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Mycotic/Infective Native Aortic Aneurysms: results after preferential use of open surgery and arterial allografts

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Abstract

Objective

Mycotic/Infective native aortic aneurysms (INAA) are heterogeneously managed. In the context of disparate literature, this study aimed to assess the outcomes of INAA surgical management and provide comprehensive data in alignment with recent suggestions for reporting standards.

Methods

We conducted a retrospective review of patients presenting INAA, from September 2002 to March 2020, in two institutions.. In-hospital mortality, 90-days mortality, overall mortality and infection related complications (IRC) were the study endpoints. Overall survival and IRC-free survival were estimated, and predictors of mortality tested using univariate and multivariate analyses.

Results

Seventy patients (60(86%) men, median age 68[59-76] years) were included. 20 (29%) were ruptured at presentation. INAA location was thoracic in 11 (16%) cases, thoraco-abdominal in 7 (10%) cases, abdominal in 50 (71%) cases. Half of abdominal INAA were supra-renal. Two INAAs were concomitantly abdominal and thoracic. Pathogens were identified in 83% of cases. Bacterial spectrum was scattered, with rare *Salmonella* species (n=6, 9%). Open repair (OSR) was performed in 66 (94%) patients including five conversions of first-attempted endovascular grafts (EVAR), 3 hybrid procedures, and one palliative EVAR. Vascular substitutes were cryopreserved arterial allografts(n=67, 96%), prosthesis (n=2), or femoral veins (n=1). Kaplan meier estimates of overall survival at 30 and 90 days was 87% [76.6-93.0], and 71.7% [59.2-80.9], respectively. The overall in-hospital mortality rate was 27.9% [1.8-66.5]. IRC occurred in 7 (10%) patients. The median follow-up period was 26.5 [13.0-66.0] months. Chronic kidney disease (CKD) was independently related to in-hospital mortality (OR 20.7, 95% CI 1.8–232.7). ASA score 3 (OR 6.0, 95%CI 1.1-33.9)4 (OR 14.9, 95%CI 1.7-129.3) and CKD (OR 32.0, 95%CI 1.2-821.5) were related to 90-days mortality.

Conclusion

We report surgical INAA management with significant mortality and low reinfection rate. EVAR necessitated secondary OR but its limited use in this report did not allow to draw conclusions.

Key words: Infected aneurysm, Mycotic aneurysm, Allografts

What this paper adds

This study assesses the outcomes of mycotic/infective native aortic aneurysms (INAA) management and provides comprehensive data in alignment with recent suggestions for reporting standards. It reports a considerable 21% in-hospital mortality, a low 10% infection-related complication (IRC) rate with the use of arterial allografts, and the influence of preoperative status on mortality. The study also shows a scattered bacteriologic spectrum with predominant staphylococci and atypical gram-negative micro-organisms. Altogether, these findings suggest that open repair using biological grafts is an acceptable first-line option until further homogenized data is obtained.

Introduction

Mycotic aneurysms, recently designated as Infective native aortic aneurysm (INAA) to replace the misleading term of “mycotic” aneurysm, is a rare and threatening disease. Specific features emerge from the literature in spite of disparate reports. INAAs are more frequently ruptured at presentation and more often located at the visceral segment of the aorta ¹ than degenerative aneurysms. They are associated with a poorer outcome because of acute presentation and the need for complex reconstructive strategies or, otherwise, slower inflammatory evolution responsible for significant alteration of preoperative status. Contemporary INAAs mostly occur in elderly atherosclerotic population with diseased aortic wall, vulnerable to micro-organism colonization from concomitant bacteremia or adjacent infectious process ^{2,3}.

Medical treatment alone is insufficient with hospital mortality rates reported as high as 82% ⁴. Associated surgery has long been based on open surgical repair (OSR), i.e. resection and debridement to eliminate the infectious process and prevent or treat rupture, and vascular reconstruction. According to the latest European Society of Vascular Surgery guidelines, surgical techniques used in mycotic aneurysm repair should be considered based on patient status, local routines, and team experience, with endovascular repair being an acceptable alternative to open repair ⁵. Despite the risk of infection-related complications (IRC), Endovascular aneurysm repair (EVAR) has been progressively adopted by many teams not only as a bridge-therapy, but also as a permanent treatment.

The resulting literature does not actually allow to draw consensus owing to significant diversity ⁶. Adhesion to homogenized reporting standards was recently advocated and reporting items suggested to enhance comparability between studies⁷. The aim of the present study was therefore to report two high-volume centers experience in the diagnosis and management of INAAs, by following the suggested criteria and evaluating the postoperative mortality and IRCs in descriptive and analytic terms.

Methods

A retrospective review of a prospectively collected computerized database included patients from September 2002 to March 2020 who presented with INAA at the authors' institutions. The study was performed in accordance with the Institutional Ethics Committee rules and followed the MR004 (*Méthodologie de Référence 004*) procedure from the national commission of data processing and freedoms regarding non-interventional studies. The study complied with the principles of the Declaration of Helsinki.

