UPDATE IN RADIOLOGY

Review of pre- and post-treatment multidetector computed tomography findings in abdominal aortic aneurysms

E. Casula*, E. Lonjedo, M.J. Cerverón, A. Ruiz, J. Gómez

Servicio de Radiodiagnóstico, Hospital Universitario Dr. Peset, Valencia, Spain

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KEYWORDS
Abdominal aortic aneurysm; Multidetector computed tomography; Covered stents; Prostheses and implants

Abstract The increase in the frequency of abdominal aortic aneurysms (AAA) and the widely accepted use of endovascular aneurysm repair (EVAR) as a first-line treatment or as an alternative to conventional surgery make it necessary for radiologists to have thorough knowledge of the pre- and post-treatment findings. The high image quality provided by multidetector computed tomography (MDCT) enables CT angiography to play a fundamental role in the study of AAA and in planning treatment.

The objective of this article is to review the cases of AAA in which CT angiography was the main imaging technique, so that radiologists will be able to detect the signs related to this disease, to diagnose it, to plan treatment, and to detect complications in the postoperative period.

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PALABRAS CLAVE
Aneurisma de aorta abdominal; Tomografía computarizada multidetector; Endoprótesis recubierta; Prótesis e implantes

Revisión de aneurisma de aorta abdominal: hallazgos en la tomografía computarizada multidetector pre y postratamiento

Resumen El aumento de la frecuencia de los aneurismas de la aorta abdominal (AAA) y el uso aceptado del Endovascular Aneurysm Aortic Repair (EVAR) como tratamiento de primera línea, o como alternativa a la cirugía convencional, hace necesario conocer en profundidad los hallazgos pre y postratamiento. Los avances tecnológicos como la tomografía computarizada multidetector (TCMD), con su alta calidad de imagen, confieren al estudio angiográfico con TCMD (angio-TC) un papel fundamental en el estudio del AAA y su planificación terapéutica.

El objetivo de este artículo es revisar los AAA estudiados con angio-TC como técnica de imagen principal, para que los radiólogos sean capaces de detectar los signos relacionados con esta enfermedad, con el fin de diagnosticar, planificar el tratamiento y detectar las complicaciones en el postoperatorio.

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* Corresponding author.
E-mail address: elisabetacas@gmail.com (E. Casula).

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Introduction

Incidence and prevalence of abdominal aortic aneurysms (AAA) are conditioned by age, sex, race and they are increasing due to growing use of diagnostic techniques and changes in quantitative criteria used to define them.\(^1\)\(^2\)\(^3\)\(^4\) AAA are caused by a degenerative process of arterial wall that affects 3 layers-intima, medial, and adventitious and is defined as a 50 per cent increase in the normal major diameter of aorta–usually over 3 cm.\(^5\)\(^6\)\(^7\)\(^8\) It is a common disease of developed countries and it is directly associated with aging population and several risk factors–high blood pressure, dyslipidemia, smoking, sedentary life. It is believed 6 per cent of males over 65 have AAA.\(^9\) Patients with family history are at higher risk of having aortic aneurysms\(^1\) than the general public. Seventy five per cent of AAA are asymptomatic. The remaining 25 per cent cause inespecific abdominal discomfort or lower back pain. Rupture is the early manifestation in one-fourth of the latter.\(^1\)

Management of AAA has been based historically on open surgical intervention. Parodi et al.\(^9\) introduced the Endovascular Aneurysm Aortic Repair (EVAR) also called endovascular therapy (EVT) achieving better survival, quality of life, faster recovery in the immediate post-op and shorter hospital stays.\(^1\)\(^1\)\(^0\)\(^1\)\(^1\)\(^1\) Today this technique is indicated in most cases even though younger patients below 65 years old with a prolonged life expectancy it does not seems reasonable to implant endoprosthesis since there is no information on its long-term stability, it is necessary to repeat intervention (reinterventions) and do repeated image monitorings.\(^1\)\(^2\)\(^4\) On the other hand certain anatomical features like supra or juxtarrenal extension of aneurysm, or the excessive angulation of aneurysmatic neck, conditions usually associated with a high risk of post-surgical complications and compromise of long-term outcomes do not represent contraindication to EVT since today we have fenestrated endoprosthesis and different materials we can use for such complex cases.\(^1\)\(^2\)\(^3\)

Technological innovations like MDCT offer high quality multilayer image reconstructions (MIR), 3D or maximum intensity projections (MIP). Evolution in computing gives the angiographical study through MDCT a very important role and first choice in the study of AAA and therapeutic planning.

