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KIDNEY TRANSPLANTATION IN CHILDREN WITH A COMPROMISED INFERIOR VENA CAVA: A UNIQUE EXPERIENCE AT SHUMAKOV RESEARCH CENTER

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Compromised inferior vena cava (IVC) is a rare but life-threatening condition in low-birth-weight children who require kidney transplantation (KT) to survive. **Objective:** to demonstrate a comprehensive approach to KT in children with IVC atresia. **Materials and methods.** In the period from December 2019 to April 2024, 5 kidney transplants were performed in children with atresia or obliteration of the IVC at Shumakov National Medical Research Center of Transplantology and Artificial Organs. The average age of the children at transplantation was 4.6 ± 2.7 (from 1 to 8 years) years, body weight 13.5 ± 4 (from 8.3 to 19.5) kg. **Results.** Vertical midline transperitoneal approach was performed, the right lobe of the liver, as well as the accessible part of the subhepatic IVC were partially mobilized. The renal graft was positioned on the right side with the formation of venous anastomosis with the accessible part of the subhepatic IVC. All the children had primary graft function. There were no acute rejection episodes at year 1 post-transplant. The average renal graft glomerular filtration rates in recipients at 3 months and at 1 year post-transplant were 95.9 ± 9.6 ml/min per 1.73 m^2 and 80.6 ± 26.2 ml/min per 1.73 m^2, respectively. **Conclusion.** When the iliac veins and/or distal IVC are compromised, venous outflow into an accessible IVC segment is the preferred option. Transplantation in the left orthotopic position and other mentioned revascularization techniques are complex surgical techniques with a higher risk of thrombotic complications in the early postoperative period.

Keywords: kidney transplantation in children, pediatric kidney transplantation, inferior vena cava compromise, inferior vena cava thrombosis.

INTRODUCTION

Venous system compromise, particularly involving the inferior vena cava (IVC), is a rare but potentially life-threatening condition in low-birth-weight children who require kidney transplantation (KT) for survival. Congenital anomalies of the great vessels, prior abdominal surgeries, and prolonged or repeated placement of temporary or permanent central venous catheters for renal replacement therapy (RRT) can result in narrowing or complete obliteration of the IVC lumen. In most instances, IVC compromise significantly challenges the technical feasibility of KT [1].

In children weighing 15 kg or less, vascular anastomosis of the graft typically involves the distal aorta and IVC. However, in cases of IVC atresia or absence, venous anastomosis – performed in a restricted operative field using available central or peripheral veins – may result in impaired venous outflow. This can lead to venous hypertension and increase the risk of graft thrombosis. Historically, children with absent or thrombosed IVCs were considered high-risk candidates for graft loss and were frequently deemed unsuitable for transplantation [1–3].

However, Eneriz-Wiemer et al. [1] reported 6 successful kidney transplants in children with IVC thrombosis using deceased donor grafts, all of which resulted in satisfactory outcomes. In their approach, the authors favored the use of small renal allografts to ensure that venous outflow did not exceed the drainage capacity of the iliac or adjacent collateral veins [2, 4, 5].

Some authors have used segments of the open IVC or iliac vein [6], ovarian vein [7, 8], left renal vein, and even the superior or inferior mesenteric veins or the portal vein [9–11]. Despite these efforts, a universally accepted surgical strategy for KT in the setting of IVC atresia or thrombosis has yet to be established.

Therefore, the aim of this study was to present a comprehensive surgical approach developed at Shumakov National Medical Research Center of Transplantology and Artificial Organs (“Shumakov Center”) for performing KT in pediatric patients with IVC atresia.

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MATERIALS AND METHODS

Between December 2019 and April 2024, five KTs were performed in pediatric patients with IVC) atresia or obliteration at Shumakov Center. The average age of recipients at the time of transplantation was 4.6 ± 2.7 years (range: 1–8 years), and their body weight ranged from 8.3 to 19.5 kg (mean: 13.5 ± 4 kg). All patients were on RRT prior to transplantation: 4 patients (80%) were on peritoneal dialysis (PD), while 1 (20%) was on long-term hemodialysis (HD).

