Robotic repair of a bilateral renal collecting system duplication: a case report and brief review of renal embryology

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ABSTRACT

A 25-year-old male presented with a history of chronic urinary tract infections, pyelonephritis, and bilateral upper pole hydronephrosis due to bilateral renal collecting system duplication. A bilateral renal collecting system duplication is a relatively rare abnormality and is often associated with an obstructed, poorly functioning upper pole moiety. Here, we report this rare case including surgical management via the robotic laparoscopic method, and we briefly discuss the embryological development of the kidney and collecting system.

INTRODUCTION

Duplication of the renal collecting system has been found in 1 out of 125 autopsies. Bilateral duplication accounts for 20-40% of these instances. Duplication leads to a variety of symptoms; however, the most common include vesicoureteral reflux, ectopic ureterocele, ectopic ureteral insertion, and significant obstruction. Most duplicated collecting systems are diagnosed incidentally as the patient is asymptomatic. When symptoms do occur, however, the patient is much more likely to have a completely duplicated system.

The treatment of symptomatic collecting system duplication is surgery, usually involving upper pole partial nephrectomy. The important principles for optimizing post-partial nephrectomy include maximizing renal mass/volume and minimizing warm ischemia. Potential advantages of robotic-assisted surgery include providing a magnified, 3-dimensional view and articulation of the robotic interface which facilitates precise renal resection. This ability to provide increased visualization and precision allow the surgeon to optimize renal volume preservation. Lengthened warm ischemia time has been shown to induce irreversible diffuse damage in post-operative preserved renal tissue, while cold ischemia has been shown to prevent ischemia to the renal remnant.

CASE PRESENTATION

A 25-year-old male with recurrent bilateral urinary tract infections, pyelonephritis, urosepsis, hydronephritis, and acute and chronic kidney disease. His past surgical history is significant for an abdominal trauma five years prior and complicated by left renal injury that necessitated a prolonged left-sided nephrostomy. At that time, he was found to have bilateral duplication of the renal collecting system and ureters. During his most recent admission, cystography did not demonstrate reflux or ureterocele. Magnetic resonance imaging suggested upper pole ureteral ectopic insertions in the prostate.

Preoperative computed tomography (CT) scans showed severely dilated tortuous ureters bilaterally with ectopic insertions in the prostate. Obstruction was noted at the upper pole moieties with significant
hydronephrosis (Figure 1). CT angiography showed widely patent bilateral renal arteries without arterial occlusion or significant stenosis. A nuclear medicine renal scan showed symmetric flow to both kidneys with split renal function of 64 and 36 percent on the left and right respectively (Figure 2). A staged surgical approach was recommended including an initial right upper pole partial nephrectomy.

**Figure 1.** Computed tomography (CT) imaging. Figure 1A. Coronal CT scan showing bilateral dilation of upper pole renal moieties and hydronephrosis, right (*) greater than left (**). Figure 1B. Coronal CT scan showing severely dilated, tortuous ureters. Figure 1C. Axial CT scan showing dilation of right (*) and left (**) upper pole moieties, hydronephrosis, and dilated ureter (arrow). Figure 1D. Axial CT scan showing severely dilated, tortuous ureter (arrows).
Figure 2. Nuclear medicine (NM) renal scan using mercaptoacetyltriglycine (MAG3) with Lasix interpretation. Figure 2A. NM renal scan displaying absence of radiotracer uptake in right renal upper pole suggestive of nonfunctional status and minimal uptake within the left upper pole. Figures 2B. Tracer uptake suggestive of a split renal function of 64 and 36 percent on the left and right, respectively. Figure 2C. Persistent radiotracer stasis within the collecting systems (right collecting system, dashed curve; left collecting system, solid curve); the administration of Lasix (yellow lines) leads to down-sloping of the curves bilaterally suggesting appropriate responsiveness of the non-obstructive lower poles.

Preoperative electrolytes were normal, serum creatinine was 0.99 mg/dL, and blood urea nitrogen (BUN) was 13 mg/dL. Glomerular filtration rate (GFR) was estimated at 118 mL/min per 1.73 m² using the abbreviated Modification of Diet in Renal Disease (MDRD) study equation.6 Pathology showed marked chronic inflammation that extended into the ureter with associated hydronephrosis, cortical atrophy, and thyroidization. There were no unusual surgical complications. Estimated blood loss was 175 mL and attributed to accessory arterial branches during ureteral dissection. He received one unit of packed red blood cells following a hemoglobin level of 7.8 g/dL. His hospital course was unremarkable, and he was discharged on postoperative day 6. A longer hospitalization than anticipated was attributed to pain control.

