REVISTA
MEXICANA DE
ANGIOLOGÍA

PERMANYER

Check for updates

CASE REPORT

3D printing and hybrid approach for renal aneurysm in fibromuscular dysplasia treatment

Impresión 3D y enfoque híbrido para el tratamiento del aneurisma renal en la displasia fibromuscular

Juan D. Zafra-Angulo[1], Elena Marín-Manzano[1], Lucia Fernández-Rodríguez[1], Teresa Hernández-Cabrero[1], Cristina De Castro-Guerín[1], Jose Ma. Alonso-Dorrego[1], and Lucas Ribé-Bernal[2]*

[1]Department of Angiology and Vascular Surgery, Hospital Universitario La Paz, Madrid, Spain; [2]Department of Cardiothoracic and Vascular Surgery, Memorial Hermann Hospital, UTHealth, Houston, TX, USA

Abstract

Renal artery aneurysms (RAAs) are rare but clinically significant, frequently associated with renovascular hypertension and conditions such as atherosclerosis and fibromuscular dysplasia (FMD). Optimal management depends on aneurysm location, vascular anatomy, and prior interventions. Our objective was to describe a hybrid surgical approach using three-dimensional (3D) printing for preoperative planning in a complex RAA associated with FMD. Clinical history, imaging, and laboratory data were reviewed. A patient-specific 3D-printed renal vascular model was created to guide surgical strategy. The procedure involved renal autotransplantation with ex vivo aneurysm repair. A 24-year-old man with refractory renovascular hypertension and bilateral RAAs due to suspected FMD previously underwent balloon angioplasty, stent placement, and coil embolization. Recurrence and new stenosis required multidisciplinary reassessment. Guided by the 3D model, right renal autotransplantation with ex vivo aneurysm resection and great saphenous vein graft reconstruction was performed. Recovery was uneventful, renal function normalized, hypertension resolved, and imaging confirmed graft patency without recurrence. Histology confirmed FMD. Renal autotransplantation with ex vivo repair and pantaloon graft reconstruction achieved excellent outcomes and durable graft patency.

Keywords: *Renal artery. Aneurysm. Printing. Three-dimensional. Fibromuscular dysplasia.*

Resumen

Los aneurismas de la arteria renal (AAR) son poco frecuentes pero clínicamente relevantes, asociados a hipertensión renovascular y a patologías como aterosclerosis y displasia fibromuscular (DFM). Su manejo requiere evaluar la localización, anatomía vascular y tratamientos previos. Nuestro objetivo fue describir un abordaje quirúrgico híbrido con planificación mediante impresión 3D en un AAR complejo secundario a DFM. Se revisaron antecedentes clínicos, estudios de imagen y laboratorio. Se elaboró un modelo vascular renal en 3D para planificar la cirugía. Se realizó autotrasplante renal con reparación ex vivo. Hombre de 24 años con hipertensión renovascular refractaria y AAR bilaterales por sospecha de DFM, tras fracaso del tratamiento endovascular inicial. La evaluación multidisciplinaria y el modelo 3D guiaron un autotrasplante renal derecho con resección ex vivo del aneurisma y reconstrucción con vena safena. La evolución fue favorable, con normaliza-

***Correspondence:**
Juan D. Zafra-Angulo
E-mail: zafraangulo.juan@gmail.com

Date of reception: 09-03-2025
Date of acceptance: 06-12-2025
DOI: 10.24875/RMA.25000007

Available online: 25-03-2026
Rev Mex Angiol. 2026;54(1):40-44
www.RMAngiologia.com

ción de la función renal, resolución de la hipertensión y adecuada permeabilidad del injerto. La histología confirmó DFM. El autotrasplante renal con reparación ex vivo e injerto en pantalón logró resultados clínicos satisfactorios y permeabilidad duradera.

Palabras clave: *Arteria renal. Aneurisma. Impresión. Tridimensional. Displasia fibromuscular.*

Introduction

Visceral aneurysms, accounting for about 5% of intra-abdominal aneurysms, include renal artery aneurysms (RAAs), with a prevalence of 0.1 to 1%[1], often detected incidentally during radiological examinations.

