INTRODUCTION

Pediatric RTX is an established procedure and treatment of choice for children with end-stage renal disease. Unlike adults, the most common causes are congenital or inherited renal disorders including CAKUT like renal dysplasia and hypoplastic-dysplastic kidney, obstructive uropathy, reflux nephropathy, focal segmental glomerulosclerosis, and lupus nephritis. The majority of pediatric patients that require RTX receive adult organs because of a lack of organs and an expansion of living kidney donation, which is only allowed for adults to do. A size mismatch between a small abdominal cavity and a relatively large graft in small children can lead to traction and insufficient compliance of the abdominal wall, which often is already diminished because of peritoneal dialysis and the operation itself.

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Intravesical monitoring of intra-abdominal pressure after renal transplantation in children: A safety and feasibility study

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Abstract

IAH after RTX can threaten graft viability. This study aimed to assess the feasibility and safety of longitudinal IAP measurements as an IAH screening method in children after RTX. A cohort of eight children with a mean ± SD [range] age 9.6 ± 6.2 [2-17] years who underwent RTX and 18 control patients were evaluated between May 2017 and February 2018. We compared longitudinal IAP measurements using a Foley manometer to other clinical monitoring data. In total, 29 IAP measurements were performed in RTX patients and 121 in controls. The mean post-operative IAP was 7.4 ± 4.3 [1-16] mm Hg following RTX and 8.1 ± 3.7 [1-19] mm Hg in controls. We noted IAH in 9 (31%) of 29 IAP measurements after RTX and in 41 (34%) of 121 IAP measurements in controls. No graft dysfunction occurred in RTX patients despite elevated IAP values. The mean ± SD [range] time expenditure for IAP measurement was 2.1 ± 0.4 [0.6-3.2] minutes. No severe complications occurred during the IAP measurements. Analysis of longitudinal IAP measurements demonstrated that IAP measurement is safe and feasible in children recovering from renal transplantation in the PICU.

KEYWORDS

IAP, IAH, intravesical pressure, PICU

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IAH after RTX can threaten graft viability. This study aimed to assess the feasibility and safety of longitudinal IAP measurements as an IAH screening method in children after RTX. A cohort of eight children with a mean ± SD [range] age 9.6 ± 6.2 [2-17] years who underwent RTX and 18 control patients were evaluated between May 2017 and February 2018. We compared longitudinal IAP measurements using a Foley manometer to other clinical monitoring data. In total, 29 IAP measurements were performed in RTX patients and 121 in controls. The mean post-operative IAP was 7.4 ± 4.3 [1-16] mm Hg following RTX and 8.1 ± 3.7 [1-19] mm Hg in controls. We noted IAH in 9 (31%) of 29 IAP measurements after RTX and in 41 (34%) of 121 IAP measurements in controls. No graft dysfunction occurred in RTX patients despite elevated IAP values. The mean ± SD [range] time expenditure for IAP measurement was 2.1 ± 0.4 [0.6-3.2] minutes. No severe complications occurred during the IAP measurements. Analysis of longitudinal IAP measurements demonstrated that IAP measurement is safe and feasible in children recovering from renal transplantation in the PICU.
to produce high IAP and graft dysfunction as part of the renal allograft compartment syndrome.8,11 Both, IAH and abdominal compartment syndrome, are also associated with higher mortality.10 In 2013, the WSACS published consensus guidelines to standardize definitions and management of IAH. In children, IAH is defined as an IAP ≥ 10 mm Hg.7 IAH affects 15%-45% of the PICU patients.12,13 Studies in adults suggest the IAH be independently associated with acute renal failure.14-16

There is still a lack of studies about the effects of abnormal IAP, especially after transplantation in children. Increased intra-abdominal pressure can develop not only immediately after intraoperative abdominal wall closure, but also in the further post-operative course after major abdominal surgery. As a very rare complication an abdominal compartment syndrome including renal allograft compartment syndrome can lead to very severe complications including graft loss. Other scientists have therefore suggested further use of monitoring the IAP to prevent its devastating consequences.8,9

This study aimed to analyze longitudinal IAP measurements in children who underwent RTX. IAP values were compared with other standards of monitoring graft viability, including laboratory and clinical parameters.

