Inverted kidney allograft technique in pediatric kidney transplantation: Results from a single-center, comparative analysis

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ABSTRACT

Introduction: Kidney transplantation (KT) is the standard of care for children with end-stage kidney disease. When the donor's kidney is right-sided, the graft can be placed ipsilaterally using an inverted kidney allograft (IKA) technique, facilitating the anastomosis of a shorter renal vein and renal hilum spatial orientation with anterior positioning of the urinary tract. We aimed to compare the safety and efficacy of IKA and standard anatomical position (AP) in pediatric KT.
Methods: We performed a retrospective study of all patients ≤18 years of age who underwent KT at the Hospital Italiano de Buenos Aires (January 2010 to December 2021). A comparative analysis of baseline demographics, urologic and vascular complications, graft survival, and one-year creatinine clearance was performed between patients with IKA and those with AP allografts.
Results: Overall, 157 KT were performed: 61 were IKA and 96 were in the AP. Median age at transplantation was nine years (range 1−18). Allografts from cadaveric donors were more frequently implanted using the IKA technique (p≤0.001). No significant difference in urologic (16.4% vs. 13.5%, p=0.79) or vascular complication rates (1.2% vs. 5.2%, p=0.47) were observed. Median one-year creatine clearance was similar between the groups (73.1 ml/min/m^2 vs. 75.3 ml/min/m^2). Graft survival and overall mortality rates were comparable between groups.

Conclusions: In the largest study of its kind, we observed that the IKA technique did not increase the risk of urologic or vascular complications and yielded comparable one-year graft survival and creatine clearance. This approach appears to be feasible when the AP is not ideal.

INTRODUCTION

Kidney transplantation (KT) is widely recognized as the standard of care for children with end-stage kidney disease (ESKD) [1,2]. Several factors, such as ischemia time, adequate intraoperative hemodynamic support, and some technical aspects, can significantly impact graft survival, particularly in pediatric patients receiving renal allografts from adult donors [3,4].
The donor kidney is usually transplanted into the right iliac fossa due to its more direct vascular access [5]. Following the implantation of a left allograft into the right iliac fossa, the spatial orientation of the renal hilum results in the renal vein lying posteriorly, in proximity to the receptor vein, while the renal artery is positioned anterior to the vein. This configuration prevents potential compression of the vein. Additionally, the anterior positioning of the urinary tract facilitates easier access in the event of urological complications. Consequently, this alignment offers significant advantages by accommodating the donor and recipient vascular anatomy.
In pediatric patients, particularly those with lower body weight, the recipient's vena cava and aorta are often preferred for vascular anastomosis due to their higher blood flow and the feasibility of accommodating a relatively larger kidney within a small abdominal cavity [4]. However, certain situations—such as ipsilateral allografts, a short renal vein, vascular anatomical variants, or pedicles with multiple vessels—can pose challenges. In these cases, repositioning the allograft in an inverted or upside-down orientation may be necessary [6]. This technique, known as "Capo Volta" and first described by Hamburger in 1972, helps reduce anastomotic tension when the renal vein is excessively short. It also allows the kidney to maintain a hemodynamically favorable position, with the renal pelvis situated anteriorly. This technique is particularly useful when KT is conducted through an extraperitoneal approach.

Despite potential benefits in the aforementioned scenarios, the IKA technique is rarely performed in pediatric KT and raises concerns about its impact on graft vascularization and urinary tract drainage. Specifically, in this orientation, the ureteropelvic junction is positioned above the renal pelvis, necessitating a longer ureter. This configuration may increase the risk of proximal ureter bending, which could impair urine drainage at the ureteropelvic junction [7,8]. Currently, there is limited evidence regarding the outcome of this technique, particularly in pediatric KT, with only a few studies addressing its efficacy [4,7,8]. At the Hospital Italiano de Buenos Aires (HIBA), allografts are typically implanted on the right side in a standard fashion for both live and cadaveric donors. Exceptions include cases involving re-transplantation, prior surgeries in the right iliac fossa, or vascular anatomical variants in the recipient. The inverted technique is routinely employed for ipsilateral allografts [9].

