of postrenal failure<br>Vascular patency<br>Immunologic status | Full urology assessment<br>Imaging of abdominal organs and vasculature<br>Serology for past infections | Voiding training<br>Immunization |
| Hormones | Reduced erythropoietin<br>Hyperparathyroidism<br>Renal osteodystrophy; brittle teeth and bones<br>Growth hormone deficiency | Anemia, full blood count<br>Serum calcium and phosphate | Erythropoietin therapy<br>Growth hormone therapy in growth retardation<br>Dental care |
| Nephrological disease | Nephrotic Syndrome<br>Glomerulonephritis<br>Renal agenesis or dysplasia | Fluid and protein status<br>Hypotension<br>Hypertension | Nephrectomy prior to transplantation in active nephrotic syndrome<br>Adequate fluid status and electrolyte control |
| Urologic disease | Obstructive uropathies | Anuria in utero: lung hypoplasia<br>Congenital cardiac disease | Urologic work up<br>Cardiologic work up |

## Anaesthesia during Kidney Transplantation

Kidney transplantation requires general anaesthesia with endotracheal intubation and controlled mechanical ventilation. It is important to recognise that children with chronic kidney disease (CKD) often have impaired growth and may have brittle bones and teeth. Tube and catheter sizes should be adjusted accordingly. In patients with pre-existing pulmonary restrictions, mechanical ventilation should be tailored according to lung-protective strategies.[2]

Monitoring and supporting circulation is essential to ensure optimal (re)perfusion of the donor kidney and to minimise ischaemia-reperfusion injury. Significant haemodynamic changes are expected, especially in young children receiving a relatively large (adult) donor kidney.[3] In cases of post-mortem donation and prolonged cold ischaemia times, haemodynamic instability may be pronounced due to the vasodilatory effects of cytokines released into the circulation after reperfusion.[4]

A relatively high blood pressure is recommended after reperfusion, as the ischaemic period may lead to cellular oedema and a compromised vasculature in the donor kidney.[5] Due to the vasodilatory effects of anaesthetics and cytokines, temporary use of vasopressors, such as norepinephrine, may be necessary. However, it is important to ensure optimal fluid status when administering vasopressors. To avoid both fluid overload and hypovolemia, fluid administration should be guided by a monitor capable of detecting changes in flow or stroke volume following fluid loading. Isotonic, balanced crystalloid fluids are recommended as the fluid of first choice.[4, 6]

In patients with systolic dysfunction, inotropes may be required to support cardiac output. However, diastolic dysfunction is more common and requires careful monitoring to prevent fluid overload.[7] Therefore, advanced haemodynamic monitoring is recommended in children who are expected to experience haemodynamic instability during transplantation. This monitoring should be able to track changes in blood flow, as well as the effects of fluid administration, vasopressors, and inotropes on flow or stroke volume.[1] Appendix 1 provides an algorithm that summarises the above recommendations.

Table 2 summarises the potential organ impairments that may arise during anaesthesia and provides recommendations for monitoring these complications.

**Table 2** Anaesthesia care during paediatric kidney transplantation: checklist of considerations and advise (continues on the next page)

| | **Considerations & Advice** | **Monitoring** |
|---|---|---|
| Airway | Adjust tube and catheter sizes to patient's size, not to age | |
| Breathing | Lung protective ventilation (TV 6–8 ml/kg, PEEP 5–10 cm $H_2O$); A reduced oxygen reserve might be present | Airway pressures<br>Pulse oximetry<br>Capnometry |
| Circulation | Reduced vascular compliance<br>Left ventricle hypertrophy<br>Diastolic dysfunction<br>Anesthesia induced hypotension<br>Set target arterial blood pressure, add vasopressors if fluid loading is insufficient | ECG<br>(Intra-arterial) blood pressure<br>Cardiac output and/or fluid responsiveness |
| Anesthesia & Analgesia | No clear advantages of one anesthetic over another; choose best cardiovascular profile<br>No succinylcholine in hyperkalemia<br>Preference for hepatic clearance or inactive metabolites if delayed graft function is anticipated | Neuromuscular monitoring |

Table 2. *(continued)*

| | **Considerations & Advice** | **Monitoring** |
|---|---|---|
| Electrolytes | Consider sodium bicarbonate solution as part of fluid therapy<br>Treat hyperkalemia with calcium gluconate and/or glucose/insulin<br>Prevent hyponatremia and brisk osmolality shifts | Regular serum electrolyte and blood gas analysis |
| Fluids | Reduce basic fluids in patient with anuria<br>Beware of hypoglycemia when patient is on continuous feeding<br>Fluid loading before graft reperfusion with isotonic solutions and mannitol<br>Withhold fluid loading when signs of fluid overload appear: increased central venous pressure or pulmonary edema<br>Compensate fluid losses; beware of poly-uric phase in first hours after transplantation | Regular glucose control<br>Fluid responsiveness<br>Central venous pressure<br>Urine output after reperfusion |
| Blood | Anemia; lower threshold to transfusion | Full blood count |
| Medication | Antibiotic prophylaxis; dose adjusted to body surface area<br>Immune suppressive medication<br>Thrombosis prophylaxis when indicated<br>No rationale for diuretics or dopamine<br>Mannitol; dose adjusted to body surface area | |

## Postoperative care

Close monitoring of respiratory function, blood pressure, diuresis, electrolytes, fluid balance, and pain management is essential in the postoperative period. The postoperative care unit should be equipped with the appropriate facilities and expertise for this level of care, often being an intensive care unit (ICU).