2 | PATIENTS AND METHODS

2.1 | Subjects

This retrospective single-center study was legitimated by the local medical statue (details for blinding omitted), and written informed consent was waived. All examinations were conducted according to the Declaration of Helsinki. We extracted data, including patient demographics, peri-operative findings, complications, and outcomes from the renal transplant database and surgery, anesthesia, and PICU records.

2.2 | IAP measurement

According to WSACS’s recommendations,7 we measured IAP intravesical. We used a hydrostatic manometer, the UnoMeter™ AbdoPressure™ IAP Monitoring System (Unomedical, ConvaTec™,) connected to a Foley catheter (Uromed™ Prosil, Kurt Drews KG) as described before.17 Patients were in a completely supine position at end-expiration during the IAP measurements that were performed in the PICU until discharge. The IAP monitoring device was removed in cases of severe Foley catheter leakage or oliguria for more than 6 hours. In all patients, urine cultures were obtained at least every 7 days. In a random sample of ten IAP measurements, we took the time required for the IAP measurement.

2.3 | Statistical analysis

For qualitative data, counts and percentages were calculated. For quantitative data, means and SDs were calculated. We used a t test to compare data between RTX patients and controls. We used a multiple linear mixed model to investigate the potential association of diuresis, volume balance, creatinine, and IAP. All analyses were performed in SPSS 23 for Mac (IBM SPSS Statistics, IBM Corporation), GraphPad Prism V6.0c (GraphPad Software), and R version 3.5.2 (R Core Team). A P value < .05 was considered statistically significant.

3 | RESULTS

3.1 | Patients

We included eight pediatric patients who underwent RTX between May 26, 2017, and February 5, 2018, at our center in this study and 18 patients who were treated post-operatively at the PICU for various reasons as controls. Table 1 summarizes demographics, clinical characteristics, and post-operative care variables of RTX patients and controls. Table 2 shows indications for RTX and donor kidney characteristics. Five patients (62%) had received peritoneal dialysis before transplantation, three (38%) received hemodialysis. In four patients (50%), the Tenkhoff catheter was left in place and open post-operatively; all patients had a transurethral catheter. One patient (12%) suffered from acute graft failure with arterio-venous thrombosis and the need for graft removal. In another patient (12%), both ureters had to be reimplanted, and double J-catheters were applied. In the remaining patients (76%), the graft quickly took up its function. None of the patients had high amounts of ascites post-operatively. In two cases (24%), the measuring system was removed before transfer for safety reasons in one patient because of hematuria and in the other because of suspected more inferior urine drainage.

| TABLE 1 | Demographics and clinical characteristics of RTX patients and controls |
|----------|---------------------------|------------------|
|          | RTX       | Controls    | P value |
| Number of patients | 8        | 18          |         |
| Sex       |           |             |         |
| Male      | 5 (63)    | 7 (39)      | .27     |
| Female    | 3 (37)    | 11 (61)     | .27     |
| Age, years | 9.6 ± 6.2 [2-17] | 6.2 ± 5.9 [2 mo-17 y] | .19     |
| Bodyweight, kg | 32.8 ± 22.3 [9.4-58.6] | 22.9 ± 19.3 [4-75] | .26     |
| Length, cm | 127 ± 35 [85-161] | 101 ± 38 [52-165] | .14     |
| Body mass index | 17.7 ± 4.4 [13.0-26.2] | 18.5 ± 6.0 [13.8-34.7] | .77     |
| Length of PICU stay, days | 2.9 ± 1.2 [1-4] | 5.8 ± 5.3 [1-21] | .15     |

Note: Counts and percentages are written as n (% of all patients). Continuous variables are reported as means ± SDs [range]. RTX: patients after.
The mean number of IAP pressure measurements performed per patient during the post-operative period ± SD (range) for the eight patients after renal transplantation was 3.6 ± 1.7 (1-6), constituting a total of 29 IAP measurements whereas in the 18 control patients 6.7 ± 5.7 (2-22) measurements were performed, constituting a total of 121 IAP measurements (Figure 1). Nurses spent a mean ± SD (range) of 1.9 ± 0.4 (0.5-3.2) minutes measuring IAP. No complications of IAP measurements occurred, and all urine cultures were negative.