In this study, we aimed to evaluate the outcomes of the IKA technique in a large cohort of pediatric patients undergoing ipsilateral KT, comparing these results to those of patients who received standard anatomical allografts.

METHODS

Following Institutional Review Board approval (PRIISA BA: 9539), a retrospective quasi-experimental study was conducted, including all patients ≤18 years of age with ESKD who underwent KT at the Hospital Italiano de Buenos Aires (HIBA) between January 2010 and December 2021. Patients who underwent KT outside our center and were referred to HIBA during the immediate postoperative period, and those with less than 1-year follow-up were excluded. Outcomes of interest included the incidence of urologic and vascular complications, long-term graft survival, and creatinine clearance at 1-year follow-up.

At our institution, the IKA technique is routinely employed for right-sided allografts, which are typically implanted ipsilaterally (Figure 1). This approach is favored because it offers greater flexibility in determining the optimal implantation height and allows for more straightforward vessel anastomosis. As such, graft laterality serves as the primary criterion for selecting the IKA technique. However, intraoperative assessment of the graft's vascular configuration also plays a critical role. If the vessel anatomy is unfavorable, the anatomical position is preferred—even for right-sided allografts—and the same principle applies when considering the IKA technique for left-sided grafts.

Descriptive statistics were used to summarize the data. Continuous variables were reported as medians with interquartile ranges (IQR), while categorical data were presented as frequencies and percentages. According to data distribution, comparisons between groups were performed using the t-test or the Wilcoxon signed-rank test for continuous variables, and the Chi-square or Fisher's exact test for categorical variables. Median time to graft survival was estimated through a Kaplan-Meier analysis, and a log-rank test was employed to assess differences across groups. Multivariable logistic regressions were performed to identify variables associated with urological complications. Additionally, Cox proportional hazards models were utilized to assess the impact of variables on graft survival. Statistical analyses were conducted using R version 4.0.2, and a p value of <0.05 was considered statistically significant.

RESULTS

During the study period, 157 KT were performed at HIBA by two surgeons. Of these, 61 were performed with the IKA technique, while the remaining 96 were placed in the standard anatomical position. Median age at transplantation was 9.9 years (range 1-18 years). Baseline characteristics were similar between the two groups; however, there was a significant difference in the type of donor, with more patients in the IKA group receiving grafts from cadaveric donors (41/61 vs 33/96, p=<0.0001). These findings are depicted in Table 1.

In 10 cases (6.3%), ipsilateral allografts were implanted in the anatomical position rather than using the IKA technique, based on the surgeon's discretion. The majority of allografts (96.2%) were implanted on the right side, while 3.8% were placed on the left side. This left-sided placement was attributed to factors such as re-transplantation or a history of prior surgeries. Uretero-ureteral anastomosis was performed in 28 cases (17.8%), while in the remaining 129 cases (82.1%), the allograft ureter was reimplanted into the bladder.
Re-transplantation was performed in five cases (5.2%) in the anatomical position group and four cases (6.5%) in the IKA group. All these procedures were conducted in the contralateral iliac fossa. In some instances, the initial transplantation had been performed either at another center or outside the study period. A double J stent was placed in 72 cases, whereas 84 cases were stentless. Details on stent use were unavailable for one case. Among patients in the IKA group, 55.7% were stented, compared to 40% in the anatomical position group. This difference was not significant.

The overall mortality rate was 4.4% (7/156), with three demises occurring within one-year post-transplantation. None of these deaths were related to operative complications. Long-term graft survival and creatinine clearance at the 1-year follow-up were comparable between the two groups. Kaplan-Meier analysis of graft survival and creatinine clearance distribution at 1 year are shown in Figure 2 and Figure 3, respectively. Multivariable regression analysis demonstrated that double J stenting was significantly associated with urological complications (OR 2.70, 95% CI 1.01 – 7.23, p=0.04). In the Cox proportional hazards model assessing graft survival, donor type and weight at surgery were significant predictors. Grafts from living donors were associated with a reduced hazard of graft failure (HR 0.08, 95% CI 0.01 – 0.65, p=0.01), whereas a lower weight at transplant was associated with better graft survival (HR 1.07, 95% CI 1.004 – 1.16, p=0.04). Table 2 depicts these results.

