33 Aortic Infection with Visceral Artery Involvement in the Endovascular Era: Treatment Options

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33.1 Introduction

In 1885, Osler described the infected peripheral aneurysms which result from endocarditis embolism for the first time [1]. Since then, the term "mycotic" has been used, in an inexact way, to identify all infected aneurysms. Theoretically, different clinical and physiopathological conditions could lead to mycotic aneurysms. Bacterial seeding can occur in normal arteries by contiguity from a nearby infectious outbreak or through vessel wall damage (e.g., atherosclerosis), with possible dangerous evolutions (perforation, suppuration, aneurysm, pseudoaneurysm), describing the typical microbial arteritis [2, 3]. Iatrogenic wall damage due to medical interventions (e.g., endovascular treatment) [4–6] or drug abuse [7–11] with an inadvertent intra-arterial injection gives rise to a local vascular infection followed by the development of a pseudoaneurysm. Bacteria could be found in the thrombus of degenerative aneurysms, even in the absence of clinical signs of infections, suggesting that a preexisting degenerative (atherosclerotic) aneurysm can be in any moment colonized by hematogenous or contiguous spread [3, 12, 13]. Last, but not least, in cases of endocarditis, septic emboli can occlude *vasa vasorum*, leading to ischemia, infection, and degeneration of the arterial wall, which develops a typical multiloculated aneurysms [1].

The diagnosis of infected aortic aneurysms is based on clinical findings and imaging features and should be made as soon as possible because sepsis and rupture frequently develop afterward [3, 14]. However, most patients are often asymptomatic or present nonspecific symptoms such as malaise and subjective fevers. In other cases, concomitant dyspnea; chest, back, or abdominal pain; nausea; gastrointestinal bleed; and jaundice, when associated with the finding of a pulsatile mass with or without associated cellulitis [9, 11, 15, 16], leukocytosis, and elevated erythrocyte sedimentation rates, should raise suspicion.

Blood cultures have been reported to be positive in approximately 75% of cases. Therefore, blood cultures alone are not sufficiently sensitive to rule out the diagnosis [7, 17]. The bacteriologic spectrum is very extensive, but *Staphylococcus* [18, 19], especially methicillin-resistant *S. aureus* [20–22], and *Salmonella* species [23] are the most common etiologic agents involved. Less frequently infected aneurysms are caused by *Streptococcus* species [8], fungal pathogens (*Candida* [24], *Cryptococcus* [25], *Aspergillus* [26]), and *Treponema pallidum*

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[27–30]. Gram-negative infections are less common but more virulent than Gram-positive, due to the release of alkaline proteinase with many kinds of elastase that lead to vascular wall necrosis, graft disruption, and stump hemorrhage after reconstruction [3, 31].

Among imaging modalities, computed tomography angiography (CTA) is reasonable as the gold standard for diagnosis of infected aneurysms. The typical appearance is a saccular aneurysm or pseudoaneurysm with an absent or minimal calcification. Periaortic collections, intramural air, and soft tissue infiltration are other common radiographic findings [32, 33]. Moreover, rapidly enlarging or rapidly evolving aneurysms are highly suggestive of infection [34–37].

Additionally, ultrasound and arterial duplex can be used for initial diagnosis [11], while positron emission tomography (PET) [38–40], magnetic resonance imaging, magnetic resonance angiography [41, 42], and indium 111-labeled white blood cell scanning [43–45] could be useful to confirm the primary suspicions.

Every vessel may be involved, and patients are often immunosuppressed by their underlying condition [2, 3, 6, 11, 46–52]. For all these reasons, the multidisciplinary approach seems to be the best strategy to manage this complex condition. The approach should comprise an antibiotic strategy, surgical management, and optimal timing for surgical intervention.

Infected aneurysms still represent a big challenge for modern surgeons, despite the great strides that have been made in vascular surgery over the past decades. Antibiotic therapy alone is not enough to eradicate the problem, and so traditional surgery represents the mainstay of therapy, even carrying a significant morbidity and mortality rate [53–56]. Recently endovascular treatment has shown new ways to approach this kind of disease, like primary treatment or bridging therapy. However, invasive hemodynamic monitoring [57] and catheter-based procedures [4–6] have opened a door on the development of vascular infectious disease.