Collected information was modelled on the list of items to be included in research on INAA to enhance comparability between studies, provided by Sörelius K⁷ in 2020. The included reporting items were (1) Preoperative patients' characteristics (sex; age; cardiopulmonary disease, immunosuppressive state/medication, ASA (American Society of Anesthesiologists) score; data on presentation: symptoms, concurrent infection, and laboratory results (inflammatory markers: C reactive protein, leukocyte levels, cultures from blood/tissues).; (2) INAA location and anatomy; (3) Type of treatment, time to treatment, intraoperative details, perioperative events, and follow-up; (4) micro-organism type, species and source of identification.

The diagnosis was based on an association of clinical, biological and radiological parameters including sepsis (fever, leukocytosis, pain, positive blood - culture and positive culture from intraoperative samples), suggestive intraoperative findings (peri aortic or intra-aneurysmal pus), or evocative radiological appearance (irregular wall, rapid growth rate, saccular shape, surrounding tissue infiltration, peri-aortic gas). Negative cultures and absence of pyrexia were not considered as exclusion criteria. In accordance with published standards⁸, a patient with negative culture was considered to have an INAA in case of previous clinical signs of infection or intraoperative findings, with at least 1 week of antibiotics. In subacute or chronic presentations, the preoperative work-up included cardiac stress testing (stress echocardiography or myocardial scintigraphy) and percutaneous coronary revascularization was considered when necessary.

Antimicrobial drug administration was always prescribed by referent infectiologists and analyzed in terms of timing, duration and specificity. Antibiotics were not administered in tolerated sepsis until preoperative or intraoperative bacterial documentation was obtained. In

severe presentations, empiric intravenous wide-spectrum antimicrobial therapy was started after all possible preoperative specimen were obtained.

All types of interventions and vascular substitutes were included. Cryopreserved arterial allografts (CAA) were the preferred material. CAA were available from two tissue banks and could be delivered within two hours in case of emergency, any day of the week. CAA were earlier harvested from brain-deceased donors and cryopreserved following incubation with antibiotics and antifungal agents. When CAA were unavailable, silver-coated vascular prosthesis or neo-aorto-iliac reconstruction using femoral veins were considered. EVAR was considered in ruptured and unstable presentations where proximal and distal landing zones offered the possibility of a straightforward INAA exclusion, or in palliative context.

Follow-up data was obtained for mortality and postoperative complications. IRCs (i.e. persistent/recurrent sepsis, graft infection, recurrent INAA and development of aorto-enteric/bronchial fistula) were specifically identified

Statistical analysis

A descriptive analysis was performed using mean \pm SD or median [interquartile range] for continuous variables. For categorical variables, absolute numbers and percentages were computed.

The primary endpoint was in-hospital mortality. The secondary endpoints were 30-days mortality, 90-days mortality, IRC rate, and overall survival. These outcomes were expressed as survival functions and their 95% confidence intervals. Logistic regression models were used to examine the association between in hospital mortality and potential factors, and 90-days mortality and potential factors. For multivariable analyses, a backwise method was used using variables with $p < .20$ in univariable analyses. Results were expressed as odds ratio (OR) and 95% confidence interval (CI). Survival times were defined as the duration between surgery and the date of IRC, or the duration between surgery and the date of death. The remaining subjects were censored at last follow-up. Overall survival and IRC-free survival curves were presented using Kaplan-Meier method. Cumulated incidence function of IRC was built, with death considered as a competing event. Tests were considered as significant at a p value $< .05$.

Among the studied factors, tertiles were compared in continuous variables (age, aneurysm diameter, time to intervention) and micro-organisms were compared as salmonella *vs* non-salmonella species, in a classic approach. Infections involving Gram-negative microorganisms (GNM), candida species, and Methicillin-resistant staphylococcus aureus— known to be associated with worse outcomes in aortic infections - were also compared to infection related to other organisms^{9,10}.

All statistical analyses were performed using SAS (SAS Institute, Inc., Cary, NC, USA) and Stata version 16.0, StataCorp, College Station, TX, USA.

Results

Preoperative findings

Seventy patients (60 (86%) men, 10 (14%) women; median age 68 [59-76] years) presented in two institutions (38 in Henri Mondor Hospital, 32 in La Pitié Salpêtrière Hospital) from September 2002 to March 2020 with INAAs. Twenty (29%) were ruptured at presentation, of whom 6 (8.5%) had patent aorto-enteric (n=4) or bronchial (n=2) fistula. Five (25%) ruptured INAAs induced hemodynamic instability. Five (7%) patients were pauci-symptomatic. Their diagnosis was based on clinical and radiologic signs. Patients preoperative characteristics and clinical presentation are displayed in **Table 1**.

INAA location was thoracic in 11 (16%) cases (one located in the ascending aorta, three in the aortic arch, and 7 in the descending aorta), thoraco-abdominal in seven (10%) cases, and abdominal in 50 (71%) cases. Half (n=25) of the abdominal INAAs were infra-renal, i.e. presenting uninvolved infra-renal aneurysm neck. The other half were juxta-renal and supra-renal aneurysms. Two (3%) INAAs were concomitantly abdominal and thoracic. They were treated in a single procedure for one using a thoraco-abdominal approach and considered as such for the analysis, and in a double -staged procedure for the other considered as a thoracic INAA for the analysis. Multiple thoracic locations were present in two (3%) patients, multiple abdominal locations in two (3%), and associated femoral infective aneurysm in one case.