Urologic and vascular complications

At the 1-year follow-up, 23 urologic complications (14.6%) were identified, with no additional complications reported in patients with longer follow-up. These included 11 cases of urinary tract infection (UTI), 5 obstructions, 5 urinomas, and 1 case each of vesicoureteral reflux (VUR) and distal ureteral necrosis. In the anatomical position group, 2 patients developed urinomas, and 3 patients experienced obstructions. Seven of the 11 UTIs, as well as the single cases of VUR and distal ureteral necrosis, were observed in this group. Among the IKA group, 3 urinomas, 2 obstructions, and 4 UTIs were identified. One of the two obstructions was attributed to the curvature of the inverted ureter, which occurred in the context of pseudo-rejection in a 17-year-old patient. Supplementary Fig 1. illustrates the initial pyelography performed during the placement of a double J stent. The obstruction was later managed successfully with a laparoscopic pyeloureteral anastomosis. The second obstruction occurred in the mid-ureter as a result of graft rejection and was therefore unrelated to the inverted technique. Initial management involved nephrostomy tube placement (Supplementary Fig 2.), followed by successful definitive treatment using balloon dilatation of the stenotic segment.

A total of 6 vascular complications were recorded. Within the IKA group, there was one instance of superior polar artery stenosis involving an independently anastomosed artery to the aorta. This complication was managed conservatively with antihypertensive therapy and did not require surgical treatment. In the anatomical position group, 2 cases of allograft renal vein thrombosis were reported, both resulting in graft loss. No statistically significant differences in urologic or vascular complications were observed between the two groups. A summary of the vascular complications is provided in Table 3.

DISCUSSION

KT remains the gold standard for managing ESKD in pediatric patients [3]. In this population, technical aspects play a critical role due to the frequent size discrepancy between donors and recipients [3]. Few studies have described their experience with the IKA positioning, particularly in pediatric patients, and typically reporting isolated cases or small series [10]. To the best of our knowledge, our study, which includes 61 pediatric KTs using the inverted position, represents the largest series to date. Previous records comparing anatomical and IKA in pediatric populations have shown variability in the selection criteria for employing this technique, often citing short renal vein and vascular anatomic variations as primary factors [4,7]. In contrast, our study systematically utilized the inverted position for ipsilateral allografts, predominantly implanted on the right side. Another notable difference is the proportion of IKA cases in our study (38.2%), which is significantly higher than the reported 7% in the previous two studies [4,7].

The significant difference in donor type between the anatomical and inverted groups in our series is attributable to presurgical evaluation. Living donors often allow for the selection of the left kidney, facilitating implantation in the standard anatomical position on the right side. Conversely, in cadaveric donors, it is not always possible to select the side of the allograft to be implanted, thereby increasing the number of cases requiring the inverted technique. In pediatric recipients, living donor transplants are associated with better short- and long-term outcomes [11,12]. This was also observed in our study, as recipients of living donor grafts had a lower hazard of graft failure.

Another important consideration in pediatric KT is pre-transplant weight status. A previous study reported that, for certain age groups, being underweight prior to transplantation may be protective against adverse outcomes [13]. This observation is particularly relevant, as in our study, lower weight at the time of transplantation correlated with improved graft survival.

In our cohort, 43.8% of patients in the anatomical group and 27.9% in the IKA group, had a history of uropathies, though this difference reached no significance. This is noteworthy, as patients with urological malformations are predisposed to urologic complications [14]. Another finding in our series that should be highlighted is graft survival at the 1-year follow-up, in which the IKA group showed improved survival compared to the anatomical group, although this difference was non-significant. Previous studies comparing both techniques in pediatrics have not reported long-term graft survival across groups, therefore, a new insight into this topic is provided in our series.

Regarding urologic complications, historical data from Peters and Lorenzo's review of 2107 pediatric KTs report incidences of stenosis in 5%, urine leaks in 3.2%, VUR in 3.5%, and urolithiasis in 1% [15]. Similarly, Bueno et al. described three urologic complications, including one instance of kinking in an inverted allograft and two ureterovesical stenoses in the anatomical position [7], while Ramesh and colleagues in their series reported one instance of VUR and another consisting of transient hydronephrosis [4]. In our series, two urologic complications potentially associated with the inverted position were observed, both occurring in the context of urinary tract dilation linked to rejection to some extent. These complications prompted performing a renal biopsy, managing the rejection, and temporary stenting with a double J catheter, followed by definitive surgery.

