Repair of complex renal artery aneurysms by laparoscopic nephrectomy with ex vivo repair and autotransplantation

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Objective: Renal artery aneurysms are being discovered more frequently due to increased use of non-invasive imaging. Complex renal artery aneurysms involving multiple secondary or tertiary branches are not amenable to in vivo or endovascular treatment and often require ex vivo repair with autotransplantation. In order to minimize incisional morbidity and hasten recovery, we developed a technique of laparoscopic nephrectomy combined with backbench ex vivo repair, followed by autotransplantation through a small laparoscopic extraction incision. This study describes our initial experience with this combined technique in patients that were not candidates for endovascular techniques or in vivo arteriovenous reconstruction.

Methods: Seven patients with complex renal artery aneurysms underwent laparoscopic nephrectomy and ex vivo repair with multiple saphenous vein grafts and autotransplantation through the small laparoscopic extraction incision. The aneurysms ranged from 2.5 to 5.0 cm. In all cases, the aneurysm was resected ex vivo, leaving multiple branch arteries that were extended with saphenous vein grafts. Arterial inflow was then re-established with sequential saphenous vein anastomoses to the external iliac artery. Ureteral reconstruction was performed via standard Lich ureteroneocystostomy. Patients were followed postoperatively for two to eight years.

Results: Laparoscopic nephrectomy with ex vivo repair of complex aneurysms was successfully employed in seven patients with renal aneurysms that were not amenable to endovascular or in vivo repair. There were no incisional morbidities and all patients had significant improvements in symptoms post-operatively. Renal function remained unchanged and there were no ureteral complications following surgery. All patients had postoperative ultrasound imaging done at two years which demonstrated patency of the anastomoses. The mean hospital stay was four days (range, two to seven days).

Conclusion: Repair of complex renal artery aneurysms involving distal branch arteries remains a challenge. This new technique combines the advantages of minimally invasive surgery with the effectiveness of ex vivo aneurysm repair.

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Renal artery aneurysms (RAA) are rare, with the incidence thought to occur in 0.3-1.3% of the population. However, renal artery aneurysms are being incidentally discovered with increasing frequency owing to increased use of non-invasive imaging such as computed tomography (CT) and ultrasound for the evaluation of other conditions. A majority of these patients are asymptomatic. Renal aneurysm rupture does occur in 5% of known aneurysms and is more likely in aneurysms greater than 2 cm in greatest diameter and non-calcified aneurysms. Surgical repair is commonly recommended for symptomatic aneurysms, rapidly expanding aneurysms or those greater than 2 cm in diameter.

Additionally, because of an increased risk of rupture during pregnancy, women of childbearing age should have renal artery aneurysms repaired regardless of size. In the largest collected series to date from the University of Michigan, Henke concluded that surgical treatment of RAA in properly selected patients is associated with both symptomatic improvement (reduction of hypertension and pain) and excellent long-term outcomes.

While open in vivo repair and endovascular stenting techniques are successful for most simple renal artery aneurysms, complex aneurysms occurring beyond the bifurcation of the main renal artery may require extracorporeal arterial reconstruction and with or without division of the ureter to salvage renal function. Some surgeons prefer to leave the ureter intact and perform ex vivo reconstruction on the body wall. However, for the most complex aneurysms that involve secondary and tertiary renal arterial branches, techniques that include division of the ureter allow for meticulous dissection and optimal cryopreservation and surgical visualization. Historically, autotransplantation has been associated with significant incisional morbidity, as an incision large enough to accommodate both nephrectomy and transplantation of the kidney is needed. This has usually involved an incision along the bed of the twelfth rib extending down to the pelvis.

Laparoscopic donor nephrectomy has become widely accepted as the least morbid technique for living renal donation. This technique results in lower morbidity and shorter convalescence when compared with the traditional open surgical technique. In order to reduce postoperative incisional morbidity associated with open renal artery aneurysm repair and autotransplantation, we utilized...
laparoscopic nephrectomy and ex vivo repair of complex renal artery aneurysms, followed by autotransplantation to provide a minimally invasive approach for repair of renal artery aneurysm. Although the technique has been previously reported, we present our series of laparoscopic nephrectomy combined with backbench ex vivo repair and autotransplantation for repair of complex renal aneurysms.