Computed-tomography was performed in all patients. Positron-emitting tomography was needed in four (6%) cases. Radiolabeled white blood cells scintigraphy was performed additionally in one case. INAAs were saccular in 41 (67%) patients, fusiform in the remaining patients. The median diameter at presentation was 52 [45-65] mm. The median diameter of ruptured INAAs was 61 [52.5-69.5] mm.

Spondylodiscitis with vertebral erosion was present in seven (10%) patients. Vertebral infection was the primum etiology in two patients, who had a history of vertebral osteosynthesis in one, and tuberculosis in the second. Contiguous vertebral damage resulted from primary vascular infection in the five other cases.

The median preoperative CRP level was 133 [59-236] mg/l. The median preoperative leukocytes count was 12 300 [9000-17000]/mm³. Eight (11%) patients did not show biological signs of infection and diagnosis was based on clinical and radiological findings. In these cases, micro-organisms were *Coxiella burnetti* (n=2), Methicillin sensible *Staphylococcus aureus* (MSSA) (n=2), *Salmonella sp.* (n=1), multiple germs from aorto-enteric fistula (n=1), and not detected in 2 patients.

Pathogens were preoperatively identified (n=30, 43%) from blood samples in 26 patients (23 blood cultures, 2 serologies, 1 PCR test), osteo-articular samples in three patients, and sputum smear examination in one. The remaining bacteriological evidence was obtained intra-operatively (n= 24, 34%) from aortic tissue culture in 22 patients, and vertebral biopsy in 2 patients. Both preoperative blood culture and tissue culture allowed same germ identification in 4 (6%) patients. In twelve patients (17%), no micro-organism could be identified. Implicated micro-organisms are displayed in **Table 2**. Noticeably, salmonella species infections were rare (n=6, 9%).

Preoperative anti-microbial therapy was administrated in 48 (69%) patients, for more than 3 days in 34 (48%) patients. Treatment was performed in emergency (i.e.<24h) in 25(36%) cases. The median time from hospital admission to operation was 4.5 [0-12.5] days.

Operative treatment

All patients underwent surgery. OSR with in-situ reconstruction was performed in the majority of patients (n=61, 87%). EVAR was performed either as a bridge-therapy or first-intention treatment in 6 patients, of whom 5 underwent early OSR secondarily because of IRCs, bringing the overall open repair rate to 94% (n=66). Hybrid procedures were practiced in three (4%) patients.

OSR procedures are detailed in **Table 3**. All interventions consisted of in-situ reconstruction with or without reno-visceral vessel or supra-aortic trunk management.

Vascular substitutes were CAA in the majority of cases (n=67, 96%). One femoral vein compilation and two silver-coated grafts were used in the remaining patients because allografts were unavailable.

Abdominal INAAs approaches were median laparotomies (n=33), or retroperitoneal (n=17) and suprarenal clamping was necessary in 25 (50%) cases. Thoraco-abdominal INAAs were approached by thoracotomies extending to the abdominal level. Thoracotomies (sternotomy, n=3, postero-lateral thoracotomy, n=4) or thoraco-abdominal approaches (n=4) were necessary in thoracic INAAs. Extracorporeal circulation was necessary in 10 cases under the form of distal aortic perfusion (n=7) and deep hypothermic circulatory arrest (n=3).

Hybrid procedures consisted of reno-visceral debranching in 2 patients and carotid-subclavian debranching in 1 patient, followed during the same procedure by tubular stent-graft implantation.

EVAR was performed in an 87 years-old patient presenting thoracic aneurysm with esophageal fistula, as a palliative approach, and to control hemorrhage in five patients, in whom IRCs (persistent sepsis, n=4 including one EVAR in the presence of an aorto-duodenal fistula; graft infection n=1) systematically lead to OSR 7 [4-55] days after EVAR.

Pedicled omentoplasty was performed in 19 (28%) patients including 16 abdominal INAA repair, 2 thoraco-abdominal INAAs and one thoracic INAA (trans-diaphragmatic omental flap). The median operative time for OSR was 261 [200-355] minutes

Early and late outcomes

Kaplan meier estimates of overall survival at 30 and 90 days was 87% [76.6-93.0], and 71.7% [59.2-80.9], respectively. The overall in-hospital mortality rate was 27.9% [1.8-66.5]. The mortality rates according to INAA location and presentation, and causes of early mortality are listed in **Table 4 and 5, respectively**. The median follow-up period for surviving patients was 26.5 [13.0-66.0] months. The overall survival rate was 45.7% [18.2-69.8]. Kaplan–Meier survival curves for overall survival and IRC-free survival are shown in Figure 1A and 1B. The cumulated incidence function for IRC is presented in Figure 1 C.

Significant early postoperative complications occurred in 35 (50%) patients (**Table 6**). Nineteen (27%) patients required reintervention: 13 hemostasis maneuvers, six intestinal

resections, four revascularization procedures, one nephrectomy, one cholecystectomy, one stent-graft extension, and one pericardial drainage.

The median (IQR) ICU time in surviving patients was 5 [3-8] days. The median hospital stay was 21 [13-32] days.

Besides those leading to open conversion of first-attempted EVAR, IRC occurred in 7 (10%) OSR patients and consisted of persistent sepsis in 4 patients, endocarditis early onset in 1 patient, and late recurrence of INAA in two (at 4 and 9 months postoperatively).