Antibiotic therapy should be initiated as soon as possible, initially as broad-spectrum and then culture-direct, and continued after surgical treatment. The duration of the course of antibiotics is variable, sometimes to lifelong courses, but in any case, no less than 6 weeks of intravenous therapy [58, 59]. Traditional infected aneurysm treatment consists of open surgical repair with resection of the infected segment, extensive local debridement, and in situ or extra-anatomic bypass [53–56].

Obviously, it depends on the location and extent of the infection, as well as patient comorbidities. Oderich et al. [17] reported the following distribution of infected aneurysms: infrarenal aorta (40%), distal thoracic aorta (16%), thoracoabdominal segment (16%), paravisceral aorta (13%), juxtarenal aorta (11%), and pararenal aorta (4%). In case of thoracic or thoracoabdominal involvement, in situ reconstruction with a homograft or antibiotic-treated prosthetic graft is the preferred treatment, with special consideration to spinal cord perfusion protection during this repair [60]. In case of infected abdominal aorta, repair can be achieved either with in situ reconstruction or by carrying out an extra-anatomic bypass [55]. If the juxtarenal or visceral aortic segments are involved, in situ repair is recommended [61], via neoaortoiliac system (NAIS) with the autogenous femoral-popliteal vein, cryopreserved arterial or venous homografts, or antibiotic-treated prosthetic grafts [49, 50, 62–68], and reimplantation of involved arteries or visceral debranching is mandatory. In particular, the most affected site is the superior mesenteric artery (SMA) [69–71], followed by the celiac artery and its branches. However, usually only a single segment is involved.

Although open repair is the established treatment, it is associated with a high morbidity-mortality rate, ranging from 10 to 44% [53–56]. Unfavorable outcomes generally result from performing major surgery in patients already debilitated by sepsis and/or massive bleeding together with having significant comorbidities. Endovascular aneurysm repair (EVAR) was first reported by Semba et al. [72], and over the past decade [17–19, 73–78], many reports of successful endovascular stent grafts for infected aortic aneurysms have been reported, as an alternative to conventional in managing infected aneurysms,

especially in patients who are considered poor surgical candidates.

Improved endovascular techniques and materials brought into focus the use of endografts alone or in combination with open repair and hybrid approach [79–81].

While feasible, the implantation of an endograft within an infected area is highly controversial. In such cases, infective aortic tissue is not removed, and controversy remains not only regarding the persistence of an established local infection [82] but also with regard to the long-term durability of the endograft. Furthermore, in such patients, long-term or even lifelong antibiotic treatment may be inevitable.

33.2 Literature Review

As mentioned above, infected aortic aneurysms involving visceral aortic branches are, fortunately, not common; however, even in an antibiotic era, related mortality is still very high, and they are considered to be one of the most challenging problems faced by vascular specialists [83, 84].

Consistent with conventional infrarenal mycotic aneurysm, antibiotic treatment alone has been reported to have a mortality rate as high as 90% [85]. Historically, the preferred treatment option was surgery, even in these fields [84–86]. However, the surgical treatment of infections involving the juxtarenal or paravisceral aorta is complex; complicated and modern surgical outcomes are disappointing with mortality rates over 40% [17, 54]. For these reasons, over the years, many authors have reported a plethora of alternative, less invasive, hybrid, or endovascular approach. Here, several cases of infectious aneurysms involving visceral branches are reported, with particular attention to treatment strategies and relative results [80, 81, 87–94].

Visceral artery involvement in mycotic aneurysm was of course described long before the endovascular era began, and several different open surgical solutions have been proposed to preserve patency and eradicate infection.

In 1986, Reddy and coworkers described a case of a 7 cm saccular mycotic aneurysm that developed in the suprarenal abdominal aorta in a severely atherosclerotic 63-year-old man. At that time the infection was presumed to originate from a hematogenous inoculation of an atherosclerotic plaque. During intervention, a right axillo-bifemoral artery bypass graft was performed along with autotransplantation of the left kidney to the left common iliac vessels, and the suprarenal aorta was ligated, excised, and widely debrided. After 6 months, patient experimented a sudden occlusion of graft requiring thrombectomy for limb salvage and to preserve renal function. After a further 2-month period, an elective thoracic aorta to bilateral iliac artery bypass was successfully undertaken. Unfortunately, the patient suffered a fatal myocardial infarction at 2 weeks from surgery. Upon autopsy, a well-perfused nephrosclerotic kidney, healed aortic ligation, and no graft infections were found [87]. A few years later, in 1989, James reported a 13-year follow-up for a relatively similar patient, confirming the potential role of this kind of surgical approach [88].