METHODS

We studied the outcomes of patients referred to our university center with complex renal artery aneurysms involving secondary and tertiary branches. Our IRB protocol, H-29472 was marked exempt by the Institutional Review Board of the University of Maryland School of Medicine. The patient population studied included seven patients who had complex renal aneurysms treated with laparoscopic nephrectomy, back-bench repair, and autotransplantation. An eighth patient referred for treatment of a renal artery aneurysm had to be treated via a standard open repair because of prior placement of renal artery stent in the proximal renal artery, precluding placement of an endoscopic stapler. This patient is not included in this series. All aneurysms were saccular and greater than 2 cm in largest diameter. All aneurysms were distal to the first or second renal artery branches, thus involving the secondary or tertiary renal arterial branches. As part of the initial work-up, patients underwent a variety of diagnostic tests including ultrasound, magnetic resonance angiography (MRA), and computed tomography angiography. Angiograms were performed in all patients to document aneurysmal involvement of secondary and tertiary branches (Fig 1). Based on the branch artery involvement, aneurysms were determined to be not amenable to standard treatment modalities such as in vivo or endovascular repair.

In all cases, the aneurysm was resected in a saline slush basin leaving multiple branch arteries. The branch arteries were then extended with three separate saphenous vein grafts. Autotransplantation was accomplished through the small laparoscopic extraction incision overlying the iliac fossa ipsilateral to the aneurysm (Fig 2A). Arterial inflow was then re-established via saphenous vein graft anastomoses to the external iliac artery and urinary reconstruction was via standard Lich ureteroneocystostomy.

Procedure details. The patient was placed in a lateral decubitus position with the affected side up. After establishing pneumoperitoneum, laparoscopic ports were then placed as previously described for donor nephrectomy. Laparoscopic dissection was initiated by reflecting the bowel and gaining access to the retroperitoneum. A standard donor nephrectomy was then performed. The renal vessels were then divided laparoscopically with an endovascular gastrointestinal anastomosis stapler. The ureter was then divided at the level of the iliac vessels. To provide access to the bladder and iliac vessels, a curvilinear incision in the lower abdominal quadrant, known as a Gibson extraction incision, was made, which also served to complete autotransplantation after back bench repair. The kidney was then extracted with an endocatch bag through the Gibson incision. The backbench preparation of the kidney begins with careful dissection along the renal artery to the level of the aneurysm. The renal vein is then isolated and all side-branches are ligated. The aneurysm is then resected, leaving the stumps of secondary or tertiary branches (Fig 2). These are reconstructed with reversed saphenous vein grafts (Fig 3). Through the extraction incision, open surgical dissection of the external iliac artery, vein, and urinary bladder is performed to prepare the site for autotransplantation. Autotransplantation is relatively straightforward with the exception of requiring three end to end anastomoses.
between the external iliac artery (created using 4.8 mm punch biopsies) and the saphenous vein grafts to complete ilio-renal bypass times three. The Lich-Gregoir ureteroneocystostomy is then performed by placing a continuous suture around the spatulated circumference of the ureter and cystostomy mucosal layer, with closure of the mucosal layer over the anastomosis to prevent reflux (Fig 4). The kidney is then placed in a hilum medial position and the wound is closed in standard fashion.

RESULTS

Seven patients with renal artery aneurysms distal to the renal artery bifurcation underwent laparoscopic nephrectomy and ex vivo aneurysm repair with subsequent auto-transplantation between 1998 and 2006. Four females and three males, 54 to 77 years old (median age, 62 years) were referred to our university for evaluation of complex renal artery aneurysms. Other than hypertension, the patients all had few additional comorbid conditions. Specifically, two of the patients had a remote history of cancer (breast and colon, respectively) and one additional patient had both insulin-dependent diabetes mellitus and chronic obstructive pulmonary disease. Of note, one patient had a solitary kidney since birth.

The diagnosis of renal artery aneurysm was made incidentally in two of the patients who were undergoing evaluation for other conditions, and was discovered during workup of the remaining five symptomatic patients. Symptomatic patients had hematuria, flank pain, or both. Preoperatively, all patients had hypertension with baseline creatinine values ranging from 0.6 to 1.2. Patients’ arterial blood pressures were measured preoperatively using a standard sphygmomanometer placed on the upper arm. Two measurements were obtained in bilateral upper extremities by our preoperative nursing staff. Blood pressures ranged from 140 to 180 systolic over 60 to 90 diastolic. Patients were all taking a beta-blocker and the majority (five of seven patients) were also taking additional anti-hypertensive medications, including angiotensin-converting enzyme inhibitors and calcium channel blockers.