The median postoperative antimicrobial therapy duration was 42 [21-45] days.

Late reinterventions consisted of additional allograft implantation because of INAA recurrence in two patients (at 4 and 9 months), three aneurysmal degeneration (at postoperative year 5, 13 and 14), and one asymptomatic allograft stenosis.

Prognostic factors for in-hospital and 90-days mortality

Univariate analysis identified seven factors associated ($p < 0.2$) with in-hospital mortality: ASA score, diabetes, coronary disease, chronic kidney disease, aorto-enteric/bronchial fistula, preoperative antimicrobial therapy administration and infection related to virulent germs (**Table 7**). Multivariate analysis only identified CKD as independently related to in-hospital mortality (OR 20.7, 95% CI 1.8–232.7). For 90-days mortality, only factors with $p \leq 0.05$ in univariate analysis were used for multivariate analysis, due to low number of events. Age ≥ 70 (OR 10.8, 95% CI 1.1-107.8), ASA score 3 (OR 6.0, 95% CI 1.1-33.9), ASA score 4 (OR 14.9, 95% CI 1.7-129.3) and CKD (OR 32.0, 95% CI 1.2-821.5) were independently related to 90-days mortality. Of note, laboratory data (leucocytes count and CRP) as well as operative time were missing in more than 14 (20%) patients which prevented us from including them in the prognostic analyses.

Discussion

The study highlights interesting results in an opposite direction to the existing literature: 1/ Pathogens were rarely *Salmonella* species, and *Staphylococcus* species did not flagrantly prevail. The provided bacteriological patterns are probably less historical and more contemporary. 2/ Emergent EVAR, although limited to a small number of patients lead to IRCs and open conversion 3/ Medical history and comorbidities were more predictive than the type of presentation or aneurysm anatomies for in-hospital death and 90-day mortality rates. 4/ IRCs rate was low, probably due to the use of CAA. Although this is not the rule^{6, 11} a striking 50% proportion of suprarenal aortic involvement was noted in the subgroup of abdominal INAAs, in line with other series,^{8,12-14}. The deadlier subcategory was the thoraco-abdominal INAAs where in-hospital death occurred in 37% of patients.

In the era of extensively used antibiotics, the bacteriologic spectrum involved in INAAs is wide. The most encountered microorganisms are *Staphylococcus* species that account for 28% to 71% of cases^{8,14-16}. *Salmonella* species used to be frequent (15% to 24% of patients), and *Streptococcus* species reported in less than 10% of the cases. However, different germs are increasingly identified^{17,18}. In contemporary European series, *Salmonella* infections are rare, accounting for 7% to 9% of cases¹⁷⁻¹⁹. In Taiwan however, where numerous and large reports are provided, the most common pathogen is non-typhi *Salmonella* (60%)¹⁹. Among atypical bacteria in our experience, *Campylobacter* is isolated in up to 23% of cases. In general, GNM were predominant. GNM have been formerly reported to be more virulent than gram-positive infections regarding aneurysm rupture and mortality in a very limited study²⁰. The reason for this increased virulence might be an augmented proteolytic activity causing vascular wall necrosis similar to what is observed in autologous and prosthetic graft infections²¹. The same GNM virulence, along with MRSA and *Candida* species, is described in prosthetic vascular infections^{9,10}. For this reason, our analysis compared aggressive germs (i.e GNM, MRSA, *Candida*) to less virulent ones without finding any significant difference. Antimicrobial therapy is an integral part of INAA treatment. In the acute phase, broad spectrum antibiotics or antibiotics directed against preoperatively identified organisms is indicated to control infection and sepsis. There is no consensus on the optimal length of antimicrobial therapy. Pre-operative antibiotics for more than three days²² and post-operative treatment for more than 6 months¹⁹ had a significant protective effect. The usual follow-up protocol includes regular assessment of laboratory markers and radiological evaluation¹⁹.

There is a growing trend to treat INAA by endovascular means. A systematic review in 2007 reported highly satisfactory 30-day and 2-year survival rates in 48 patients ($89.6 \pm 4.4\%$ and $82 \pm 5.8\%$, respectively) despite a 23% rate of highly fatal persisting sepsis or re-bleeding²³. Ruptured aneurysms and fever at operation were significantly associated with poor EVAR results. The same authors published a limited series in 2012²⁴, with favorable outcomes in selected 12 patients who all had positive blood cultures, mainly salmonella infections, and adjunctive drainage or debridement in 33% of cases. These early reports lacked sufficient sample size and follow-up. Afterwards, a nationwide Swedish study identified 132 patients over a 20 years period (1994-2014) in whom OSR (n=62) was performed principally in the first study period, and EVAR (n=70) in the later one¹⁹. Survival at 3 months was lower for OSR than for EVAR (74% versus 96%, $P < .001$). There was no difference in long-term survival (5 years 60% versus 58%, $P = .771$), IRC (18% versus 24%, $P = .439$), or reoperation (21% versus 24%, $P = .650$). The authors literally described a paradigm shift in treating INAA in Sweden. Later Taiwanese experience in 40 consecutive patients²⁵ was less optimistic mainly in terms of IRC (20%) that were uniformly fatal. In 2019, a systematic review identified 963 patients treated by OSR (n= 556 ;58%), endovascular aortic repair (EVAR; n = 373; 39%), and medical treatment alone (n=34;3%)⁶. Because of patient and study heterogeneity, along with missing data, no strong conclusions could be obtained nor meta-analyses performed. The overall IRC rate, irrespective of surgical technique, was 21%. However, specific IRC rates individually extracted from the selected series, provided as supplemental data in that paper, appear lower in OSR (10% to 25%^{17,19,24-31}) than EVAR (24% to 66%)^{19,32-35}. IRCs are even absent in OSR studies using biological material³⁶. Our study included a vast majority of biologically replaced INAAs using CAA with subsequent low IRC rate estimated at 10%. Conversely, the few EVAR cases uniformly presented IRCs leading to conversion. Some authors have demonstrated that OSR, after EVAR, is more likely to be complicated and lead to higher operative mortality³⁷⁻⁴⁰. However, all these EVAR procedures were performed in ruptured INAAs. They were rarely performed and therefore no solid conclusion can be drawn.