Such reports and relatively good results, although probably affected by the so-called publication bias, justified the widespread use of open surgical solution even when the endovascular era was established.

In 2007, Itatani and collaborators described treatment performed to a 66-year-old man, presenting with back pain, high fever, and constipation and with a suprarenal infected abdominal aortic aneurysm involving the visceral vessels [89]. Blood cultures revealed *Bacteroides melaninogenicus*. The patient was successfully treated by an ex situ arterial reconstruction. After establishing temporary bypass from the right axillar artery to the right external iliac artery, the right renal artery, SMA, and common hepatic artery were bypassed from the right iliac artery using a Dacron graft, and the artery proximal to each anastomosis was ligated. These procedures were performed with an ascending colon and the second portion of the duodenum reflecting toward left side. The left renal artery was bypassed from the left external iliac artery using Dacron graft reflecting a descending colon, left kidney, spleen, and pancreas tail toward the right. Keeping the visceral blood flow through a temporary bypass

graft from the right axillary artery, the abdominal aorta was cross-clamped between the supraceliac aorta and bilateral external and internal iliac arteries. Aneurysm wall excision and retroperitoneal space lavage were carried out. Aortic trunk reconstruction was performed using a different Dacron graft from the aorta at the diaphragm to bilateral terminal common iliac arteries with the body twisting left side to separate the graft from the infected field. In addition, omental flap was packed into the space where the aneurysm was situated. The patient had good recovery and no evidence of recurrent infection at a 31-month follow-up [89].

Dubois, in 2010, reported the first case series of 44 consecutive mycotic aneurysms, treated from 1990 to 2008 [90]. Among those patients, nine presented a juxtarenal aneurysm and two a thoracoabdominal aneurysm. Urgent surgery was performed in 18 cases (40.9%). Revascularization was achieved by in situ reconstruction in 37 patients (84.1%), while extra-anatomic reconstruction was performed in six patients (13.6%), reserving this approach to more compromised patients. One patient was treated with a combined in situ and extra-anatomic reconstruction. In 32 patients (72.7%), a transperitoneal approach to the mycotic aneurysm was performed. In 11 patients (25%), the access was retroperitoneal. A retroperitoneal approach was preferred when reimplantation or bypass of the visceral arteries was planned. In one case (2.3%), EVAR was performed. In patients with an extra-anatomic reconstruction, axillo-bifemoral reconstruction was performed in five cases (83.3%). One patient (16.7%) underwent a bilateral axillo-femoral bypass. In all of these patients, a resection of the mycotic aneurysm and a transfixion of the aortic stump with a nonabsorbable running suture and coverage by omentoplasty were carried out, followed by a debridement of all surrounding infected tissue. This second-stage procedure took place at a mean of 2 days after the extra-anatomic reconstruction. In 36 patients with an in situ repair, reconstruction to the iliac arteries was performed in 16 patients (44.4%) and to the femoral arteries in 6 patients (16.7%). Fourteen patients (38.9%) were treated with an aorto-aortic tube interposition. In 10 patients (27.8%), a Dacron graft was used, while in 13 patients (36.1%), silver-impregnated Dacron graft was used. In 18 (78.3%) of these, 23 patients were treated with a prosthetic graft. A homograft was used in eight cases (22.2%). In five patients (13.9%), an autologous deep vein was used for in situ reconstruction. Despite a such large series, only few patients required visceral or renal artery procedures. In seven patients (15.9%), visceral and renal arteries had to be reimplanted, while in five patients (11.4%), a bypass to the visceral or renal arteries was constructed. Resection of the mycotic aneurysm and rigorous debridement of all infected tissue was carried out in 43 patients (97.7%), and healing was supported by an omentoplasty in 30 cases (68.2%). Despite all reported adjunctive techniques in surgical management of infected aneurysms, in the Dubois series, in-hospital mortality was 22.7%, 50% in the extra-anatomic reconstruction group, and 18.9% in the in situ repair group. One-third (33.3%) of patients presenting with a ruptured aneurysm died in the perioperative period. Out of the 34 surviving patients, 12 patients (27.3%) died after hospital discharge and 3 (8%) showed reinfection [90].

