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Interventional and Surgical Treatments for Renal Artery Aneurysms

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Abstract

Renal artery aneurysm (RAA) is an infrequent entity. Most of them are asymptomatic, but when they present as a rupture a high mortality is associated. Due to the potential risks of rupture and renal dysfunction and some persistent symptoms like hypertension, RAAs must be treated if feasible. Coil embolization or covered stent placement can now be used to treat patients with aneurysms whose size or location would make a surgical approach problematic and patients in whom surgery is considered to pose considerable risk. However, many aneurysms in renal artery branches are not suitable for this management and nowadays surgical repair remains an important approach.

Keywords

Renal artery aneurysm, Treatment, Endovascular treatment, Surgery

Introduction

Renal artery aneurysm (RAA) is a rare entity and is defined as a dilated segment of renal artery that exceeds twice the diameter of a normal renal artery [1]. It is often diagnosed incidentally and has been detected more commonly as increased CT (computerized tomography) and MRI (magnetic resonance imaging) examinations for other non-related diseases. Renal artery aneurysms are more frequent in those patients with fibromuscular dysplasia, atherosclerosis [2-4] and are also associated with neurofibromatosis, renal Behçet's disease, polyarteritis nodosa, and Ehlers-Danlos syndrome [3-5]. Most patients are asymptomatic. However, hypertension is the main manifestation in these patients [6-10]. There are five major types of renal aneurysms, namely, saccular, fusiform, dissecting, intrarenal, and pseudoaneurysm. The majority is saccular at the main renal bifurcation (60% - 100%) where congenital abnormalities are most common and the plaques found by microscopy may be reactional to flow disturbances [11].

The natural history of RAA is generally benign. Rupture is the most serious complication and occurred reportedly during pregnancy. While most RAAs are detected incidentally, a useful diagnostic tool is ultrasound with color Doppler imaging and contrast-enhanced CT or magnetic resonance angiography [6]. The decision for intervention has to take into account the size and the natural history of the lesion, the risk of rupture, which is high during pregnancy, and the relative risk of surgical or radiological intervention. For most asymptomatic aneurysms, expectant treatment is acceptable [7-10].

While there are still controversies on the size indication for RAA to get interventional or surgical treatment since some studies showed that the rupture incidence is low for those < 2.5 cm in size [12,13], indications for interventional or surgical repair of RAAs generally include: (1) rupture, (2) renovascular hypertension (HTN), (3) dissecting aneurysm, (4) expanding aneurysm, (5) thrombotic aneurysms, (6) maximal diameter > 2.0 cm, (7) women who are pregnant or of child bearing age, (8) significant stenosis, flank pain, or hematuria, (9) patients with hypertension and a solitary functional kidney [7-10].

Over the years, many case reports of interventional and surgical treatments have been presented and be successful, which included endovascular therapy, percutaneous transluminal angioplasty (PTA), vascular reconstructive surgery, and nephrectomy. The RAAs successfully treated included giant RAA, bilateral RAAs, ruptured RAA, RAA on renal allograft, intraparenchymal RAA (IPRAA), RAA coexisted with renal cell carcinoma, etc...[14-112]. Limited studies of long-term follow-up on outcomes showed that there were no significant differences between endovascular repair and open repair [39,74].

Endovascular therapy

The best surgical treatment option is resection of the aneurysm and reconstruction of the artery. However, such an operation carries the risk of morbidity (12%) and mortality (1.6%) [7]. More recently, many reports have described endovascular approaches to treat RAAs, including coil embolization and stent graft coverage. Endovascular management of visceral artery aneurysms is a reasonable alternative to open surgical repair in carefully selected patients and individual anatomic considerations play an important role in determining the best treatment strategy if intervention is warranted [46,113,114]. Coil embolization or covered stent placement can now be used to treat patients with aneurysms whose size or location would make a surgical approach problematic, as well as patients in whom surgery is considered to pose considerable risk [115,116]. With the exception of distal lesions, endovascular repair is the first-line treatment for RAAs in anatomically suitable cases. Only very few complications were noted, which include microrenal infarction, lateral abdominal pain, fever, and coil migration [114,117-119].