This study complies with the recent recommendations and calls for homogeneous reporting. Previously identified mortality factors (ruptured INAA, suprarenal location, non-salmonella infections) were not identified as such in our report which might be explained by the small number of patients in each subgroup of the study, in addition to the fact that the majority of ruptured cases were stable at presentation. The preoperative patient status (CKD, age, ASA Score 3-4) was more influential than infection-specific variables. Overall, our experience helps

draw the outlines of INAA management: 1/ treat all INAAs including the suprarenal and ruptured presentations 2/ perform OSR in non-ruptured presentations, and prioritize biological material 3/ use EVAR as a bridge-therapy in ruptured INAAs to prepare the patient for secondary OSR if eligible, or permanent treatment otherwise. The latter suggestion is however balanced with very limited use of EVAR in the present report and the possibility of more favorable outcomes with a wider application, including non-ruptured presentation with significant comorbidities.

References

1. Chan FY, Crawford ES, Coselli JS, Safi HJ, Williams TW, Jr. In situ prosthetic graft replacement for mycotic aneurysm of the aorta. *Ann Thorac Surg.* 1989;47:193-203.
2. Reddy DJ, Shepard AD, Evans JR, Wright DJ, Smith RF, Ernst CB. Management of infected aortoiliac aneurysms. *Arch Surg.* 1991;126:873-8; discussion 8-9.
3. Brown SL, Busuttil RW, Baker JD, Machleder HI, Moore WS, Barker WF. Bacteriologic and surgical determinants of survival in patients with mycotic aneurysms. *J Vasc Surg.* 1984;1:541-7.
4. Hsu RB, Chang CI, Wu IH, Lin FY. Selective medical treatment of infected aneurysms of the aorta in high risk patients. *J Vasc Surg.* 2009;49:66-70.
5. Wanhainen A, Verzini F, Van Herzele I, Allaire E, Bown M, Cohnert T, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. *Eur J Vasc Endovasc Surg.* 2019 Jan;57(1):8-93.
6. Sorelius K, Budtz-Lilly J, Mani K, Wanhainen A. Systematic Review of the Management of Mycotic Aortic Aneurysms. *Eur J Vasc Endovasc Surg.* 2019;58:426-35.
7. Sorelius K, Wanhainen A, Mani K. Infective Native Aortic Aneurysms: Call for Consensus on Definition, Terminology, Diagnostic Criteria, and Reporting Standards. *Eur J Vasc Endovasc Surg.* 2020;59:333-4.
8. Oderich GS, Panneton JM, Bower TC, Cherry KJ, Jr., Rowland CM, Noel AA, et al. Infected aortic aneurysms: aggressive presentation, complicated early outcome, but durable results. *J Vasc Surg.* 2001;34:900-8.

9. Calligaro KD, Veith FJ, Schwartz ML, Savarese RP, DeLaurentis DA. Are gram-negative bacteria a contraindication to selective preservation of infected prosthetic arterial grafts? *J Vasc Surg* 1992; 16:337-345; discussion 345-336.
10. Nasim A, Thompson MM, Naylor AR, Bell PR, London NJ. The impact of MRSA on vascular surgery. *Eur J Vasc Endovasc Surg* 2001; 22:211-214.
11. Lin CH, Hsu RB. Primary Infected Aortic Aneurysm: Clinical Presentation, Pathogen, and Outcome. *Acta Cardiol Sin.* 2014 Nov;30(6):514-21.
12. Moneta GL, Taylor LM, Jr., Yeager RA, Edwards JM, Nicoloff AD, McConnell DB, et al. Surgical treatment of infected aortic aneurysm. *Am J Surg.* 1998;175:396-9.
13. Muller BT, Wegener OR, Grabitz K, Pillny M, Thomas L, Sandmann W. Mycotic aneurysms of the thoracic and abdominal aorta and iliac arteries: experience with anatomic and extra-anatomic repair in 33 cases. *J Vasc Surg.* 2001;33:106-13.
14. Vallejo N, Picardo NE, Bourke P, Bicknell C, Cheshire NJ, Jenkins MP, et al. The changing management of primary mycotic aortic aneurysms. *J Vasc Surg.* 2011;54:334-40.
15. Fichelle JM, Tabet G, Cormier P, Farkas JC, Laurian C, Gigou F, et al. Infected infrarenal aortic aneurysms: when is in situ reconstruction safe? *J Vasc Surg.* 1993;17:635-45.
16. Hsu RB, Lin FY. Surgical pathology of infected aortic aneurysm and its clinical correlation. *Ann Vasc Surg.* 2007;21:742-8.
17. Brossier J, Lesprit P, Marzelle J, Allaire E, Becquemin JP, Desgranges P. New bacteriological patterns in primary infected aorto-iliac aneurysms: a single-centre experience. *Eur J Vasc Endovasc Surg.* 2010;40:582-8.