The decision to keep the child intubated and on mechanical ventilation depends on the child's age and the haemodynamic and metabolic changes that occur during anaesthesia and surgery. Young children receiving a relatively large donor kidney often remain sedated and on ventilatory support in the ICU until their haemodynamic and metabolic status has stabilised. If possible, the aim is to withdraw sedation and ventilatory support within 24 hours. This approach minimises the risk of circulatory compromise due to positive pressure ventilation and the vasodilatory effects of sedatives.

### Continuous monitoring:

- Administration of fluids and vasopressors guided by an advanced haemodynamic monitor, together with continuous assessment of diuresis.
- Frequent checks of blood gas analysis, glucose and electrolytes.

Additional monitoring may be required if diuresis decreases despite optimal haemodynamic support. For example, Doppler ultrasound may be used to assess vascular patency or to rule out post-renal obstruction.

### Postoperative pain management:

Pain can be managed with paracetamol and opioids. Non-steroidal drugs are not recommended as they compromise renal capillary blood flow. Opioids are usually given intravenously, either continuously or on demand, depending on the child's age and cooperation. In cases of delayed graft function, reduced opioid clearance may increase the risk of apnoea. Therefore, careful monitoring of consciousness and respiration is recommended in all children receiving intravenous opioids. Epidural anaesthesia is less commonly used for postoperative pain management because of its potential effects on blood pressure and the increased risk of bleeding in patients with kidney failure.

## References


1 Voet M, Cornelissen EAM, van der Jagt MFP, Lemson J, Malagon I. Perioperative anesthesia care for the pediatric patient undergoing a kidney transplantation: An educational review. Paediatric anaesthesia. 2021;31(11):1150–60.

2 Kneyber MC. Intraoperative mechanical ventilation for the pediatric patient. Best Pract Res Clin Anaesthesiol. 2015;29(3):371–9.

3 Voet M, Nusmeier A, Lerou J, Luijten J, Cornelissen M, Lemson J. Cardiac output-guided hemodynamic therapy for adult living donor kidney transplantation in children under 20 kg: A pilot study. Paediatric anaesthesia. 2019;29(9):950–8.

4 Weiss SL, Peters MJ, Alhazzani W, Agus MSD, Flori HR, Inwald DP, et al. Surviving sepsis campaign international guidelines for the management of septic shock and sepsis-associated organ dysfunction in children. Intensive Care Med. 2020;46(Suppl 1):10–67.

5 Gingell-Littlejohn M, Koh H, Aitken E, Shiels PG, Geddes C, Kingsmore D, Clancy MJ. Below-target postoperative arterial blood pressure but not central venous pressure is associated with delayed graft function. Transplant Proc. 2013;45(1):46–50.

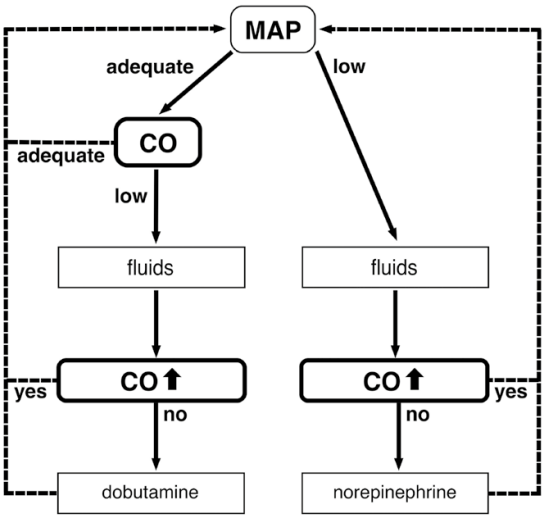
6 Collins MG, Fahim MA, Pascoe EM, Hawley CM, Johnson DW, Varghese J, et al. Balanced crystalloid solution versus saline in deceased donor kidney transplantation (BEST-Fluids): a pragmatic, double-blind, randomised, controlled trial. Lancet. 2023;402(10396):105–17.

7 Lindblad YT, Axelsson J, Balzano R, Vavilis G, Chromek M, Celsi G, Barany P. Left ventricular diastolic dysfunction by tissue Doppler echocardiography in pediatric chronic kidney disease. Pediatr Nephrol. 2013;28(10):2003–13.

# Appendix 1: Hemodynamic monitoring and support algorithm

*Basic hemodynamic management*

- administer crystalloid solution* according to body weight to cover basic fluid requirements
- give $NaHCO_3$ 1.4% solution: 5 mL $kg^{-1}$ in case of metabolic acidosis, especially in patients on $NaHCO_3$ supplements before transplantation
- administer mannitol 10%: 500 mL 1.73 $m^{-2}$, 20 minutes before reperfusion of donor kidney
- transfuse erythrocytes to maintain hemoglobin > 8 g $dL^{-1}$




*Cardiac output strategy*

- target values
  - before reperfusion: CI > 3.0 L $min^{-1}$ $m^{-2}$
  - after reperfusion : CI > 3.5 L $min^{-1}$ $m^{-2}$
- administer boluses of 10 mL $kg^{-1}$ crystalloid solution* when CI is too low; stop when patient is no fluid responder
- start dobutamine at 2 mcg $kg^{-1}$ $min^{-1}$ if target CI is not met after fluid loading
- adjust dobutamine dosing if target CI is not achieved but reduce dose when patient becomes tachycardic

*Blood pressure strategy*

- target values
  - before reperfusion: MAP > 70% of base line value
  - after reperfusion : MAP = 65 - 100 mmHg depending on donor blood pressure and visual judgment of renal perfusion during surgery
- administer boluses of 10 mL $kg^{-1}$ crystalloid solution* when MAP is too low; stop if patient is no fluid responder
- start norepinephrine infusion at 0.05 mcg $kg^{-1}$ $min^{-1}$ when MAP is too low and fluid loading is ineffective
- adjust norepinephrine dosing to reach target MAP