Moving from reported good, but still unsatisfactory, results of open surgical treatment, in more recent years, several authors have proposed a “less invasive” hybrid or totally endovascular approach.

In the same year, Soule et al. reported a successful hybrid treatment to treat a 69-year-old man presenting symptomatic sacciform aneurysm of the abdominal aorta involving visceral arteries [80]. The patient’s blood cultures were positive for *Escherichia coli*. CTA showed a sacciform aneurysm developed on the right side of the suprarenal aorta. The right aortic defect wall was almost punctiform measuring 17 mm in diameter and was located near the SMA origin, 18 mm above the renal arteries. The celiac trunk itself did not originate from the aortic pseudoaneurysm. However, the aneurysmal sac extended above the level of the celiac trunk. To avoid surgical risk associated with open surgical repair, the authors decided to exclude the celiac pseudoaneurysm by endograft implantation, as well as visceral debranching. A prosthetic bypass between the left common iliac artery and

the hepatic artery with prepancreatic tunnel was performed, associated with direct reimplantation of SMA in the prosthesis. The infrarenal aortic wall approached to perform visceral bypass was normal. The celiac trunk and SMA area were slightly inflammatory without pus, and both their stumps were oversewn without difficulty. The graft was covered with an omentum flap. Then, a 30-mm diameter, 40-mm-length aortic endoprosthesis was implanted to exclude the pseudoaneurysm. Intraprocedural angiogram showed complete exclusion of the pseudoaneurysm and patency of all visceral vessels, without endoleak. At an 18-month follow-up, the patient remained asymptomatic without inflammatory syndrome. Enhanced CT showed complete shrinkage of the aneurysmal sac and patency of ilio-hepatic bypass and visceral arteries, in absence of graft migration or evidence of reinfection [80].

Kan, 1 year later, reported a series of 12 patients (three thoracic, two thoracoabdominal, and seven abdominal aortic aneurysms) in order to assess the supposed efficacy and outcome of EVAR for infected aneurysms with an adjunctive antibiotic treatment strategy [81]. All patients had positive blood culture reports showing *Salmonella* (ten cases), *Staphylococcus* (one case), and *Streptococcus* spp. (one case). In their experience six patients had ruptured aneurysms, and five received emergency EVAR. One patient received concomitant laparotomy for visceral vessel (right hepatic artery, SMA, and renal artery) bypass graft surgery. Three patients underwent CT-guided percutaneous drainage and one minilaparotomy for open debridement due to persistent fever, preserving the implanted endografts. No hospital deaths occurred, while one patient (treated by TEVAR for thoracic aneurysm) died 8 months after the procedure. All other patients were well, with no evidence of EVAR graft infection, at a mean follow-up of 23.6 months (range 2–48 months) [81].

Over the years, despite the emerging role of endovascular surgery, open reconstruction has continued to perform with favorable results as in a very interesting East-European experience [91]. Petrunic et al. described a very rare and interesting case of patient with ruptured suprarenal aortic aneurysm, involving origins of visceral and renal arteries, associated with spondylodiscitis and an abscess of the left psoas muscle. After an initial medical management with antibiotics, the patient was submitted to open repair. Thoraco-phreno-laparotomy with medial visceral rotation was employed for the operative approach. A bifurcated silver-impregnated Dacron graft was used for a bypass from the uninvolved descending thoracic aorta to the uninvolved portions of the celiac trunk and SMA. The aneurysm was then opened, and a rupture of the posterior wall of 3 cm in length was identified. The aneurysm and surrounding fibrotic and necrotic tissues were debrided. Curettage of the adjacent vertebral body and disk was also performed. The resected aneurysm was replaced with a cryopreserved homograft of 25 mm in diameter. Renal arteries were reimplanted within the homograft using short silver-impregnated Dacron grafts of 8 mm in diameter. Cultures were positive for *Staphylococcus* species and *Propionibacterium* species. No recurrence of infection or other complications were evident at a 7-month follow-up [91].