18. Tshomba Y, Sica S, Minelli F, Giovannini S, Murri R, De Nigris F, et al. Management of mycotic aorto-iliac aneurysms: a 30-year monocentric experience. *Eur Rev Med Pharmacol Sci.* 2020;24:3274-81.
19. Sorelius K, Wanhainen A, Furebring M, Bjorck M, Gillgren P, Mani K, et al. Nationwide Study of the Treatment of Mycotic Abdominal Aortic Aneurysms Comparing Open and Endovascular Repair. *Circulation.* 2016;134:1822-32.
20. Jarrett F, Darling RC, Mundth ED, Austen WG. Experience with infected aneurysms of the abdominal aorta. *Arch Surg.* 1975;110:1281-6.
21. Geary KJ, Tomkiewicz ZM, Harrison HN, Fiore WM, Geary JE, Green RM, et al. Differential effects of a gram-negative and a gram-positive infection on autogenous and prosthetic grafts. *J Vasc Surg.* 1990;11:339-45; discussion 46-7.
22. [Kan CD, Lee HL, Luo CY, Yang YJ. The efficacy of aortic stent grafts in the management of mycotic abdominal aortic aneurysm-institute case management with systemic literature comparison. *Ann Vasc Surg.* 2010;24:433-40.](#)
23. Kan CD, Lee HL, Yang YJ. Outcome after endovascular stent graft treatment for mycotic aortic aneurysm: a systematic review. *J Vasc Surg.* 2007;46:906-12.
24. Kan CD, Yen HT, Kan CB, Yang YJ. The feasibility of endovascular aortic repair strategy in treating infected aortic aneurysms. *J Vasc Surg.* 2012;55:55-60.
25. Luo CM, Chan CY, Chen YS, Wang SS, Chi NH, Wu IH. Long-term Outcome of Endovascular Treatment for Mycotic Aortic Aneurysm. *Eur J Vasc Endovasc Surg.* 2017;54:464-71.
26. Hsu RB, Chen RJ, Wang SS, Chu SH. Infected aortic aneurysms: clinical outcome and risk factor analysis. *J Vasc Surg.* 2004;40:30-5.

27. Kyriakides C, Kan Y, Kerle M, Cheshire NJ, Mansfield AO, Wolfe JH. 11-year experience with anatomical and extra-anatomical repair of mycotic aortic aneurysms. *Eur J Vasc Endovasc Surg.* 2004;27:585-9.
28. Woon CY, Sebastian MG, Tay KH, Tan SG. Extra-anatomic revascularization and aortic exclusion for mycotic aneurysms of the infrarenal aorta and iliac arteries in an Asian population. *Am J Surg.* 2008;195:66-72.
29. Chen IM, Chang HH, Hsu CP, Lai ST, Shih CC. Ten-year experience with surgical repair of mycotic aortic aneurysms. *J Chin Med Assoc.* 2005;68:265-71.
30. Dubois M, Daenens K, Houthoofd S, Peetermans WE, Fourneau I. Treatment of mycotic aneurysms with involvement of the abdominal aorta: single-centre experience in 44 consecutive cases. *Eur J Vasc Endovasc Surg.* 2010;40:450-6.
31. Yu SY, Hsieh HC, Ko PJ, Huang YK, Chu JJ, Lee CH. Surgical outcome for mycotic aortic and iliac aneurysm. *World J Surg.* 2011;35:1671-8.
32. Sorelius K, Mani K, Bjorck M, Sedivy P, Wahlgren CM, Taylor P, et al. Endovascular treatment of mycotic aortic aneurysms: a European multicenter study. *Circulation.* 2014;130:2136-42.
33. Jia X, Dong YF, Liu XP, Xiong J, Zhang HP, Guo W. Open and endovascular repair of primary mycotic aortic aneurysms: a 10-year single-center experience. *J Endovasc Ther.* 2013;20:305-10.
34. Sedivy P, Spacek M, El Samman K, Belohlavek O, Mach T, Jindrak V, et al. Endovascular treatment of infected aortic aneurysms. *Eur J Vasc Endovasc Surg.* 2012;44:385-94.
35. Clough RE, Black SA, Lyons OT, Zayed HA, Bell RE, Carrell T, et al. Is endovascular repair of mycotic aortic aneurysms a durable treatment option? *Eur J Vasc Endovasc Surg.* 2009;37:407-12.