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Embolization: The materials for embolizing could be Gianturco coils [120], Platinum coils [121], Guglielmi detachable coils (GDCs) [122], interlocking detachable coils (IDCs) [120]. In some occasions polyvinyl alcohol [120], thrombin, or bucrylate [120] was added.

This approach may generally be applicable for RAAs depending on the shape, size, and location of the aneurysm [118]. Coil embolization was reported to be successful in different RAAs [6,118] including large RAAs [123], coexistent RAA and arteriovenous fistula [124,125], saccular and proximal RAAs [117], fibromuscular dysplasia-related renal artery stenosis associated with aneurysm [2], ruptured RAA from Behçet's disease [2], some RAAs near the renal hilum [126], and intraparenchymal RAAs (IPRAAs) [127]. The embolization led to improved blood pressure, renal function, and symptoms such as flank pain [128].

Comparison of different materials used for embolization: Endovascular embolization of RAAs by means of detachable balloons, non-detachable steel coils and particulate agents have been reported previously. However, these embolic materials have a major disadvantage in that they occlude not only the aneurysm, but also the parent artery. Furthermore, these devices require the use of a stiff microcatheter which carries the risk of aneurysm rupture. In contrast, detachable coils can be withdrawn easily before detachment if the coil herniated out of the aneurysm, which helps to avoid serious complications such as renal artery occlusion. The RAA could be embolized without occlusion of the renal artery using IDCs [120,129].

One study evaluates the efficacy and safety of endovascular occlusion of true RAAs with conventional non-detachable microcoils (NDCs) and GDCs. Superselective endovascular treatment of RAAs with microcoils is a safe, efficient, and less invasive alternative to surgical treatment. The high flexibility and softness of the GDC and the controlled detachment enables a safer and more complete occlusion of RAA [122]. The main advantage of GDCs and IDCs is controlled detachment which allows for precise placement and thus a successful, safe procedure. This capability and the flexibility and softness of the coils enable one to pack an aneurysm densely and to isolate it from the parent vessel without the risk of rupture. These two devices differ in the mechanism of detachment. GDCs use an electric current for detachment, and thus no mechanical force is necessary to detach the coils. In contrast, a disadvantage of the GDC is that detachment is not instantaneous. IDCs are better suited for embolization of giant RAAs because GDCs are more expensive than IDCs and electrothrombosis is not necessary. In conclusion, endovascular embolization should be considered as the primary treatment modality for RAA, as IDCs are safe and effective [120]. Selective transcatheter embolization using an interlocking detachable coil had been successful in excluding RAA near the renal hilum [126].

Preserve the native arterial circulation while embolizing: To preserve the native arterial circulation, transcatheter coil embolization with aneurysm packing was used. The procedure includes coil embolization and coil-packing of the aneurysmal sac. Transcatheter coil embolization with aneurysm packing was technically successful in 72.7% patients [117]. The detachable coils also had been shown to embolize RAAs without occlusion of the renal artery [120].

Coil emboliztion for RAA with arteriovenous fistula: Renal arteriovenous fistula (AVF) is rare. Renal AVF complicated by aneurysm of the feeding artery presents a technical challenge for endovascular treatment. One study reported a case managed by covered stenting of the RAA, coil embolization of the fistula, and bare stenting of the aorta [124]. Coil embolization is an alternative to surgery for coexistent RAA and arteriovenous fistula arising from a branch of adequate length for placement of embolic coils. Successful treatment is not limited by aneurysm size or presence of arteriovenous connection [125].