Vascular thrombosis is a significant concern in pediatric KT, contributing to 6-11% of allograft rejections [16]. Younger recipients, particularly those weighing less than 15 kg, are at a higher risk of thrombosis compared to older children, although long-term outcomes remain similar between these groups [14]. Mohammed et al reported a single event of vein thrombosis within the inverted allograft cohort in adult patients [18]. In our study, only one vascular complication (1.6%) occurred within the IKA group, which did not affect allograft function. In contrast, five vascular complications (5.2%) were observed among patients with anatomically positioned allografts, three of which led to graft loss. Importantly, none of these complications were directly related to graft positioning. Two instances of renal vein thrombosis with subsequent graft loss occurred in hypotensive recipients with low body weight at the time of transplantation. The remaining graft loss in this group was attributed to an arterial aneurysm in a patient with Alagille syndrome, a condition known to predispose individuals to vascular abnormalities [19]. While vascular complications were more frequent in the anatomical group (5.2%) than in the IKA group (1.6%), this difference did not reach statistical significance.
Of the nine graft losses (5.8%) documented at 1-year follow-up in our study, three were attributed to vascular complications, while the remaining six were due to other causes. None of the reported deaths were linked to vascular or urologic complications. Routine stent placement remains a topic of debate in both adult and pediatric urology, particularly regarding its role in preventing complications [20,21]. While some evidence suggests that stent placement may reduce complication rates in adult KT [22], its benefits in pediatric transplantation are yet to be elucidated. In our series, the decision to place a double J stent is based on the presence of unresolved uropathy, uretero-ureteral anastomosis, small-caliber ureters, tension at the anastomotic site, or anuric patients. Double J stent utilization occurred in 55.7% and 40% of cases in the IKA and anatomical position group, respectively. While no statistically significant

difference was observed in the utilization of double J catheters between the two groups, the multivariable analysis identified double J utilization as the only predictive factor of complications, although this variable did not have any effect on graft survival.

This study has a number of strengths and weaknesses. One major strength is the large sample size within the IKA group, making this the largest series to date employing this technique in pediatric KT. The relatively balanced sample sizes between the intervention and comparison groups reduce the risk of skewed comparisons and enhance the reliability of statistical analyses. Another strength is the standardization of this technique for ipsilateral allografts at our center, with all procedures performed by only two surgeons, minimizing variability in technique.

Despite following a quasi-experimental design, the major limitation of this study lies in the nonrandomized nature of patient allocation and its retrospective nature, inherently introducing risks of bias and confounding. Additionally, we must acknowledge that the nonrandomized design further constrains the strength of causal interpretations. The applicability of this technique is particularly relevant in extraperitoneal KT, where limited surgical space for choosing the ideal site to perform the anastomosis, short vessel length in right-sided allografts, and the need to maintain the urinary tract anterior to the vascular anastomosis present technical challenges. However, this may not apply to intraperitoneal approaches, where the aforementioned scenarios are not typically encountered. As such, the generalizability of this technique may be limited across different surgical contexts and healthcare settings. Although this study represents the largest cohort to date, the overall sample size remains limited, potentially reducing the generalizability of our findings. While the number of patients with missing data was low, we implemented the listwise deletion technique. Therefore, the limitations of reducing the sample size and the introduction of potential biases with this approach should be acknowledged. Despite these limitations, we consider this endeavor highly valuable, as our results contribute to the limited body of evidence on this topic, demonstrating the feasibility and safety of the IKA technique. Our study provides a valuable foundation for future research and highlights the need for prospective, multicenter studies—ideally incorporating randomization or propensity score methodologies—to validate our findings and support the development of standardized criteria for this surgical technique.