36. Heinola I, Sorelius K, Wyss TR, Eldrup N, Settembre N, Setacci C, et al. Open Repair of Mycotic Abdominal Aortic Aneurysms With Biological Grafts: An International Multicenter Study. *J Am Heart Assoc.* 2018;7.
37. Sorelius K, Mani K, Bjorck M, Nyman R, Wanhainen A. Endovascular repair of mycotic aortic aneurysms. *J Vasc Surg.* 2009;50:269-74.
38. Forbes TL, Harding GE. Endovascular repair of Salmonella-infected abdominal aortic aneurysms: a word of caution. *J Vasc Surg.* 2006;44:198-200.
39. Koepfel TA, Gahlen J, Diehl S, Probst RL, Dueber C. Mycotic aneurysm of the abdominal aorta with retroperitoneal abscess: successful endovascular repair. *J Vasc Surg.* 2004;40:164-6.
40. Gonzalez-Fajardo JA, Gutierrez V, Martin-Pedrosa M, Del Rio L, Carrera S, Vaquero C. Endovascular repair in the presence of aortic infection. *Ann Vasc Surg.* 2005;19:94-8.

FIGURE LEGEND

Figure 1

Kaplan-Meier survival curves : (A) Overall survival (B) Survival without infection-related complications (C) Cumulated incidence function for infection-related complications (IRC) (D) Overall survival by INAA type

<i>Patients characteristics</i>	N=70
Median age (min-max)	68 (18-91)
Male gender, n(%)	60 (86%)
Arterial hypertension, n(%)	45 (64%)
Hypercholesterolemia, n(%)	25 (36%)
Active smoking, n(%)	23 (33%)
Coronary disease, n(%)	22 (31%)
Diabetes mellitus, n(%)	16 (23%)
Chronic kidney disease, n(%)	6 (9%)
ASA score, n(%)	
2	29 (41%)
3	32 (46%)
4	9 (13%)
<i>Clinical presentation</i>	N (%)
Sepsis + Abdominal / Thoracic pain	20 (29%)
Sepsis	15 (22%)
Rupture	14 (20%)
<i>Free rupture</i>	5 (7%)
<i>Contained by muscles/vertebrae</i>	9 (13%)
<i>Aorto-enteric/bronchial fistula</i>	6 (9%)
Abdominal / Thoracic pain	9 (13%)
Pauci-symptomatic	5 (7%)

Table 1: Patients preoperative characteristics and clinical presentation. ASA, American Society of Anesthesiologists.

Microorganism	N=58
<i>Staphylococcus aureus</i>	12 (1 MRSA) (18.5%)
<i>Campylobacter sp.</i>	8 (11.5%)
<i>Escherichia coli</i>	6 (8.5%)
Salmonella sp. *	6 (8.5%)
<i>Streptococcus pneumoniae</i>	4 (5.7%)
<i>Coxiella burnetti</i>	3 (4.5%)
<i>Candida albicans</i> **	3 (4.5%)
Enterobacter sp	3 (4.5%)
Group A Streptococcus	3 (4.5%)
<i>Mycobacterium tuberculosis</i>	2 (3%)
Anaerobic germs *	2 (3%)
<i>Klebsiella pneumoniae</i>	1 (1.4%)
<i>Clostridium septicum</i>	1 (1.4%)
<i>Corynebacterium jeikeium</i>	1(1.4%)
<i>Proteus vulgaris</i>	1(1.4%)
<i>Streptococcus constellatus + oralis</i> *	1(1.4%)
<i>Escherichia coli + streptococcus sp.</i> *	1(1.4%)

Table 2 : Micro-organisms identified from preoperative (blood, osteo-articular, or sputum) and/or intraoperative samples (aorta, peri-aortic tissue, vertebrae) . In twelve patients (17%), no micro-organism could be identified

MRSA = methicillin-resistant *Staphylococcus aureus*.

* Including an aorto-enteric/bronchial fistula

** All patients presenting aorto-enteric/bronchial fistula

Type of aortic repair	N=70
Aortic tube *	26 (37%)
Aorto-iliac **	19 (27%)
Aortic tube with reno-visceral arteries management	12 (17%)
Aorto-femoral	6 (9%)
Aortic tube with supra-aortic trunks management	3 (4%)
Reno-visceral debranching + EVAR	3 (%)
EVAR	1 (%)

Table 3: Types of aortic reconstruction in all 70 patients undergoing surgical treatment of infective native aortic aneurysms.

*including 3 early emergent EVAR conversion to open repair

**including 2 early emergent EVAR conversion to open repair

Early overall survival rates	Day 30	Day 90
	Survival rate [95% CI]	Survival rate [95% CI]
Overall	87.0 [76.6; 93.0]	71.7 [59.2; 80.9]
<i>Thoracic INAA</i>	71.6 [35.3; 89.9]	61.4 [26.6; 83.5]
<i>Thoraco-abdominal INAA</i>	88.9 [43.3; 98.4]	55.6 [20.4; 80.5]
<i>Abdominal INAA</i>	90.0 [77.5 ; 95.7]	77.1 [62.5; 86.7]
Ruptured	85.0 [60.4; 94.9]	74.7 [49.4; 88.6]