The leading underlying causes of end-stage kidney disease were congenital anomalies of the kidney and urinary tract in 3 patients (60%), autosomal recessive polycystic kidney disease in 1 patient (20%), and infantile nephrotic syndrome in 1 patient (20%). Notably, none of the patients exhibited clinical signs or symptoms of IVC thrombosis.

KT was performed using deceased donor organs in 4 cases and a living related donor in 1 case. Detailed recipient characteristics are summarized in Table.

All recipients underwent standard pre-transplant evaluation protocols. At the preoperative stage, each patient underwent intravenous bolus contrast-enhanced computed tomography (CT) scan using the GE Revolution EVO CT scanner (General Electric, USA), followed by three-dimensional (3D) image reconstruction. Contrast enhancement was utilized to delineate the vascular anatomy of the abdominal aorta, iliac arteries, IVC, and iliac veins, in order to identify suitable zones for vascular anastomosis (Fig. 1).

Renal function was assessed based on serum creatinine levels and the estimated glomerular filtration rate (eGFR), calculated using the Schwartz formula. Post-transplant follow-up ranged from 1 to 55 (23 ± 19) months.

RESULTS

A vertical midline transperitoneal approach was used for all recipients. Depending on clinical indications and the need to create adequate space for graft placement, patients underwent either unilateral right nephrectomy

Table

Recipient characteristics

Case	Sex	Height, cm	Weight at time of transplantation, kg	Type of RRT	Age at time of transplantation, year	Time on RRT, year	Related or deceased donor	Right or left kidney
1	F	100	13.5	PD	8	3.1	Deceased	Left
2	F	86	12	PD	3	1.9	Deceased	Left
3	M	109	19.5	PD	6	2.2	Deceased	Right
4	F	96	14	HD	5	1.8	Deceased	Right
5	F	71	8.3	PD	1	0.9	Related	Left

Note: RRT, renal replacement therapy; PD, peritoneal dialysis; HD, hemodialysis.

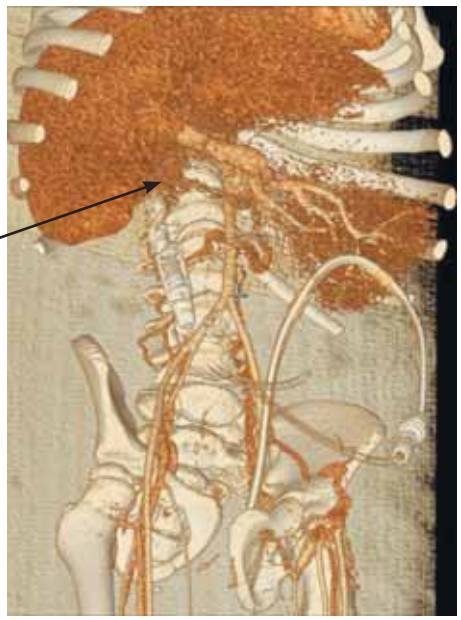

Fig. 1. Contrast-enhanced CT scan to visualize the vascular architecture of the abdominal aorta and iliac arteries

or bilateral nephrectomy (Fig. 2, a). The right lobe of the liver and the accessible area of the subhepatic IVC were partially mobilized (Fig. 2, b).

Following preparatory steps, the renal graft was placed on the right side, with venous anastomosis constructed to the accessible portion of the subhepatic IVC (Fig. 3). The renal artery was anastomosed to the aorta and/or common iliac artery where two graft arteries were present. When the left kidney was used, the graft vein typically provided adequate length. In cases where the right kidney was used, the graft vein was lengthened using a segment of the donor's vena cava (Fig. 4).

In all cases, ureteral-bladder anastomosis was performed using the Lich-Gregoir technique, with the placement of a graft ureteral stent (Fig. 5). The stent was removed on day 21 post-transplantation.

Immunosuppressive therapy followed a standardized regimen consisting of three medications: calcineurin inhibitors, mycophenolic acid, and glucocorticosteroids.