CONCLUSIONS

Our findings suggest that IKA positioning is a viable and non-inferior alternative for pediatric patients where anatomical positioning is not the most ideal. This technique demonstrated comparable long-term graft survival without increasing the risk of urologic or vascular complications. As such, it warrants consideration in cases where technical challenges may be mitigated through its use. Future clinical trials involving larger populations and employing randomization or propensity-score matching are necessary to validate these findings and further support the adoption of this technique in clinical practice.

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Data availability: *The data for this study is not publicly available as it contains protected health information.*

FIGURES AND TABLES

Figure 1. Right kidney implanted using the IKA technique before clamp removal. Proper vessel positioning is demonstrated with the double renal arteries located anteriorly and the renal vein posteriorly. The ureter is shown pending reimplantation.

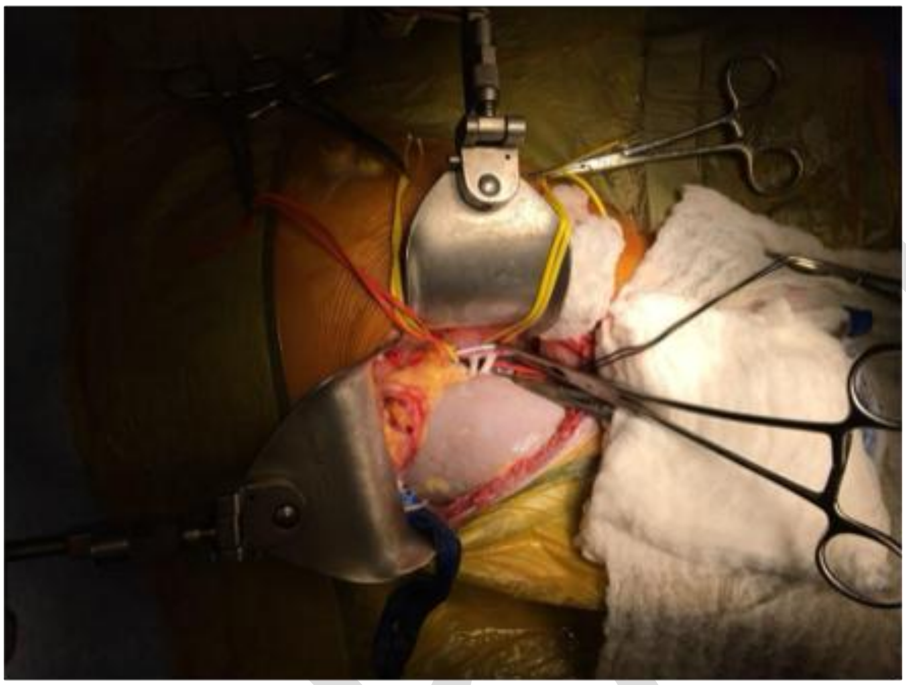

Figure 2. Kaplan Meier curve with survival graft analysis.

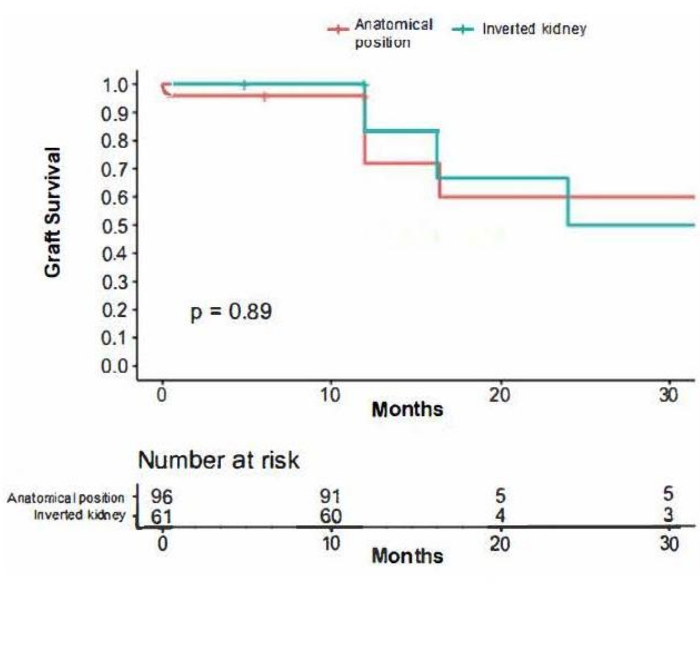

Figure 3. Creatinine clearance at 1-year post-transplantation.