Post-operatively, the mean IAP ± SD (range) was 7.4 ± 4.3 (1-16) mm Hg following RTX and 8.1 ± 3.7 (1-19) mm Hg in controls. Increased IAP fulfilling the criterion of abdominal hypertension (≥10 mm Hg) defined by the WSACS² was found in 9 (31%) of 29 IAP measurements distributed among four (50%) of the eight RTX patients and in 41 (34%) of 121 IAP measurements distributed among 10 (55%) of the 18 controls (Figure 1). Post-operative IAP values did not differ significantly between patients after RTX cases compared with controls (P = .39). Multiple mixed linear model analysis showed no significant association of diuresis, fluid balance, creatinine, and the IAP.

We report on longitudinal measurements of IAP in children following RTX as a tool to screen for intra-abdominal hypertension. Avoiding elevated IAP is considered to be a critical element in the successful surgical management of abdominal surgery and especially of transplantation in children because impairment of blood supply due to IAH can impair graft function of kidney or other organs.⁸-¹¹,¹⁷ Already in the past century, Harman et al described the influence of IAP on renal blood flow and GFR in anesthetized dogs: At 20 mm Hg, IAP renal blood flow and GFR decreased to less than 25% of normal and renal vascular resistance increased 555%.¹⁶ Whether the impairment of renal function is caused by parenchymal compression, renal vein pressure or other pathophysiological pathways remains unclear.¹⁰,¹⁹

We did not observe any side effects of manometric intravesical IAP measurement, and the time expended to perform the additional measurements was low. Post-operative IAP measurements were similar in patients after renal transplantation and controls (Figure 1). However, we observed a relatively high prevalence of IAH episodes in our cohort of RTX patients (31%). In the group of control patients, we observed the occurrence of IAH with a similar frequency (34%). This prevalence is consistent with previous reports in PICU patients.¹²,¹³ In contrast to data in adults, we did not detect a significant effect of IAP on diuresis, fluid balance, or kidney function.¹⁴-¹⁶ In our cohort of children recovering from RTX, half of the patients had transient episodes of IAH, however, without a negative impact on graft viability. We did not see relevant adverse effects on graft function despite elevated IAP values. The IAP is dependent on numerous factors and represents only a momentary value. Short-term elevations of the IAP probably do not pose a relevant threat to graft function. The real potential of a routinely applied intra-abdominal pressure monitoring is that it could detect episodes with permanently elevated IAP. Especially a gradual increase of the IAP up to the development of an abdominal compartment syndrome including the associated serious complications could potentially be detected and averted at an early stage. Our data show that intravesical measurement using a Foley manometer is safe, fast, and feasible in renal transplanted children. As the effort to measure IAP is low and, given the potential advantage of early detection of intra-abdominal compartment syndrome, we recommend routine IAP monitoring in children after renal transplantation.

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### Limitations

1. The study design was retrospective and, therefore, subject to potential selection bias.
2. Data were acquired in only a small group of patients.

### Conclusion

Retrospective analysis of longitudinal IAP measurements demonstrated that IAP measurement is a safe, feasible supplemental...
assessment that can be performed easily and quickly in children recovering from renal transplantation. The effort to measure intra-abdominal pressure is low and, given the potential advantage of early detection of intra-abdominal compartment syndrome, IAP monitoring may be a useful addition to post-operative monitoring of children after renal transplantation. More studies are needed to determine whether routine post-operative IAP monitoring can improve the quality of post-operative management in children after renal transplantation.

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CONFLICT OF INTEREST
There is no conflict of interest.

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