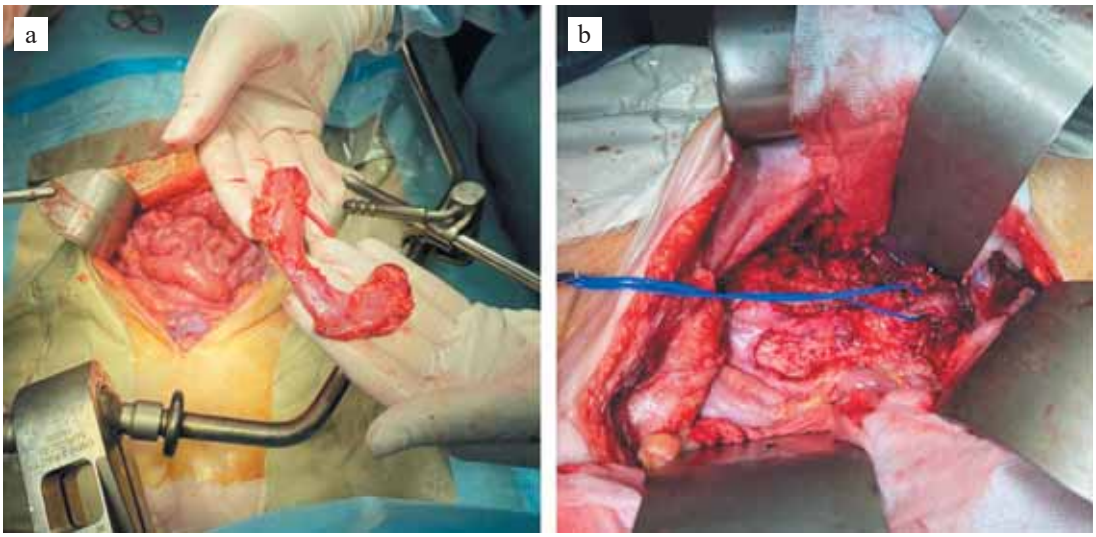

Fig. 2. Intraoperative anatomical features: a, horseshoe kidney nephrectomy; b, mobilized section of the subhepatic inferior vena cava on a holder

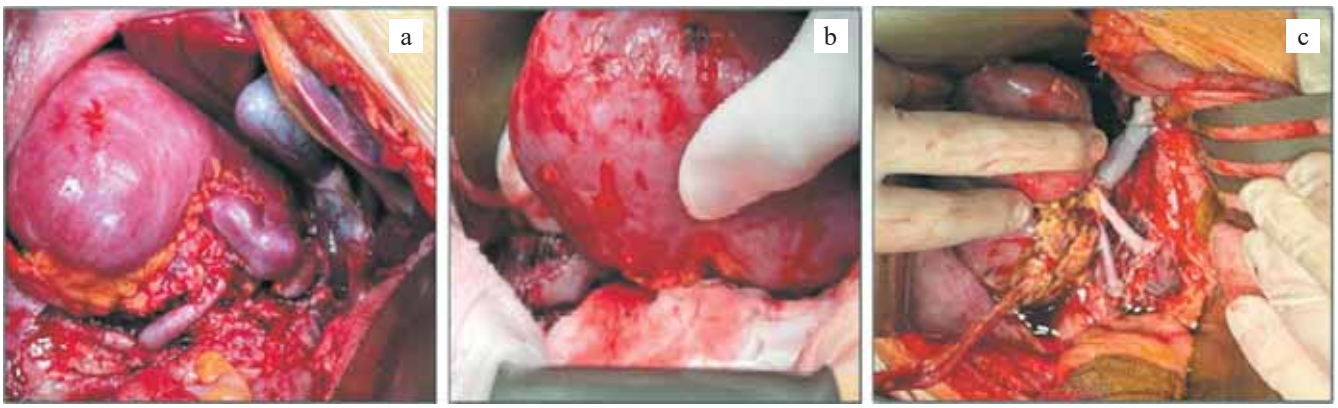

Fig. 3. Features of the formation of vascular anastomoses in conditions of IVC deficiency: a, vascular anastomoses after reperfusion; b, elongation of the renal vein of the graft due to the donor's IVC site; c, vascular anastomoses before reperfusion