Almost contemporarily, a completely different approach was proposed by Flis [92] and Reijnen [93]: both of whom suggested a role for multilayer flow-modulator stent in mycotic paravisceral aneurysms. Of note, it has been postulated that the absence of graft material provided the opportunity for the stent to remain in situ for life even in an infected field [93].

The first patient was a 50-year-old man admitted to hospital for rapid onset of intractable abdominal pain and high fever. Computed tomographic scan showed two different juxtarenal saccular aneurysms of abdominal aorta suggestive for an infectious etiology. The patient was treated with multilayer flow-modulating stent implantation in order to preserve renal and visceral artery patency. Follow-up imaging showed aneurysm exclusion and complete sac shrinkage 1 year after procedure. After 24 months, the patient was in a generally good state of health, with no recurrence of infection [92].

In accordance with the previously described paper, Reijnen presents a case of a *Salmonella serotype enteritidis*-induced rapidly expanding aortic pseudoaneurysm with a penetrating ulcer

treated with a multilayer stent implantation. At 18 months of follow-up, the patient was in good clinical condition, with no infection-related signs or symptoms. CTA and 2-deoxy-2-[F18]-fluoro-d-glucose positron emission tomography/computed tomography showed a stable, mostly thrombosed aneurysm, with adequate perfusion of the side branches and no signs of recurrent or persistent infection [93].

Despite those encouraging results, recently Houston experience "rediscovered" the role of open surgery and direct visceral artery reconstruction for a mycotic aneurysm [94]. Coselli and his group described the case of a 60-year-old woman who presented with a 2-month history of back pain, associated with nausea and unintended weight loss. CT scans revealed a saccular aneurysm of the thoracoabdominal aorta, together with occlusion of the celiac artery. At hospital admission, blood and urine cultures were negative. An open Crawford extent III thoracoabdominal aneurysm repair was performed, with reimplantation of the celiac trunk using a prefabricated single-branched graft. During surgery, the opened aortic wall, visually suggestive for infection, was debrided. Intraoperative culture was positive for *Streptococcus pneumoniae*. After more than 17 months from repair, the patient was alive and free from infection [94].

In conclusion, from the few and fragmentary data in literature, it emerges that there is no unanimous consensus on the treatment of infected aortic aneurysms involving visceral vessels.

Facing this rare and difficult condition, each center must make a case-by-case choice on the intervention that feels more effective and safe. This is often based on their own experience and also on the patients' clinical and anatomical characteristics.

33.3 Personal Experience

Although our center has always been dedicated to diagnosis and treatment of primary and secondary aortic infections [95–98], in the last 8 years at Vascular and Endovascular Surgery of "La Sapienza" University of Rome, only two cases of aortic infections with visceral branch involvement have been observed and treated.

Those two cases, which are completely different in terms of clinical presentation and the surgical strategy adopted, are reported briefly.

33.3.1 Case 1

An 18-year-old female patient was admitted to our department with a history of recurrent fever, headache, lower back pain, and renovascular hypertension (250/130 mmHg). Her medical history was silent. Blood samples were normal. CTA revealed a partially thrombosed visceral abdominal aortic pseudoaneurysm with severe SMA stenosis and left renal artery occlusion. Broad-spectrum intravenous antibiotic therapy was initiated.

Due to the patient's young age, clinical presentation, and recent medical history, open surgical repair was performed in order to remove the infected aneurysm and restore all vessel patency.

Via the seventh intercostal space, the visceral pseudoaneurysm extending from the celiac trunk origin to the under renal abdominal aorta was reached. The entire aorta was found surrounded by an inflammatory tissue. A direct in situ aortic reconstruction with a 14-mm Dacron graft was performed, associated with a direct revascularization of all visceral arteries (Dacron graft for celiac trunk, SMA, and right renal artery; PTFE for preoperative occluded left renal artery).