Stent-assisted coiling: Endovascular coil occlusion of narrow-necked saccular sidewall or bifurcation aneurysm is usually straightforward. The use of stent-grafts (or covered stents) is also feasible for exclusion of wide-necked side-wall aneurysms of the main renal artery. However, if the aneurysm involves the arterial bifurcation or even if it is located only a few millimeters distal or proximal to the bifurcation, the stent graft unavoidably occludes the other branch artery because 5-10 mm of healthy artery proximal and distal to the aneurysm neck is mandatory for adequate fixation of the stent-graft and sealing of the aneurysm. Stent assisted coil embolization is currently a widely used technique in the treatment of wide-necked intracranial aneurysms, and the technique has greatly increased the feasibility and utility of endovascular therapy for even the most challenging aneurysms. The preliminary experience indicates that stent-assisted coil embolization is technically feasible and effective for the exclusion of challenging renal artery bifurcation aneurysms without the sacrifice of any branch arteries [130]. In the meantime, stent-assisted coil occlusion assisted by 3-D angiography is a potential renal-sparing endovascular approach to treating wide-necked renal artery aneurysms with complex vascular anatomy [131]. Stent-assisted Coiling is also needed when there is stenosis at the aneurysmal neck necessitating placement of a stent before transcatheter coil embolization [117].

Stent grafting: Technological advances have expanded indications for percutaneous treatment of complex peripheral lesions. A limiting factor in the use of stents in treating of RAAs has been the small-caliber vessels characterized by tortuosity. Normal-caliber artery must be presented proximal and distal to the aneurysm to form a seal zone for the stent graft. Anatomic suitability is crucial to prevent endoleaks [132]. The short-term results of stent grafting are promising [86,114,132-135] even though the long-term durability of endovascular stent grafts requires further study [114]. This excellent result includes ruptured RAA in elderly patients who are hemodynamically stable [135], bilateral RAAs [136], RAA with renal arteriovenous fistula [128], extrarenal transplant pseudoaneurysms (combined use of a thrombotic agent) [137], and renal artery with angulation within the aneurysm [138]. There are very few complications such as stent migration, stent crush, and compromise of the side-branch vessel [132].

Different stents and applications: Autologous saphenous vein-covered stent deployment had been successful in treating a saccular aneurysm on the distal renal artery [134]. A self-expandable polytetrafluoroethylene (PTFE)-covered nitinol stent-graft was deployed in each renal artery to treat the stenoses and to exclude the aneurysm. The Symbiot is a self-expanding monorail nitinol stent covered with ePTFE that is usually used in the coronary district. For this reason the stent has a highly flexible structure, smooth surface and low profile that allow easy advancement in tortuous vessels with fibromuscular alterations across the lesion. The ePTFE cover allows the total exclusion of the sac and endothelization. The use of a self-expanding stent gives high adaptability to the vessel anatomy and the predilation of the stenosis, together with the radial force of the stent, supports the long-term primary patency of the renal artery [139].

Stent therapy for RAA with extreme vessel tortuosity or angulation of the afferent vessel: Certain anatomical settings such as extreme vessel tortuosity or angulation of the afferent vessel continue to pose challenges. New steerable devices may play a crucial role in those cases where conventional techniques have failed. One study reported a case of successful percutaneous treatment of a RAA and stenosis in a young male using the Venture catheter; a ballon-expandable covered stent was then implanted for its exclusion [133]. In another study, one patient who was operated on for an abdominal aortic aneurysm 7 years earlier presented with recently discovered iliac and renal artery aneurysms. The renal artery had an angulation of 90, but the aneurysm was successfully excluded using a covered vascular stent graft placed over an extra stiff guidewire.

Even in cases of complex anatomy of RAA, endovascular treatment should be considered. With development of more flexible and low-profile endoprosthesis with accurate deployment, these have become more usable, even in complex lesions [138].

Percutaneous transluminal angioplasty

Percutaneous transluminal angioplasty was chosen to treat the RAA which was involving the renal artery at the origin of the segmental vessels and was successful in lowering the blood pressure [6]. Percutaneous transluminal angioplasty yields excellent results and is the treatment of choice for patients with fibrous dysplasia of the main renal artery and non-ostial atherosclerotic lesions [140].