The primary causes of visceral aneurysms include atherosclerosis or degenerative processes, leading to the weakening of arterial walls' elastic fibers, muscles, and medial layers. In addition, conditions such as fibromuscular dysplasia (FMD), collagen disorders, inflammation, and genetic anomalies contribute to their development[2].

Renovascular hypertension, primarily caused by renal artery stenosis due to FMD or atherosclerosis, manifests as a predominant symptom, especially in young individuals. Therefore, arterial hypertension is a crucial indication for treatment in such cases.

Advances in diagnostic imaging have revealed a low rupture rate of RAA, estimated at 5%, with associated mortality rates below 10%. Consequently, surgical intervention now considers a minimum aneurysm diameter of 30 mm, symptomatic patients or refractory hypertension and renal stenosis, and pregnant women regardless of size[2,3].

Once surgical criteria are met, various treatment options become available. These include less invasive endovascular techniques such as embolization or stenting and open surgical approaches such as aneurysm resection, aorto-renal, spleno-renal, or hepato-renal bypass, nephrectomy, and renal autotransplantation. This last technique is widely accepted when endovascular treatment is not suitable or has failed.

The aim of our study was to describe the specific technique involving pre-operative planning with three-dimensional (3D) model printing, as well as renal autotransplantation with *ex vivo* repair for a symptomatic complex renal artery aneurysm. Before the publication of this manuscript, we obtained signed authorization from the patient to disclose this clinical case and associated information.

Case report

This case report was conducted in accordance with the CAse REport guidelines. Clinical data were collected through a detailed review of the patient's medical history, including previous diagnoses, treatments, and relevant comorbidities. Laboratory and radiological studies were reviewed to support the diagnostic process. All data were anonymized to ensure patient confidentiality.

We present the case of a 24-year-old male diagnosed with poorly controlled renovascular hypertension despite treatment with three different antihypertensive medications. The patient had no history of prior surgical or endovascular interventions and exhibited normal kidney function. Computed tomography (CT) imaging revealed a 22 mm saccular RAA in the right renal hilum and a 20 mm saccular RAA in the left renal hilum, prompting suspicion of FMD (Fig. 1).

Initial management involved satisfactory balloon angioplasty (5 × 40 mm) of the right renal artery by interventional radiology. Subsequently, detailed angiography of the left RAA identified two different arteries. Three months later, the left RAA underwent treatment with a flow-diverting stent (5 × 40 mm) and coil embolization within the aneurysmal sac. Follow-up angiography revealed patency of the distal left renal artery and new stenosis in the previously treated right renal artery (Fig. 1A).

Given the patient's profile and the complexity of the case, it was discussed in our multidisciplinary committee, comprising transplant surgeons, urologists, and vascular surgeons. Considering factors such as the patient's age, refractory hypertension, bilateral renal artery pathology, and prior treatment failures, our primary objective was kidney preservation. Utilizing 3D printing (®Elegoo Mars 2 Pro 3D printer, approximately 100 mL of rapid resin, and a printing time of 3 h, Figs. 1 B-D) for enhanced anatomical visualization, various treatment options were discussed, including prosthetic bypass, autologous bypass, and separate artery reimplantation. Finally, the selected plan of treatment involved autotransplantation, *ex vivo* aneurysm resection, and grafting with the great saphenous vein (GSV), potentially incorporating reimplantation of an inferior polar renal branch.

Surgical intervention was performed through a right oblique retroperitoneal approach, with resection of the

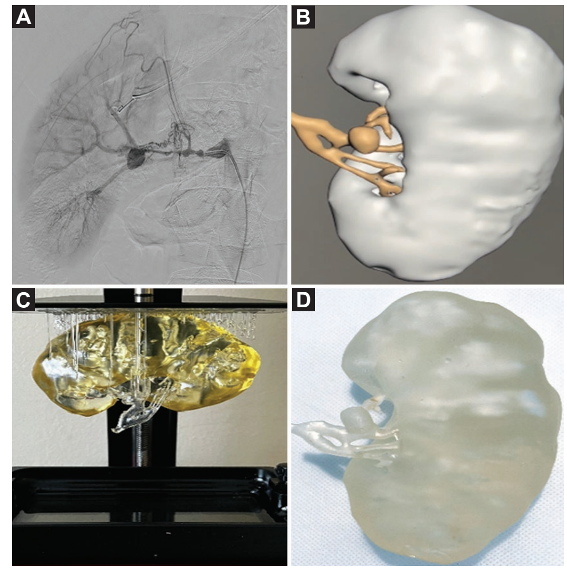

Figure 1. Composite image. **A:** angiography revealing a new stenosis in the previously treated right renal artery. **B:** pre-operative 3D model planning and segmentation. **C** and **D:** three-dimensional printed model including the right renal aneurysm in a posterior view.