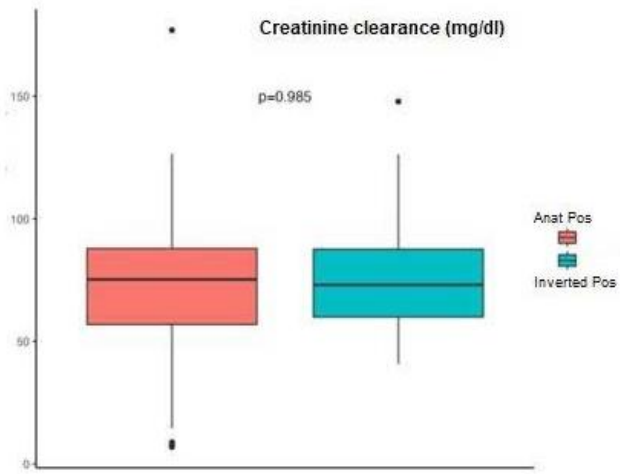

Table 1. Baseline characteristics and outcomes of the studied population			
	Anatomical position (n=96)	**Inverted kidney allograft (n=61)**	**P**
Age at surgery (median, IQR)	9.0 (4.0–14.2)	11.0 (6.0–14.0)	0.416
Weight (median, IQR)	25.5 (13.7–37.1)	27.0 (16.6–41.4)	0.684
Nephropathy n (%)	54 (56.2)	44 (72.1)	0.067
Uropathy n (%)	42 (43.8)	17 (27.9)	0.067
Double J n (%)	38 (40.0)	34 (55.7)	0.078
Living donor n (%)	63 (65.6)	20 (32.8)	<0.001
Cadaveric donor n (%)	33 (34.4)	41 (67.2)	<0.001
Complications n (%)	18 (17.7)	11 (18.0)	1
Urologic complications n (%)	13 (13.5)	10 (16.4)	0.794
Vascular complications n (%)	5 (5.2)	1 (1.2)	0.478

Graft loss n (%)	11 (11.5)	6 (9.8)	0.956
Creatinine clearance at 1-year (median, IQR)	75.3 (56.9–87.9)	73.1 (59.9–87.6)	0.985
Deaths n (%)	6 (6.2)	1 (1.6)	0.333

IQR: interquartile range.

Table 2. (**A**) **Multivariable logistic regression analysis of patients with urological complications; (B) Multivariable Cox regression analysis of graft survival.**

(A)

	Complications	**P**
	OR (95% CI)	
Age at surgery	0.83 (0.69–1.01)	0.07
Weight at surgery	1.02 (0.95–1.08)	0.52
Double J	2.78 (1.03–7.48)	0.04
Donor type	0.72 (0.26–2)	0.53
Inverted kidney allograft	1.16 (0.42–3.18)	0.77

(B)

	Graft survival	**P**
	HR (95% CI)	
Age at surgery	0.80 (0.61–1.04)	0.09
Weight at surgery	1.07 (1.004–1.16)	0.04
Double J	0.40 (0.09–1.70)	0.21
Donor type	0.08 (0.01–0.65)	0.01
Inverted kidney allograft	1.66 (0.44–6.23)	0.44

CI: confidence Interval; HR: hazard ratio; OR: odds ratio.

Table 3. Description of vascular complications across the affected patients

Patient	Age (years)	Weight (Kg)	Complication	IKA	Evolution	Creatinine clearance at 1-year FU (ml/min/1.73 m^2)
1	12	20	Polar artery stenosis	Yes	HT with normal RF	79.6
2	18	43	Iliofemoral thrombosis	No	Normal RF	84.4
3	13	34	Arterial aneurysm	No	Graft loss	–
4	3	13.6	Renal vein thrombosis	No	Graft loss	–
5	6	14.1	Renal vein thrombosis	No	Graft loss	–
6	4	14	Polar artery thrombosis	No	Graft’s partial necrosis, urinoma, normal RF	87.9

FU: followup; HT: hypertension; IKA: inverted kidney allograft; RF: renal function.