Goal of this study is do a thorough review of AAA based on angio-CT as the most important image technology so that radiologists can diagnose it and plan therapy, find post-op complications and assess evolution.

Image studies

Advances in computed tomography technology especially with the appearance of MDCT have turned CT into a one of a kind diagnostic modality.\(^1\)\(^4\) Today angio-CT is the leading vascular diagnostic technique for its availability, rapidity, and usefulness. It is indicated for almost all vascular diagnoses so angiography catheterization has been relegated to therapeutic interventions.\(^1\)\(^5\) Some of its indications are to evaluate AAA prior to therapy and keep a follow-up after EVAR.

MDCT protocols used vary from one center to the next. These can be: (a) studies with a single arterial stage; (b) two-stage studies with primary stage without contrast and a second arterial stage--these are useful to distinguish calcification endoleaks within aneurysm sac or a first stage with arterial contrast followed by a delayed stage\(^1\)\(^6\)\(^7\)\(^8\); or (c) three-stage studies with a stage without contrast, another arterial stage and one last delayed one\(^1\)\(^8\) to help identify small endoleaks misdiagnosed at the arterial stage.\(^1\)\(^9\)

Angio-CT studies are always done using hydrosoluble iodine contrast media by cannulating one peripheral vein with 18–20 G needles--enough caliber for a 3–6 ml/s flow. Aorta is adequately enhanced when it reaches 250–300 Hounsfield units (HU) which coincides with the maximum vascular enhancement with time of acquisition. From axial reconstruction MIR are done for a better assessment of the light of vessels, thickening, wall alterations, light of endoprosthesis and quantification of stenoses; MIP are images especially useful to study small vessels; 3D volumetric reconstructions (3DVR) allow us to come closer to vascular anatomy, anatomical variants, tortuous vessels or colateral obstruction and areas.\(^1\)\(^0\)\(^1\)\(^1\) Biggest issues with this technique are ionizing radiation and in the case of iodine contrast media, possibility of nephrotoxicity and allergic reactions.\(^2\)\(^3\)\(^4\)

Conventional angiography is the test normally used to diagnose AAA. It allows us to locate them, determine the length of sac, visceral branch affectionate, characteristics of flow, and other vacluopaties: renal artery stenoses, iliac artery aneurysma. However it is an invasive test with associated morbomortality and important diagnostic limitations since it only studies the internal light of Wessel and can underestimate the real size of aneurysma if it is partially thrombosed. Other limitations are radiation on the patient, iodine contrast media, and high cost compared to other techniques. Today it is used to plan EVT with a cemeterized catheter that determines the adequate measures of endoprosthesis within the same surgical act.\(^2\)\(^5\)

Anteroposterior and lateral simple X-ray is useful to suspect AAA and evaluate the structural alterations of endoprosthesis like ruptures and migrations. It is a very cost-efficient available diagnostic test but it should not be used isolatedly because it cannot assess the diameter of aneurysms or endoleaks.\(^2\)\(^6\)

Doppler ultrasound is a good test used to discard AAA and keep a follow-up too. It is a cost-efficient non-invasive test without ionizing radiation or iodine contrast media that can be a good alternative combined with a non-contrast CT in patients with chronic renal failure or who are allergic to iodine contrast media. However exploration depends largely on the observer and when measuring diameter of the aneurysma the intra and inter-observer variability is greater than that of MDCT.\(^2\)\(^7\)\(^8\) To find endoleaks we need to use color Doppler or power Doppler. Thanks to its high specificity (89–97 per cent) some studies support it to detect endoleaks.\(^2\)\(^9\)\(^3\)\(^0\) However its sensibility is lower than that of angio-CT which instills doubts on how to use it as a single follow-up method.\(^3\)\(^1\) New ultrasound contrast agents have increased sensibility of ultrasound especially to find and characterize endoleaks according to speed and direction of flow and in patients allergic to iodine too.\(^3\)\(^2\)