Patients were followed at yearly intervals for two to eight years and more frequently as clinically indicated. All patients underwent a renal duplex within the first postop-
erative week as well as at two years. All ultrasound exams performed at the two-year postoperative visit demonstrated patent anastomoses with good renal blood flow. Three patients had additional MRA imaging performed at four, five, and eight year intervals, respectively. These duplex ultrasounds demonstrated patent vessels as did the MRA (Fig 5).

Fig 4. A, Illustration depicting reimplantation of the kidney following successful arterial, venous and ureteral anastomoses. B, Successful ileo-renal bypass following nephrectomy and aneurysmectomy.

Fig 5. Representative magnetic resonance angiography performed to evaluate for pseudoaneurysm in a postoperative patient 10 years following laparoscopic nephrectomy and ex vivo aneurysm repair and autotransplantation. Three patent anastomoses between the saphenous vein graft extensions and the external iliac artery are illustrated.

erative mortalities at one year. Renal function remained unchanged in all of the patients postoperatively. Median preoperative creatinine level was 0.8 mg/dL. Postoperatively, the median creatinine level was 0.9 mg/dL. Minor postoperative complications included wound infection (14%) and small bowel obstruction requiring reoperation (14%). Mean intraoperative blood loss was 350 cc and no patients required transfusion. The mean length of hospital stay was five days (Table).

DISCUSSION

Repair of renal artery aneurysms, particularly involving branch arteries, remains a challenge. Currently, operative indications are limited to those patients with renovascular hypertension (uncontrolled), lesions greater than two cm in diameter and women of childbearing age. Although the majority of these aneurysms are located in the main renal artery, some are located distal to the bifurcation. Owing to the technical difficulty in treating complex branch aneurysms, there is no current consensus regarding standard operative treatment for these lesions. In this article, we detail our experience using this technique that has been recently described. The use of laparoscopic nephrectomy reduced the incisional morbidity, allowing for the treatment of an elderly patient (age 77 years) with a very short length of stay (two days). Previously, these cases required a mini-thoracoabdominal incision based on the twelfth rib extending in a curvilinear fashion into the pelvis. The laparoscopic approach eliminates the proximal portion of the incision over the bed of the twelfth rib, in turn, reducing postoperative chronic pain, which occurs in 5-15% of patients after open donor nephrectomy through the twelfth rib bed.

The association of renal artery aneurysms with hypertension has been well documented in numerous studies. We found this association in six out of seven of our patients.
Potential reasons for this association include segmental ischemia secondary to microemboli or loss of blood velocity (kinetic energy) in the aneurysm.\textsuperscript{1} Postoperatively, hypertension was controlled in all seven cases, as expected, based on previously reported data.\textsuperscript{21} Thus, successful surgical revascularization plays an important role in improving renal hemodynamics.

Current surgical revascularization techniques for renal artery aneurysms include aneurysmectomy followed by simple arterial repair, in-situ segmental resection with end to end anastomosis, and extracorporeal bench aneurysmectomy with reconstruction and autotransplantation.\textsuperscript{7,22} These first two techniques are often not feasible for repair of complex branch aneurysm, and traditional ex vivo repair and autotransplantation are associated with significant incisional morbidity. Although renal artery reconstruction ex vivo with the ureter intact eliminates the risk of ureter leak and late stricture, these cases were technically challenging and required increased ex vivo time and therefore optimal cryopreservation provided by ureteral division and reimplantation allowing for optimal cryopreservation and longer back-table operative times. The urologic rate of complications associated with the ureteral reimplantation (Lich-Gregoir ureteroneocystostomy) is low (3.3%) and includes leak (1.3%), stenosis (1%), obstruction (0.1%), and necrosis (0.4%).\textsuperscript{28} In this study, we report our initial experience with a new technique using laparoscopic nephrectomy with ex vivo backbench repair for complex renal artery aneurysms not amenable to current conventional treatment. Repair of aneurysms utilizing this new technique was done in order to avoid nephrectomy, since these aneurysms were not treatable using conventional repair options. This technique was successfully used in seven cases where complex renal artery aneurysms occurred distal to the bifurcation of the renal artery. There were no mortalities and all patients experienced improvement in symptoms postoperatively. Complex renal artery aneurysm repair using laparoscopic nephrectomy with ex vivo repair and autotransplantation is safe and feasible.

**AUTHOR CONTRIBUTIONS**

Conception and design: SB, KG  
Analysis and interpretation: SB, KG  
Data collection: TS, KG  
Writing the article: KG, SB  
Critical revision of the article: SB, KG  
Final approval of the article: SB, TS, MP, KG  
Statistical analysis: KG  
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