Fig. 4. Right kidney, renal vein reconstruction using IVC

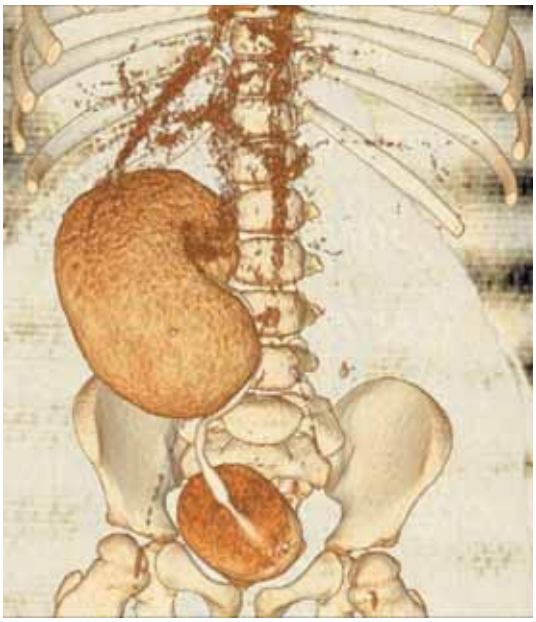

Fig. 5. CT scan – urinary phase

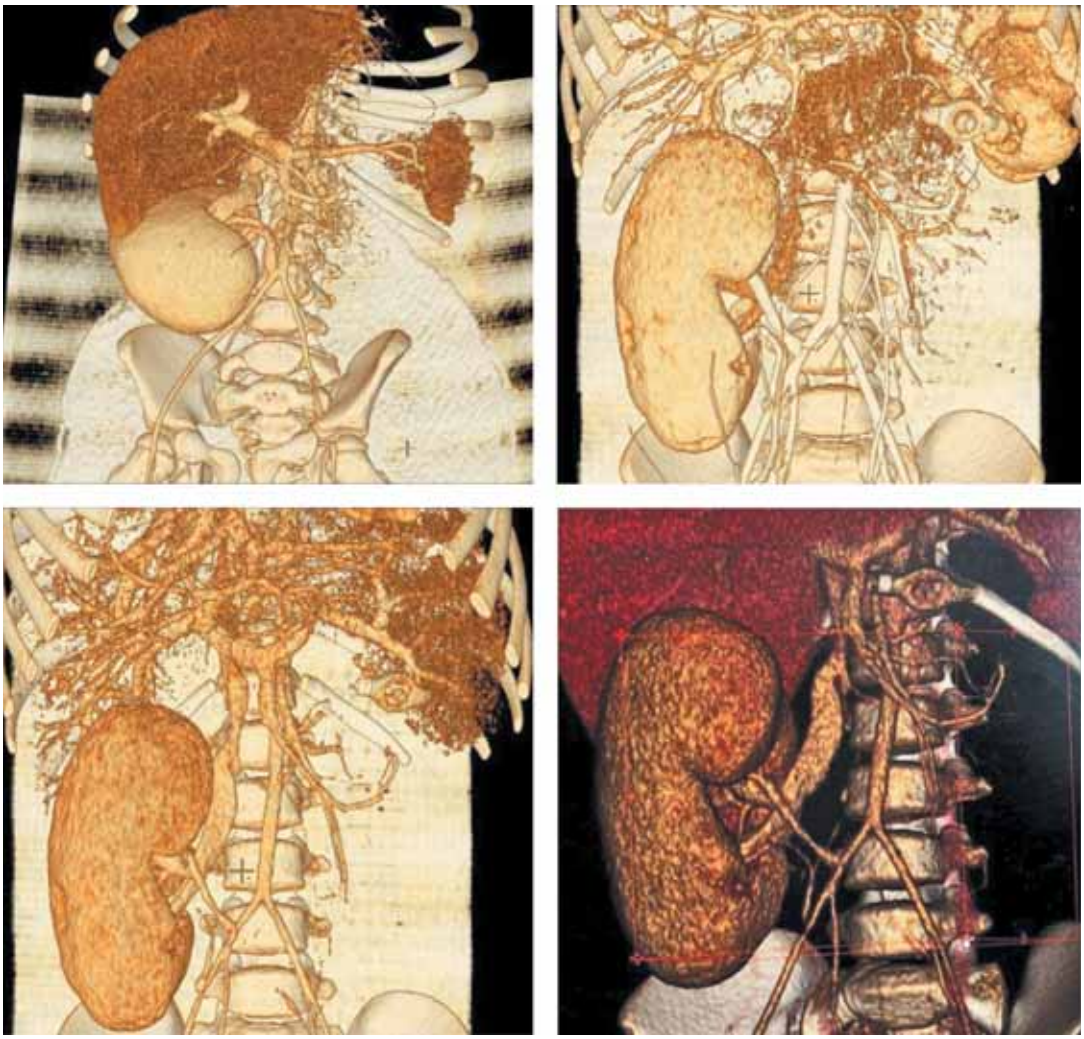

Fig. 6. Intravenous bolus contrast-enhanced CT scan MSCT 3 months after kidney transplantation

All patients exhibited primary kidney graft function, with no instances of acute rejection observed within the first year after transplantation. A follow-up intravenous bolus contrast-enhanced CT scan was performed 3 months post-KT (Fig. 6). The mean eGFR of the renal grafts at 3 months was 95.9 ± 9.6 mL/min/1.73 m^2. By the end of the first year, mean eGFR for the five functioning grafts was 80.6 ± 26.2 mL/min/1.73 m^2.

DISCUSSION

Compromised IVC may be detected in pediatric patients requiring KT for survival. Historically, this condition was regarded as an absolute contraindication to KT due to significant technical challenges and the heightened risk of graft thrombosis resulting from impaired renal venous outflow. Detailed preoperative imaging of the vascular network is therefore crucial, particularly in children with congenital anomalies or a history of repeated central venous catheter placement for RRT. When IVC compromise is suspected, a thorough preoperative assessment of the vascular anatomy is essential to guide surgical planning and ensure the feasibility and safety of KT.

Intravenous bolus contrast-enhanced multislice CT scan combined with 3D reconstruction is an accurate, reliable, and noninvasive tool for assessing organ transplantation feasibility [11]. This imaging technique enables detailed visualization of the patient's vascular anatomy, allowing for identification of optimal sites for vascular anastomosis, particularly in cases of IVC or iliac vein thrombosis or atresia. In our clinical experience, the thrombus-free subhepatic segment of the IVC has proven to be the most suitable site for renal vein anastomosis. This approach aligns with findings reported by Salvatierra et al. [12], who emphasized that, in pediatric recipients with IVC thrombosis receiving large renal allografts, an open segment of the IVC is preferred for the venous anastomosis.

Martinez-Urrutia et al. [5] also reported successful orthotopic left KT in 4 children with infrarenal IVC thrombosis. In these cases, the renal allografts were positioned orthotopically on the left, and venous anas-