Reliability of magnetic resonance angiography (MRA) to diagnose and monitor treated AAA is similar to that of
angio-CT.\textsuperscript{13} Its sensibility to measure aneurysmal sac and find endoleaks is exactly the same as two-stage angio-CT.\textsuperscript{34} Benefit of angio-MR is that it does not use ionizing radiation or iodine contrast media so it can be used in young patients, in those with moderate renal failure or in patients allergic to iodine. Measurements of aneurysmal diameter and length through MRA do not vary from those obtained through angio-CT and its correspondence to select endoprosthesis is 100 per cent.\textsuperscript{35} However MRA has important limitations like its less availability or higher cost, less tissue resolution, impossibility to assess calcifications,\textsuperscript{36} limited view of collateral vessels, false impressions of stenosis due to strong vessel tortuosity or lack of bone structures as anatomical references. Other issues such as incompatibility with certain types of endoprosthesis or risk of nephrogenic systemic fibrosis of gadolinium contrasts prevents from using MRA in patients with advanced renal failure or dialysis.\textsuperscript{37} Lastly its general contraindications have to do with pacemaker carriers, defibrillators or cochlear implants.

Intravascular ultrasound (IVUS) is another image technique we can use to reduce dose of contrast iodine and fluoroscopy time during EVAR both with infra-renal and thoracic aneurysms. IVUS accurately measures size of aneurysma, and identifies the origin of critical vessels to plan therapy and assess endoprosthesis, its stability or complications like wall thrombus (Fig. 1) after therapy. Drawback is that such a technique is fully dependent on the observer.\textsuperscript{38}

**Figure 1** (a and b) Intravascular ultrasound (IVUS) showing movement of endoprosthesis (arrow in a and b) due to proximal anchorage to fresh wall thrombus (asterisk in a). (c) Control arteriography after extension of left branch (arrow).

Multidetector computed tomography study prior to therapy

When AAA is diagnosed and it is indicated to treat it with an endoprosthesis we need to determine the morphological parameters that allow us to do the intervention safely and efficiently. With the passing of time these parameters have been modified thanks to technological progress and they vary depending on the type of endoprosthesis used that based on the type of anchorage requires this or that anatomical condition.\textsuperscript{39} Thus there are infra or supra-renal endoprosthesis anchorages and fenestrated endoprosthesis for renal arteries, superior mesenteric artery and celiac trunk. We can preserve hypogastrical arteries with endoprosthesis with fenestrated iliac extensions or use artery coil embolizarion if aneurysma makes it to external—not internal iliac arteries. Therefore prior to intervention it is very important to study carefully the number of visceral arteries to treat as well as its anatomical position in an effort to build millimetrically a device that can be easily adaptable to the anatomical features of patients.

For preoperative study we should do angio-CT and if necessary complete it with a through angiography with a centimeter catheter. It is recommended that planning and therapy are not over 6 months.\textsuperscript{40} Main goals are to thoroughly describe morphological features of aneurysma for a perfect panning of intervention and detect situations which might make EVAR difficult or contraindicated.

In general these are the parameters we will study with MDCT\textsuperscript{41} son: (a) shape of aneurysma—saccular or fusiform; (b) features of calcifications and wall thrombi because if they occur fixing the prosthesis is more difficult to do and the possibility of proximal leaks increases. Isolated non-circumferential calcifications and non-circumferential light-weight thrombi do not contraindicate implanting prosthesis; (c) dimensions of aneurysm, antero-posterior and external peak diameter, diameter of fixation areas when trying to implant an auto-expandable prostheses, diameter of light when implanting balloon-expandable prostheses and cranio-caudal length of aneurysm; (d) dimensions and features of the neck—measuring the diameter of supra-renal artery, the diameter of neck in its superior, middle and inferior slopes and length of neck. Even though diameters of prostheses vary based on the device manufacturer, the diameter of neck should be <31 mm and it should have a minimum length to anchor the prosthesis of 15 mm. Distance can be shorter in cases of endoprostheses with supra-renal free end and fenestrated prostheses where neck <10 mm or <15 mm and anatomical changes like thrombi or funnel shape are associated\textsuperscript{42,43}; (e) “Time” position of the origin of visceral vessels on axial reconstructions. In complex aneurysmas where aortic segment includes some visceral branch it is very important to establish such position to determine the orientation of fenestrations and measure the longitudinal relations among them and measurements of the fenestrated visceral segment and the rest of the device remaining body\textsuperscript{44}; (f) shape of neck—favorable with a regular cylindrical shape. Conical necks can give rise to displacement of prosthesis; (g) angulation of neck — determined by the line of neck axis and that of supra-renal aorta. Neck is straight when angulation is 0°. Certain endoprosthesis are more adaptable than others but the ideal is that there is no angle between neck and aneurysma at risk of displacement of prosthesis and if anything angulation <60° is recommended. Angulation is assessed through arteriography and rigid wire; (h) diameter of left and right primitive iliac arteries and length from infra-renal line to iliac artery bifurcation. They should not have excessive bifurcations <90° or extreme elongations precisely in the presence of calcifications because...
there is this possibility of not being able to move forward the device towards the aorta. Common iliac arteries are recommended to have a minimum diameter of 7 mm and a maximum caliber of 20 mm; (i) associated findings that can influence therapy as over-developed lumbar arteries and the inferior mesenteric artery patency that can cause endoleaks and keep patency of aneurysm with a higher risk of deferred rupture; (j) anatomical particularities like polar renal arteries (Fig. 2) with a higher risk of trombosis and loss of renal mass and endoleaks, the horseshoe kidney, poisonous rings (Fig. 2), ectopic kidney or fibrous tissue in the case of inflammatory AAA or classical findings like the signal of "surrounding aorta" or vertebral erosion suggestive of AAA chronic contained rupture; and (k) other concomitant pathological conditions such as tumors or infectious or inflammatory diseases.