Postoperative course was complicated by prolonged intensive care unit for multiorgan failure. Repeated blood cultures were always negative. The patient was discharged on the 27th postoperative day in a good general condition, in good clinical condition with an absence of fever, or other symptoms. Antibiotic therapy was maintained for a year following surgery. A two-year follow-up CT showed good patency of the aorta and visceral arteries with an absence of any complication (Fig. 33.1).

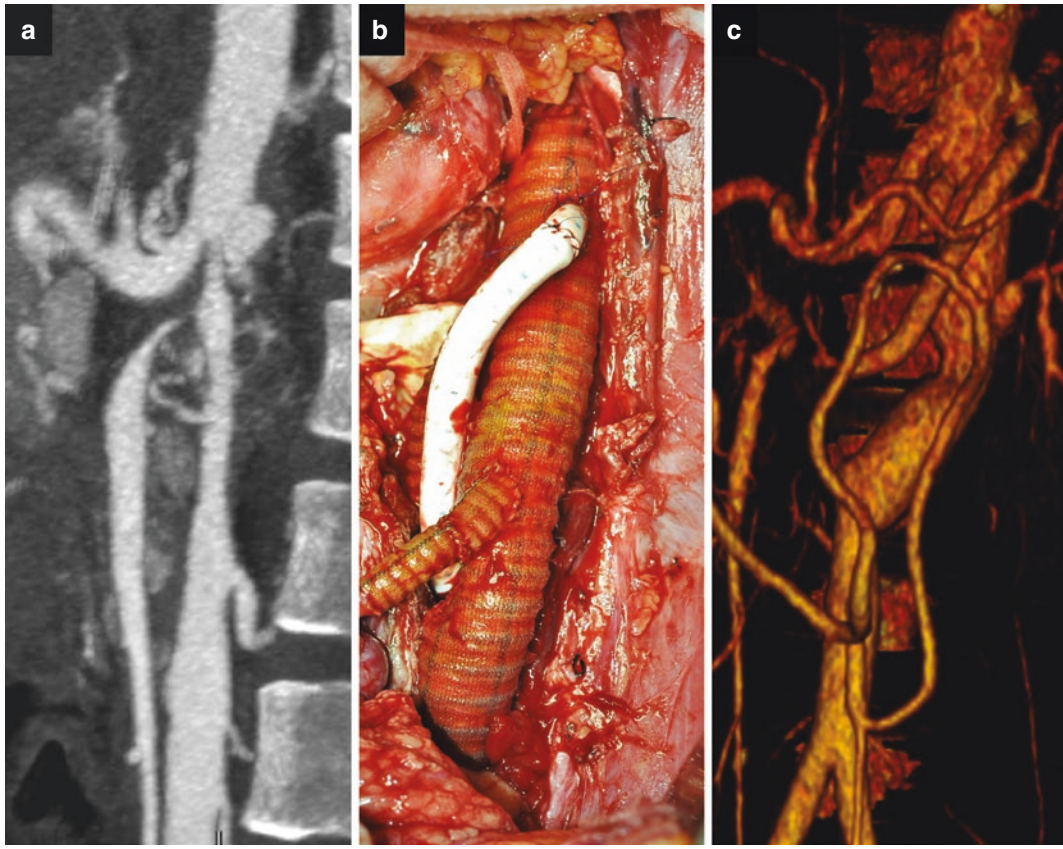

Fig. 33.1 (**a**) Preoperative multiplanar CT reconstruction showing the pseudoaneurysm associated with a narrowed aortic lumen, severe stenosis at SMA origin, and left renal artery occlusion; (**b**) intraoperative finding after extensive debridement and in situ aortic reconstruction; (**c**) postoperative CT 3D reconstruction, showing good patency of all visceral arteries

33.3.2 Case 2

An 81-year-old man was admitted to our emergency department for fever and severe anemia. His medical history was significant for mild hypertension, paroxysmal atrial fibrillation and a previous endovascular infrarenal aneurysm repair (Medtronic Endurant, 28-20-140 mm), and tobacco abuse. Physical examination revealed a palpable, pulsatile mass in the upper abdomen.