aneurysm and creation of a pantaloon vein (GSV) graft due to the suitable diameter and patency of a polar renal branch and the right renal artery. The kidney was reimplanted at the level of the right external iliac artery using the same incision, following the standard surgical technique routinely performed by the urology team (Fig. 2). The total cold ischemia time during the repair and implantation was 90 min.

Histopathological examination of tissue samples confirmed the presence of FMD.

Postoperatively, the patient experienced transient acute kidney failure, which resolved with subsequent normalization of renal function and improvement of the intrarenal resistance index. Dual antiplatelet therapy was initiated and maintained, whereas antihypertensive medications were gradually tapered off and completely discontinued within 2 weeks post-surgery.

Magnetic resonance angiography screening ruled out aneurysms in other locations and confirmed satisfactory mid-term (4-month follow-up) patency of the right renal autotransplantation without stenosis, along with patency of the vascular graft (Fig. 3). Over a 15-month follow-up period, serial Doppler ultrasound evaluations consistently demonstrated sustained graft patency.

Discussion

RAAs are a relatively uncommon vascular condition characterized by low rates of growth and rupture. Recently, when the surgical risk is deemed low, a treatment threshold of 30 mm in diameter or the presence of a saccular morphology has been established. In addition, treatment may be considered regardless of aneurysm size in patients presenting with refractory hypertension, concomitant renal artery stenosis, or pregnant women, regardless of size[2,3].

FMD, primarily affecting young women, is an idiopathic pathology involving small and medium vessels, leading to stenosis, dissection, or aneurysm formation due to muscular layer injury. Clinical presentation varies based on the type, location, and severity of the vascular lesion, with renovascular hypertension commonly observed in cases involving the renal arteries[4].

About 60% of patients with RAA present with renovascular hypertension, and 66% are associated with renal artery stenosis. Treatment is indicated for uncontrolled arterial hypertension or impaired kidney function, with successful outcomes seen in approximately 67% of treated patients[5].

No clear superiority has been established between open surgical repair and endovascular treatment in the literature. Surgical approaches include *ex vivo* and *in situ* repairs, whereas endovascular techniques involve aneurysm exclusion using covered stents or embolization of the aneurysmal sac. The choice of treatment depends on factors such as aneurysm location, with endovascular treatment typically preferred for main renal artery involvement and open surgery for distal and branched aneurysms[6,7].

Autotransplantation is a well-established technique for treating RAA in patients with FMD when endovascular methods are not viable, have failed, or when severe complications arise from such treatments. This procedure typically has low morbidity and mortality rates, with secondary nephrectomy required in approximately 20% of cases. Endovascular treatment may be appropriate for selected patients; it often necessitates a second procedure in 34% of cases due to incomplete exclusion of the aneurysmal sac[8].

While endovascular techniques such as embolization and covered stents are commonly used, they carry a risk of end-organ ischemia, particularly in cases with complex anatomy. The emergence of flow-diverting stents, initially designed for intracranial arteries, has