**Multidetector computed tomography study after therapy**

Guidelines recommend to monitor AAA angio-CT before discharge or during first month, every 6 months during first year, and then annually. Main goal of follow-up is to evaluate efficacy of therapy by measuring regularly the diameter of aneurysm (it should decrease/increasing is suspicious of endoleak) and aneurysmal neck (increases when position of endoprosthesis is correct). Even though aneurysmal volumen can also be used—where there is less inter and intra-observer variability than when measuring diameter only, practical superiority of this parameter for the follow-up is still under discussion. Similarly position and shape of endoprosthesis need to be evaluated as well as all possible complications associated with endoprosthesis or the technique used.

EVAR is a technique originally thought for patients at high surgical risk but in light of its results target population has grown bigger. Nevertheless it requires follow-up with image techniques more regularly and in a more complex way than open or conventional surgery.

**Complications associated with endoprosthesis**

The most common complication is endoleak. It consists of persistence of blood flow in light of aneurysm (pressurization of aneurysmal sac) that continues to grow and can lead to rupture if untreated.

There are 5 types according to the origin of blood flow:

- **Type I:** Blood flow due to defective seal at anchorage points of endoprosthesis can be seen. Type Ia occurs when endoleak depends on proximal anchorage (Fig. 3a) and Ib when it depends on distal anchorage (Fig. 3b). In both cases separation occurs between endoprosthesis

![Figure 2](image1.png)  
*Figure 2* Pre-therapy angio-CT in a patient with AAA. (a) Right renal polar artery (arrow). (b) Left retroaortic renal vein (arrow).

![Figure 3](image2.png)  
*Figure 3* Post-therapy angio-CT in 2 patients with aortic endoprosthesis. (a) Type Ia endoleak due to seal defect in proximal anchorage points of endoprosthesis (arrow). (b) Gadolinium-enhanced angio-CT study due to allergy to iodine. Type Ib endoleak (arrow) in distal anchorage of endoprosthesis
and the native arterial wall creating direct communication between the arterial circulation and the aneurysmal sac. It is a common complication in patients with anatomically complex arteries: short neck, difficult angulation, ulceration, thrombosis in the proximal portion and irregularly dilated tortuous iliac arteries. The therapy administered is surgical replacement of endoprosthesis. Type Ic occurs when there is an embolization flaw of contralateral common iliac artery at EVAR with aorto-monoiliac abdominal endoprosthesis combined with femoro-femoral bypass causing endoleak through this towards aneurysmal sac. In this case the embolization is the right therapy.\textsuperscript{17,46,50}

- Type II: It is the most common complication of EVAR with an incidence of 8–45 per cent of all endoleaks according to different series.\textsuperscript{51–53} It consists of the retrograde flow of aorta-dependent arteries or is due to anastomosis between iliac arteries and other collateral vessels in direct communication with the aneurysmal sac. The most common thing is that re-entry flow originates in the inferior mesenteric artery (Fig. 4) and lumbar arteries (Fig. 5). Involvement of median sacral artery or renal polar arteries is less common (Fig. 4). Number of contralateral vessels and thrombosis in this preoperative study correlates directly with this type of complication.\textsuperscript{54} Usual standard is conservative and only if sac increases artery coil embolization with sclerosing agents like thrombina, glue or coils is used through transarterial or translumbar approach (Fig. 5) with transcaval catheterization\textsuperscript{25–27} or linking surgically collateral branches.