Blood test results showed hemoglobin (8.8 g/dL), peripheral white blood cells (18,500/μL), C-reactive protein (27,700 μg/L), and erythrocyte sedimentation rate (100 mm/h). Transthoracic echocardiogram revealed no evidence of endocarditis or vegetation. CTA showed the patency of the previous implanted endoprosthesis, the presence of a type IA endoleak, and a contained rupture of the visceral aorta surrounded by a non-specific tissue with contrast enhancement. Blood culture revealed the presence of *Salmonella* spp.

The patient underwent an exclusion of the contained rupture of the paravisceral aorta and correction of the type IA endoleak by implanting two proximal aortic extensions (W.L Gore & Ass., Gore C-Tag 40-40-10 mm) with selective visceral artery stenting (W.L Gore & Ass., Viabhan peripheral endograft). Celiac trunk (9 × 100), SMA (9 × 100), and right renal artery (7 × 150 mm) were stented on a chimney fashion, while the left

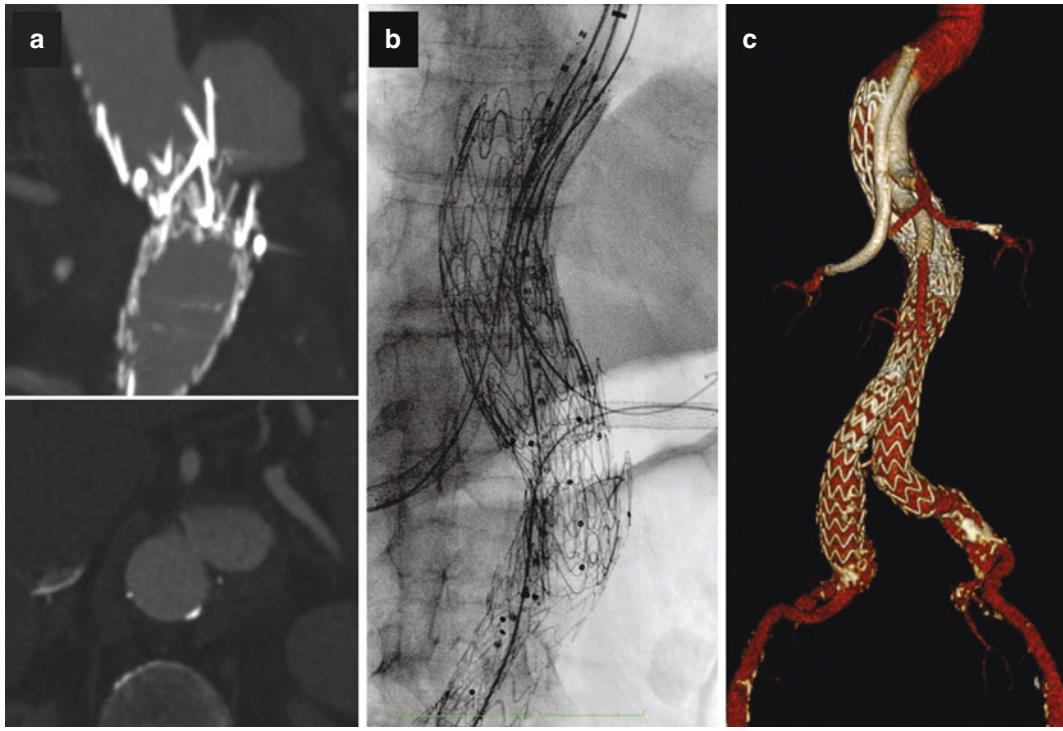

Fig. 33.2 (**a**) Preoperative sagittal and axial CT images showing the mycotic at renal arteries level, just above the implanted endograft; (**b**) intraoperative finding with all devices in place (3 chimney, 1 periscope); (**c**) postoperative CT 3D reconstruction, showing patency of all the implanted graft, complete aneurysm exclusion, and no sign of recurrent infection

renal (7 × 100 mm) was treated by periscope technique. Completion angiography showed patency of all the visceral vessels, absence of any type of endoleak, and complete exclusion of the contained aortic rupture.

The postoperative course was uneventful, and blood cultures were negative. The patient was discharged on the 18th postoperative day under levofloxacin and ceftriaxone. No evidence of recurrent infection was evident at 18-month follow-up CT scan (Fig. 33.2).

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