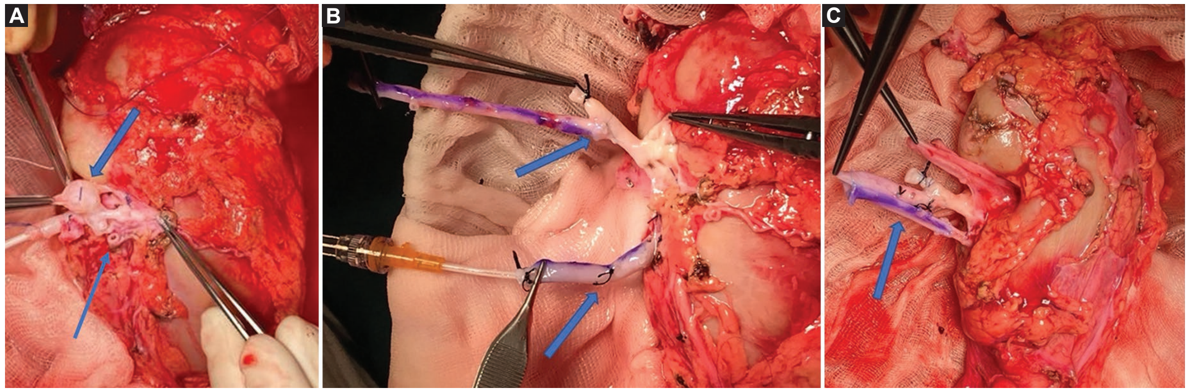

Figure 2. Right kidney, posterior view. Intraoperative image **(A)** of right renal artery aneurysm (big arrow) and inferior polar renal branch (small arrow). Great saphenous vein graft (GSV). **(B)** to the inferior polar renal branch (big arrow) and GSV graft to the right renal artery (small arrow). **(C)** Pantaloon vein graft.

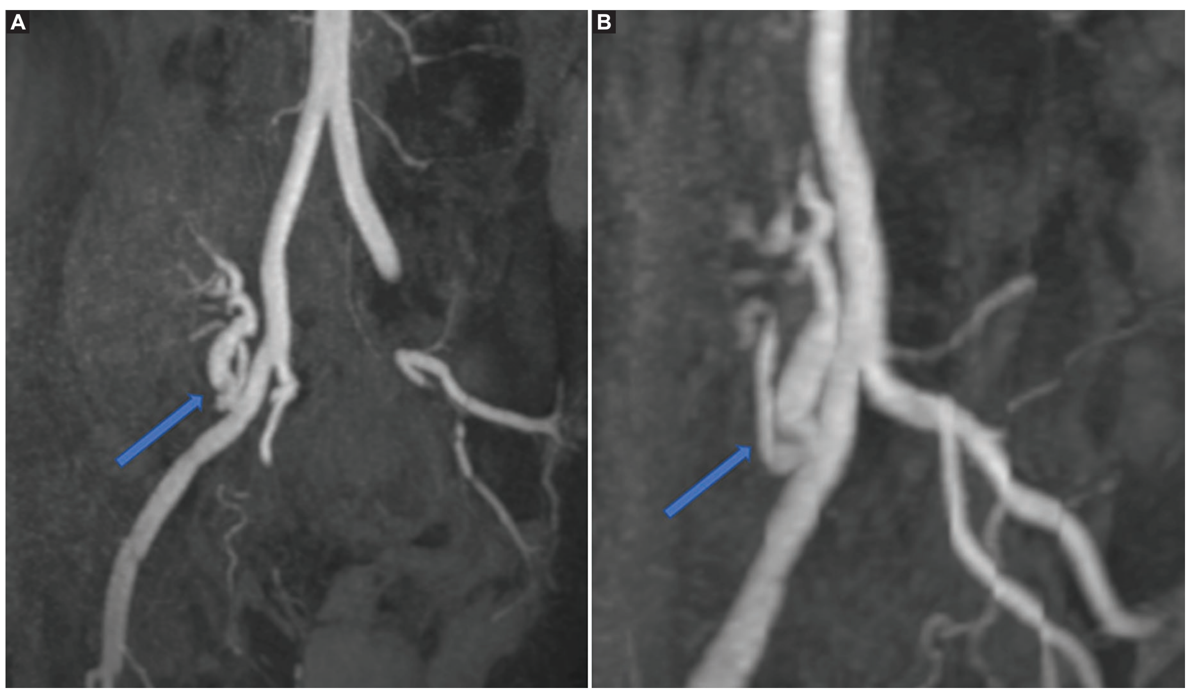

Figure 3. Post-operative magnetic resonance angiography. In panel (**A**), the pantaloon vein graft is observed with patency of the right renal artery, and inferior polar branch (**B**).

expanded their application to other locations, offering benefits such as vessel wall reconstruction and arterial branch patency preservation[9].

Advancements in radiological diagnosis, coupled with the use of models and 3D printing, have revolutionized our ability to analyze complex anatomical structures. This technology allows for a detailed understanding of individual patient anatomy, facilitating precise surgical planning and enhancing training methodologies[10,11].