- Type III: It is caused by a flaw in the structure of endoprosthesis due to manufacturing defect or inadequate implantation of endoprosthesis. Continuous pulsatility in aorta or other stress forces that can dearticulate or break apart the components of endoprosthesis–modular disconnection of different segments (Fig. 6). We treat it with a brand new endoprosthesis inserted coaxially or if not possible through surgery.\textsuperscript{58}

- Type IV: It is due to an increase in the size of aneurysmal sac conditioned by porosity of endoprosthesis. It is found in the postoperative angiogram and it is more difficult to recognize in late control studies. Conservative therapie is

Figure 4  Post-therapy angio-CT in one patient with aortic endoprosthesis. (a) Type II (asterisk) interior mesenteric artery-dependent endoleak (arrow). (b) Type II (asterisk) left lumbar artery-dependent endoleak (arrow) in one patient with horseshow kidney (c)

Figure 5  Abdominal and pelvic CT in patient in the prone position. Treatment of type II (arrow in a) right lumbar artery-dependent endoleak with thrombin injection in the aneurysmal sac. Pre-therapy (a) and post-therapy study (b–d).
Review of pre- and post-treatment multidetector computed tomography findings in abdominal aortic aneurysms

applied though it can be reviewed surgically if size of the sac increases.
- Type V or "endotension": There is an increase in size of aneurysmal sac with no clear origin—maybe due to type I, II, III undetected leaks with the usual study techniques or maybe due to blood ultrafiltration through prosthetic stent. It is an exclusion diagnosis with respect to other types of leak for which Doppler ultrasound is very useful (Fig. 7). It is treated with a brand new endoprosthesis—if not possible through surgery. It is different from type IV in that there is no contrast within the aneurysmal sac.

Complications associated with intervention

Thrombosis of endoprosthesis: It occurs in nearly 3 per cent of cases treated, usually affects one limb of endoprosthesis (Fig. 8) and its origin is unclear. It is seen as a round or semicircular-shaped intraluminal repletion defect. It can resolve spontaneously or end up in complete thrombosis which is why regular monitoring is necessary.

Bending-migration of endoprosthesis: Incorrect position of endoprosthesis can occur if when inserted blood flow pressure is high or if there is a segment with accentuated

Figure 6  (a and b) Post-therapy angio-CT in one patient with aortic endoprosthesis: type III endoleak due to modular disconnection of different segments.

Figure 7  Control Angio-CT recently (a) and after one year (b) showing increase of aneurysmal sac without contrast extravasation. Doppler ultrasound images (c and d) showing flow inside the sac. Findings are concordant with type V endoleak.
Migration occurs caudally in infra-renal AAA following a decrease in the size of aneurysm and the diameter of sac after EVAR. Hematomas and other collections: They usually occur at the groin region—in the femoral approach site and other periprosthetic locations too. They look like a rounded low-key accentuated area uptaking contrast at periphery due to fat alteration and an adjacent collection.

Prosthetic infection: It is a rare short-medium term complication of EVAR with a high morbimortality. Clinical suspicion is accompanied by inespecific findings on angio-CT (Fig. 9) like an increase of soft parts, periprosthetic gas bubbles or trombosis of the affected segment. It is important to diagnose it quickly and treat it by removing the infected endoprosthesis and administering IV antibiotic therapy.

Strokes and heart attacks: These are rare today. They are usually due to technical difficulties when inserting the wire, the arterial introducer or the endoprosthesis allowing displacement of fragments from a pre-existing friable thrombus on wall into the arterial light. It can affect pelvis, lower limbs and visceral and renal branches to cause segmental renal infarctions (Fig. 10) or small intestine ischemia. This last complication is lethal and has a mortality of 100 per cent. Microembolization of hypogastrical arteries or lower limbs can cause skin or muscle ischemia that potentially can lead to necrosis. Massive microembolization of lower limbs is extremely rare in endovascular repair but it is a very serious complication that can cause a high mortality acute renal failure in patient. When it affects renal arteries it can cause heart attacks presenting as an altered or absent contrast uptake. Heart attacks can be due to exclusion of polar renal arteries by endoprosthesis.