Vascular reconstructive surgery

Renovascular reconstruction was successful in salvaging kidneys, including rupture of RAA, fibromuscular dysplasia and RAA that fail or are unsuitable for PTA [141]. For young patients with RAAs from different lesions including fibromuscular dysplasia and neurofibromatosis, surgery remains the best treatment alternative. This provides a durable repair, essential for younger patients affected by this pattern of disease who anticipate a normal life span after renovascular repair. Successful long-term correction of diastolic hypertension and aneurysmal disease was accomplished without significant morbidity [3,4,142]. Very few complications were noted for vascular reconstructive surgery such as reconstructions thrombosed in the early postoperative period [3,4,142]. In a very recent report, three-dimensional printing was reported for preoperative planning of a right prehilar renal artery aneurysm, 21 × 16 × 17 mm that originated from the distal right renal artery and continued as the upper pole segmental artery in a 37-year-old woman. The patient underwent an open repair of the RAA using a reversed, bifurcated right great saphenous vein graft and the surgery was successful [27].

Surgical techniques and conduits: The indications for aortorenal bypass, extra-anatomic bypass, or simultaneous aortic substitution and renal revascularization are based on the cause, location, and extent of the vascular lesion. Techniques of bench surgery mainly depend on location of the renal artery disease and availability of autologous graft material [143]. There are in situ, *ex vivo*, and combined reconstructions. In situ repair primarily with use of the bifurcated internal iliac artery autograft was used for primary lesions of the proximal renal artery bifurcation (two branches). *Ex vivo* repairs, primarily with use of the multibranch internal iliac autograft and hypothermic perfusion preservation, were used for all other patterns of distal renal artery branch disease and reoperative problems [3]. Reconstructions include aneurysmorrhaphy (patch angioplasty, suture exclusion procedures, tailoring technique), saphenous vein, cephalic vein, and segmental renal artery reimplantation. Dacron or composite (vein and hypogastric artery) graft, PTFE, and composite vein/PTFE. Where there is branch involvement, *ex vivo* repair is the procedure of choice for renal salvage [7,26,143-146]. In detail, methods applied for reconstruction in aneurysms included aneurysm resection with tailoring, saphenous vein graft interposition, tailoring and saphenous vein graft interposition, resection and reanastomosis, saphenous vein graft interposition and resection and reanastomosis, polytetrafluoroethylene bypass, and homologous vein graft interposition. Some reconstructions had to be performed *ex situ* because of multiple branch involvement and rupture. Surgical reconstruction of RAA is a safe procedure that provides good long-term results, prevents aneurysm rupture, cures or improves hypertension in about half of the cases, and can be achieved with autogenous reconstruction in 96% [7]. Both *ex vivo* and in situ cold perfusion protection extend the safe renal ischemia time for complex branch renal artery repair and avoid the need for nephrectomy [143-146].

While reconstruction of the renal artery with both saphenous vein and prosthetic material as bypass graft is durable in atherosclerotic disease, extensive experience with saphenous vein grafts in pediatric patients and patients without atherosclerosis reveals a disturbing incidence of vein graft aneurysm degeneration. Distal renal artery reconstruction involving small branch vessels is generally not amenable to prosthetic reconstruction. Autologous artery is the preferred conduit for renal reconstruction in the pediatric population. Radial artery was found to be a technically satisfactory conduit for distal renal reconstruction in a patient without atherosclerosis [147].

Surgical measures for different types of RAA: There are different surgical measures for different types of RAAs. All saccular aneurysms were treated with resection followed by reconstruction with vein patch or end-to-end anastomosis. All fusiform and dissecting aneurysms were managed with resection and reconstruction using aortorenal bypass [10].

Bilateral RAA: For bilateral RAAs, most were received repair in a staged approach and others were received repair simultaneously [7,18].

Branch RAA reconstruction: Preservation of functioning renal tissue should be the ultimate goal of renovascular surgery. Branch RA reconstruction includes *ex vivo* cold perfusion, in situ cold perfusion, and warm in situ repair. Where the *ex vivo* technique, when indicated, will achieve favorable results in most patients RAAs were repaired with low morbidity and mortality.

The *ex vivo* reconstructions included vessel plasties, vein and arterial interponates, followed by autotransplantations to the iliac fossae. Because of advances in organ preservation, nephrectomy, *ex vivo* repair, and autotransplantation is a safe and successful procedure. This technique has been successful in past 4 decades [7,145,148-153], including ruptured or unruptured RAAs in solitary kidney [144], RAA associated with surgical treatment of abdominal aortic aneurysm [145], RAA with arteriovenous fistula [151], IPRAAs [127], and RAAs in renal grafts for renal transplantation [152].