Six months later, the patient underwent a left-sided robotic-assisted upper pole partial nephrectomy and ureterectomy of the proximal ureter with cold ischemia. Preoperative electrolytes were normal, serum creatinine was 1.10 mg/dL, and BUN was 11 mg/dL. Estimated GFR was 105 mL/min per 1.73 m². The pathology of the left upper pole was as expected and similar in nature to that of the right. Pathology of the left proximal ureter showed benign circular fibromuscular tissue with scant residual epithelium and chronic inflammation. There were no unusual surgical complications. Estimated blood loss was <50 mL. The postoperative period was uneventful, and he was discharged on postoperative day 2.

At approximately 1-month post-surgery, a follow-up CT showed significant improvement (Figure 3). The right-sided hydronephrosis was markedly decreased and nearly completely resolved. The left-sided hydronephrosis was decreased but remained partially dilated. Ureteral dilation was reduced but still
evident; however, this was to be expected given the relatively abbreviated follow-up time. Electrolytes were normal, serum creatinine was 1.31 mg/dL, and BUN was 14 mg/dL. Estimated GFR was 86 mL/min per 1.73 m².

**Figure 3.** Computed tomography imaging. **Figure 3A.** Coronal CT scan showing near complete resolution of the dilated right upper pole moiety and hydronephrosis (*) and reduced left upper pole dilation and resulting diminished hydronephrosis (**). **Figure 3B.** Axial CT scan showing reduced bilateral hydronephrosis with continued dilation of ureters bilaterally (arrows).

**DISCUSSION**

Bilateral duplicated renal collecting systems and ureters are a rare occurrence. To the best of our knowledge, we have presented one of the few reports of an adult individual involving a bilateral renal collecting system and ureteral duplication that has been corrected via robotic-assisted partial nephrectomies. Others have reported favorable results from robotic-assisted partial nephrectomies in both pediatric7 and adult patients8 with unilateral duplicated collecting systems. These reports and our current experience collaborate the findings of Zargar et al in which robotic partial nephrectomy was found to be potentially superior to the traditional laparoscopic partial nephrectomy approach.9

The renal response observed after this surgery is characteristic of the response we have seen in our robotic partial nephrectomy experience. Our data indicates there is an initial decline in GFR of about 10%, followed by a progressive recovery and near normalization by one month. The etiology of this response is unknown, however, the most obvious potential cause would relate to a direct tubular dysfunction associated anoxia.

Additional mechanisms are possible, and an intriguing potential mechanism involves the cascade of events that results from the oxidative stress that we know is caused by anoxia. There is accumulating evidence that ischemia activates the immune system, and that this activation is both local and systemic, and involves the release of toxic cytokines, including TNF.10,11 Additionally, this release of TNF may activate protective mechanisms in the form of superoxide dismutase.12

This unique case provides the opportunity to discuss the organogenesis of the renal system. The embryological development of the kidney is a tightly regulated process. The embryological development of the renal system stems from intermediate mesoderm on day 22 of embryonic life. Three kidney systems are formed in a cranial-to-caudal sequence: the pronephros, a rudimentary structure; the mesonephros, which functions for a brief time during early fetal development; and the metanephros, which forms the permanent kidney. The metanephros is derived from two sources: metanephric mesoderm and the ureteric bud, an epithelial outgrowth of the Wolffian duct which occurs on day 28. The ureteric bud penetrates the metanephric tissue and dilates to form the renal pelvis, major and minor calyces, and eventually the collecting tubules. The metanephric mesoderm surrounding the ureteric bud will give rise to tubules that, in conjunction with the newly formed glomeruli, form the
nephron. The complex co-inductive process between the collecting ducts and the metanephric tissue is driven by the expression of specific transcription factors, growth factors, and gene networks that, among other effects, stimulate proliferation and branching of the ureteric bud and epithelization of the metanephric mesoderm. Nephrogenesis is complete by 34-36 weeks of gestation.13,14

The development of the duplication of a renal collection system occurs when the ureteric bud, arising from a single Wolffian duct, splits. This splitting results in the formation of two distinct collecting systems with associated ureteral segments that may extend to the bladder or insert ectopically, as in the present case. In general, the bud that arises from the more cranial aspect extends into the upper pole moiety, while the caudally positioned bud extends into the lower pole metanephric mass. The lower pole orifice contacts the urogenital sinus first. Rotational and migration forces result in the lower pole orifice’s final position being lateral and cranial to the final position of the upper pole orifice. In this orientation, the lower pole ureter is more prone to reflux, while the upper pole ureter is more prone to obstruction. The relationship of the upper and lower pole ureters is defined by the Weigert-Meyer rule, which states that the upper pole ureter insertion is medial and caudal in relationship to the lateral and cranially positioned lower pole ureter.15,16,17

CONCLUSION

Congenital abnormalities of the renal collecting systems and/or ureters, such as the present case of a completely duplicated renal collecting system, should be considered in patients with chronically recurring urinary tract infections, pyelonephritis, and obstruction. CT imaging is the study of choice in evaluating changes in kidney and ureteral anatomy, and in skilled hands, robotic-assisted surgery provides an excellent minimally-invasive option due to its precision and enhanced intraoperative visualization.

REFERENCES