Intestinal ischemia: It is a serious complication occurring by occlusion of the inferior mesenteric artery (commonly) or iliac arteries due to position of endoprosthesis. MDCT findings vary depending on time of evolution and severity. Intestinal wall thickening is the most common finding. Mucosal edema makes the wall look like a “halo” or “bullseye” with trabeculation of mesenteric fat due to edema and hemorrhage. Air in the intestinal wall (bowel pneumatosis) allows us to come up with a specific diagnosis; it implies severity and might require surgery with exeresis of the portion of the affected bowel.

Arteriovenous fistula: In most cases formation of a false aneurysm or arteriovenous fistula (Fig. 11) is due to vessel laceration during intervention. In a single-stage contrast study it can be misdiagnosed while in a bi or three-stage angio-CT study a drainage vein with a contrast enhancement curve running parallel to that of the aorta can be seen at an early arterial stage. MPR curves are very useful to know where fistula exactly is. Blood vessel medium line allows us

Figure 8  Post-therapy angio-CT. Right iliac extension thrombosis in control 4 days after implanting the aortoiliac endoprosthesi.

Figure 9  Angio-CT. (a) Periprosthetic collection with loss of fat planes (arrow) and reactive adenopathies (asterisk). (b) Wall thickening of aneurysmal sac with contrast uptake (arrow).
to study its length fully. 3DVR reconstructions allow us to find other adjacent lesions.\textsuperscript{21}

\textit{Aortoenteric fistula} (Fig. 12): It is a late uncommon complication with an incidence <1 per cent in most series and high mortality that can present as a high digestive hemorrhage, abdominal pain and sepsis.\textsuperscript{21} Duodenal erosions secondary to endoprosthesis poorly covered, prosthetic aneurysms, or endoprosthesis infections can occur too. In up to 50 per cent of cases clinical presentation is acute with great hemodynamic repercussion that requires emergent surgery.\textsuperscript{63} It is important for MDCT study protocol to include two stages (arterial and portal) to find small low-flow fistulas.\textsuperscript{64} Contrast extravasation in the intestinal lumen is diagnostic but ectopic gas, focal thickening of intestine wall, disrupted aortic wall, fat plane loss between the aorta and intestinal loop or pseudoaneurysm can also be found.\textsuperscript{7}

![Figure 10](image1.png)

\textbf{Figure 10} Post-therapy angio-CT in one patient with aortic endoprosthesis. (a) Segment infarction in the inferior pole of both kidneys (arrows) due to exclusion of polar arteries by the prosthesis (b).

![Figure 11](image2.png)

\textbf{Figure 11} Post-therapy angio-CT in one patient with aortic endoprosthesis. Arteriovenous fistula (arrow) and collection at the right femoral approach site (curved arrow).

![Figure 12](image3.png)

\textbf{Figure 12} Post-therapy angio-CT in one patient with aortic endoprosthesis. Aortoenteric fistula with gas bubbles inside the aneurysmal sac due to fistulization at the second part of the duodenum. Radiodense material (arrow) put there by the endoscopist.

\section*{Conclusions}

Higher frequency of AAA and acceptance of EVAR as first line therapy or alternative to conventional surgery make us be familiar with pre and post-therapy findings necessary to manage AAA. MDCT is a quick minimally invasive relatively non-expensive technique that allow us to do thorough preoperative and postoperative studies. MPR and curves in preoperative study give us anatomical data on the aorta and aneurysmal sac, and tortuosity and angulation of aneurysmal neck that help us plan therapy and choose the type of endoprosthesis we will need. Similarly wall thombi, renal polar arteries and alteration of the inferior mesenteric artery patency will predict risk of complications such as endoleaks, renal infarctions, strokes and mesenteric ischemia. In post-therapy study we will need to evaluate the
position of endoprosthesis, its features and changes in the aneurysmal sac and complications to be able to solve them adequately.

Ethical responsibilities

Human and animal protection. Authors declare that for this research they have not done any experiments on human beings or animals.

Data confidentiality. Authors declare that in article does not show the names of patients.

Privacy right and informed consent. Authors declare that in article does not show the names of patients.

Authors

1. Manager of the study: EC.
2. Study Concept: EC, EL and AR.
3. Study Design: EC and MJCI.
4. Data gathering: AR.
5. Data analysis and interpretation: JG.
6. Statistical treatment: N/A.
7. Bibliographic search: EC and JG.
8. Writing: EL, EC and MJCI.
9. Critical review and intellectually relevant notes: EL, AR, JG and MJCI.
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Conflict of interest

Authors report no relevant conflicts of interest.

References