Advantages of *ex vivo* repair: Extra corporeal replacement of the renal artery for the treatment of complex renal artery diseases offers numerous advantages: safe approach for the branches of the renal artery and division of the intra-hilar arteries, easy repair and sutures, excellent quality of intra-operative arteriogram, easy repair of venous damage, excellent renal preservation [154], and long-term results including patency were encouraging [30]. Despite the seeming complexity of *ex vivo* vascular reconstruction, branch RAA repair using cold perfusion preservation and *ex vivo* techniques resulted in no unplanned nephrectomy, with an estimated primary patency of 96% at 48 months. Beneficial blood pressure response was observed in the majority of hypertensive patients [7].

Laparoscopic donor nephrectomy: Studies have demonstrated the morbidity of laparoscopic donor nephrectomy (LDN) to be less than that with an open donor nephrectomy (ODN) while the long-term renal graft function was equivalent to that of ODN. In particular, LDN is more suitable for obese patients. We therefore selected this technique for LDN in the present case. Laparoscopic nephrectomy and *ex vivo* repairs are both considered being effective for treating complex RAA [148].

Robotic-assisted laparoscopic approach: Robot-assisted laparoscopic technique may be a valid alternative to open surgery in complex cases. In a case report, an expanding 2.5 cm left-sided RAA was exluded by using a robotic-assisted laparoscopic approach. Using the da Vinci surgical robotic system, the aneurysm was resected and the anterior-inferior branch of the renal artery was reconstructed with an end-to-end anastomosis. Follow-up imaging and functional analysis demonstrated resolution of the aneurysm and preservation of renal function [155]. In another case report, a 41-year-old woman had an accidentally discovered saccular aneurysm of the right renal artery with a maximum diameter of 20 mm, with one in and four out. A laparoscopic robot-assisted approach was planned. Intraoperatively, they confirmed the strategy to group the four output branches in two different patches. Thus, a Y-shaped autologous saphenous graft was prepared and introduced through a trocar. For the three anastomoses, a polytetrafluoroethylene running suture was preferred. No intraoperative or postoperative morbidity was noted. A CT scan performed 2 months later revealed the patency of all the reconstructed branches [81]. Robot-assisted laparoscopic RAA repair with selective arterial clamping was also reported successful in the management of a 1.6 cm right-sided renal artery aneurysm in a 35-year-old man who presented with flank pain [76].

Simultaneous reconstruction of infrarenal abdominal aorta and renal arteries: Simultaneous reconstruction of infrarenal abdominal aorta and renal arteries is needed when there are aortic aneurysms including the renal arteries. The right tributaries of the aorta, the hepatic artery, the renal artery and the common iliac artery are only easily approached by a transperitoneal route. So intra-abdominal method was chosen [155].

Nephrectomy

In the setting of ruptured RAA persistent bleeding and refractory hypotension, very large RAA, difficulty in removing the aneurysm with preservation of the involved renal unit, early failures of repair, unreconstructable renal arteries, RAA in a poorly functioning kidney with hypertension, and if there is normal contralateral kidney, nephrectomy was indicated [7,11,123,142,143,156,157]. Partial nephrectomy by the laparoscopic approach has been proposed for managing IPRAAs and the procedure is considered feasible and safe [127].

Future Research Direction

Although the many reports of successful treatment using interventional and surgical approaches for RAAs, indication of treatment should be decided only when the benefit of treatment outweighed the risk of rupture [13,53]. In the future, we can do research to investigate which type of RRA is more prone to rupture and which type of RAA should be followed-up. Calcification of arterial wall of RAA has been proposed to be a protective factor against rupture but there are still arguments [13,53,158,159]. Over sizing of stent graft and endoleak have been reported after treatment for other types of aneurysm [160,161]. It is worthwhile to carry out a study to investigate which size of stent is most appropriate for RAA treatment to prevent the rupture and endoleak. Also, in reference to outcome after endovascular repair of aortic aneurysm [162], post-operative medication after endovascular or surgical treatment of RAA could significantly improve long term patency without significant increase in endoleak, warranting further research.

Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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