tomosis was performed either with the subhepatic IVC or the recipient's native renal vein following ipsilateral nephrectomy. However, this technique presents certain limitations. One significant drawback is the insufficient length of the donor renal vein, particularly when using a right kidney graft, which introduces additional technical complexity during venous anastomosis. Another concern is the potential for external compression of the graft vein by the root of the small-bowel mesentery. In our view, the technical limitations associated with the Martinez-Urrutia technique can be mitigated by lengthening the donor renal vein using a segment of the donor IVC, thereby facilitating more secure and tension-free anastomosis.

Several researchers have proposed the use of the portal venous system for kidney graft revascularization. In these techniques, venous outflow is achieved through the creation of porto-renal or mesenterorenal shunts [10–11]. From a technical standpoint, anastomosis of the donor renal vein to the superior mesenteric vein (SMV) appears relatively straightforward, as the SMV is anatomically accessible and has adequate length for mobilization within the abdominal cavity. However, a significant limitation of this approach lies in the size mismatch between the donor renal vein and the recipient's SMV, which may increase the risk of venous thrombosis. Furthermore, this type of venous reconstruction is associated with a higher risk of graft malposition or rotation [10].

CONCLUSION

A comprehensive preoperative assessment of the potential recipient is essential for determining the most appropriate surgical tactics for KT in children with venous anomalies. In cases where the iliac veins and/or distal IVC are compromised, using an accessible segment of the subhepatic IVC for venous outflow remains the preferred option. Alternative approaches, such as orthotopic transplantation on the left side or revascularization using the portal venous system, represent technically demanding procedures that are associated with an elevated risk of early postoperative thrombotic complications.

The authors declare no conflict of interest.

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