In our case, the use of 3D printing was essential in the surgical planning of this complex parahilar renal artery aneurysm. The 3D model provided an accurate, tactile representation of the patient's unique vascular anatomy, particularly highlighting the relationship between the aneurysm and its associated branches. This enhanced visualization allowed the surgical team to identify and preserve a viable inferior polar artery and to plan a pantaloon vein graft reconstruction that would otherwise have been difficult to anticipate from imaging alone. As a result, the multidisciplinary team was able to confidently opt for renal autotransplantation with *ex vivo* repair, rather than proceeding with nephrectomy or other surgical treatments. The 3D model facilitated pre-operative simulation, intraoperative orientation, and ultimately contributed to kidney preservation and a successful surgical outcome.

Conclusion

RAA is often associated with FMD and refractory systemic hypertension. The use of a multidisciplinary approach, alongside diagnostic tools such as CT scan, arteriography, and 3D printing, is essential for precise surgical planning, particularly in cases involving complex anatomy, distal branches, or prior interventions at the renal hilum level.

This comprehensive approach provides significant benefits in determining the best treatment strategies, identifying potential limitations, and mitigating complications. In our case, pre-operative planning guided by radiological studies and 3D model printing played a crucial role in selecting the most appropriate intervention for our patient. Multidisciplinary collaboration is essential to achieve the most effective treatment options, potentially combining various approaches for an optimal outcome.

Funding

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical considerations

Protection of humans and animals. The authors declare that no experiments involving humans or animals were conducted for this research.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

References

1. Zhang LJ, Yang GF, Qi J, Shen W. Renal artery aneurysm: diagnosis and surveillance with multidetector-row computed tomography. Acta Radiol. 2007;48:274-9.
2. Chaer RA, Abularrage CJ, Coleman DM, Eslami MH, Kashyap VS, Rockman C, et al. The society for vascular surgery clinical practice guidelines on the management of visceral aneurysms. J Vasc Surg. 2020;72:3-39.
3. Koelemay MJ, Geelkerken RH, Kärkkäinen J, Leone N, Antoniou GA, De Bruin JL, et al. Editor's choice - European society for vascular surgery (ESVS) 2025 clinical practice guidelines on the management of diseases of the mesenteric and renal arteries and veins. Eur J Vasc Endovasc Surg. 2025;70:153-218.
4. Li K, Cui M, Zhang K, Liang K, Zhai S. Clinical characteristics and long-term outcomes of endovascular treatment of renal artery fibromuscular dysplasia with branch lesions. Pediatr Nephrol. 2021;36:3169-80.
5. Martin RS 3rd, Meacham PW, Ditesheim JA, Mulherin JL Jr., Edwards WH. Renal artery aneurysm: selective treatment for hypertension and prevention of rupture. J Vasc Surg. 1989;9:26-34.
6. Pfeiffer T, Reiher L, Grabitz K, Grünhage B, Häfele S, Voiculescu A, et al. Reconstruction for renal artery aneurysm: operative techniques and long-term results. J Vasc Surg. 2003;37:293-300.
7. Irsara S, Russo F, Ferretto L. *In situ* treatment of branch renal artery aneurysms with pantaloon vein graft. Vasc Endovascular Surg. 2020;54:272-7.
8. Marone EM, Mascia D, Kahlberg A, Brioschi C, Tshomba Y, Chiesa R. Is open repair still the gold standard in visceral artery aneurysm management? Ann Vasc Surg. 2011;25:936-46.
9. Rabuffi P, Bruni A, Antonuccio EG, Ambrogi C, Vagnarelli S. Treatment of visceral artery aneurysms and pseudoaneurysms with the use of cerebral flow diverting stents: initial experience. CVIR Endovasc. 2020;3:48.
10. Chang D, Tummala S, Sotero D, Tong E, Mustafa L, Mustafa M, et al. Three-dimensional printing for procedure rehearsal/simulation/planning in interventional radiology. Tech Vasc Interv Radiol. 2019;22:14-20.
11. Itagaki MW. Using 3D printed models for planning and guidance during endovascular intervention: a technical advance. Diagn Interv Radiol. 2015;21:338-41.