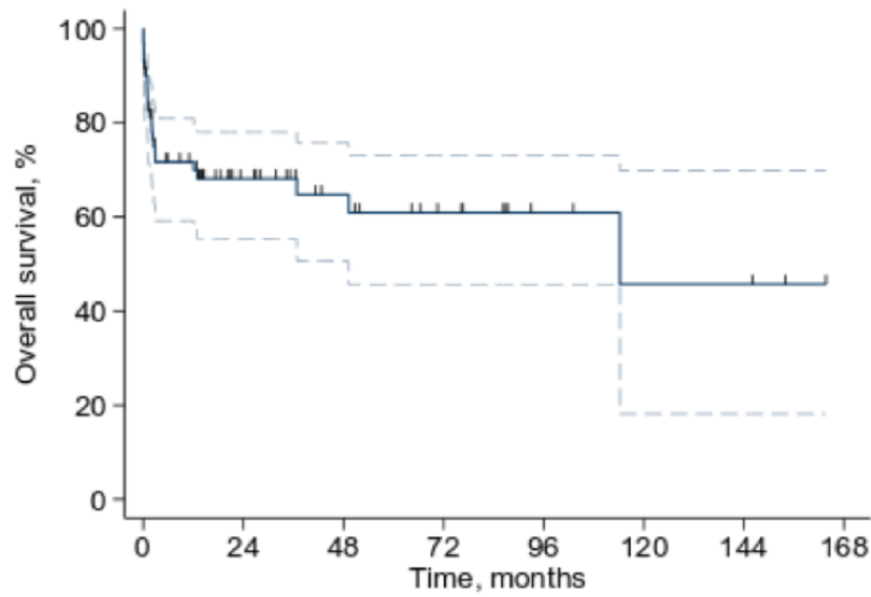
Table 4: Mortality rates after preferential use of open surgery and arterial allografts in 70 patients presenting with infective native aortic aneurysms

Causes of postoperative death	N=15
Postoperative bleeding <i>Allograft rupture</i> <i>Lumbar artery</i> <i>Retroperitoneal bleeding</i>	3 (20%)
Multi-organ failure - <i>Following colonic ischaemia</i>	6 (40%) 3
Pulmonary infection	2 (13.3%)
Septic shock	2 (13.3%)
Cardiac arrest of unknown origin	1 (6.6%)
Acute coronary syndrome	1 (6.6%)

Table 5: Causes of postoperative deaths after preferential use of open surgery and arterial allografts in 70 patients presenting with infective native aortic aneurysms

Postoperative complications	N (%)
Acute bleeding	9 (13)
<i>Retroperitoneal bleeding requiring embolization</i>	2
<i>Retroperitoneal/Thoracic bleeding</i>	5
<i>Anastomotic/allograft disruption</i>	2
Ischemic events	11 (16)
<i>Ischemic colitis with bowel resection</i>	7
<i>Lower limb by allograft segmental occlusion</i>	2
<i>Renal ischemia by allograft bypass thrombosis</i>	2
Cardiac events	4 (6)
<i>Acute coronary syndrome</i>	2
<i>Arrhythmia</i>	1
<i>Cardiac arrest (unknown origin)</i>	1
Pulmonary events	8 (11)
<i>Acute respiratory failure</i>	5
<i>Pulmonary embolism</i>	3
<i>Pulmonary infection</i>	10
Acute renal failure	14 (20)
<i>Requiring dialysis</i>	6
Paraplegia (total/partial)	3 (4)
Stroke	2 (3)
Early IRCs	6 (9)
<i>Persistent sepsis</i>	5
<i>Postoperative endocarditis</i>	1
Compressive pericardial effusion	1(1.4)
Infected renal infarct	1 (1.4)

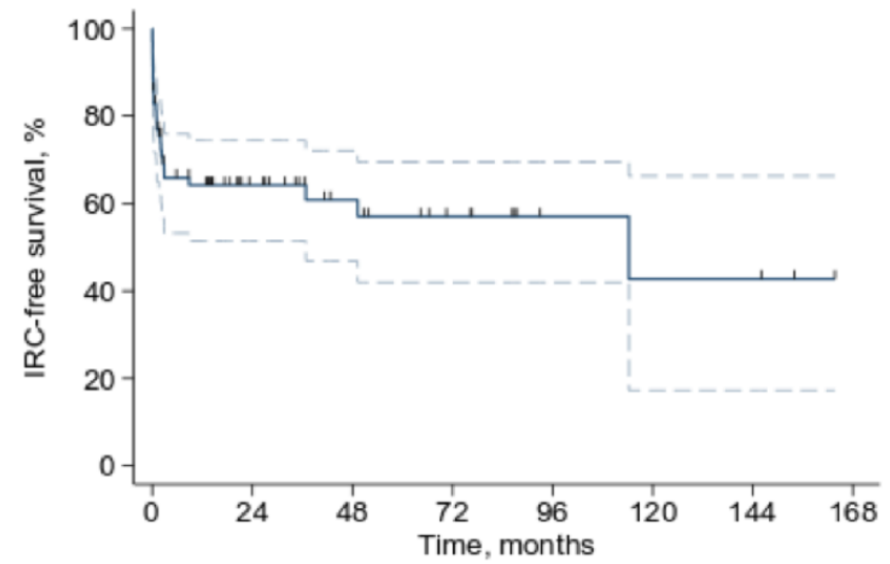
Table 6: Postoperative complications after preferential use of open surgery and arterial allografts in 70 patients presenting with infective native aortic aneurysms



Number at risk (events)
 70 (21) 27 (1) 17 (1) 11 (0) 5 (1) 3 (0) 3 (0) 0

95% CI Survivor function

A

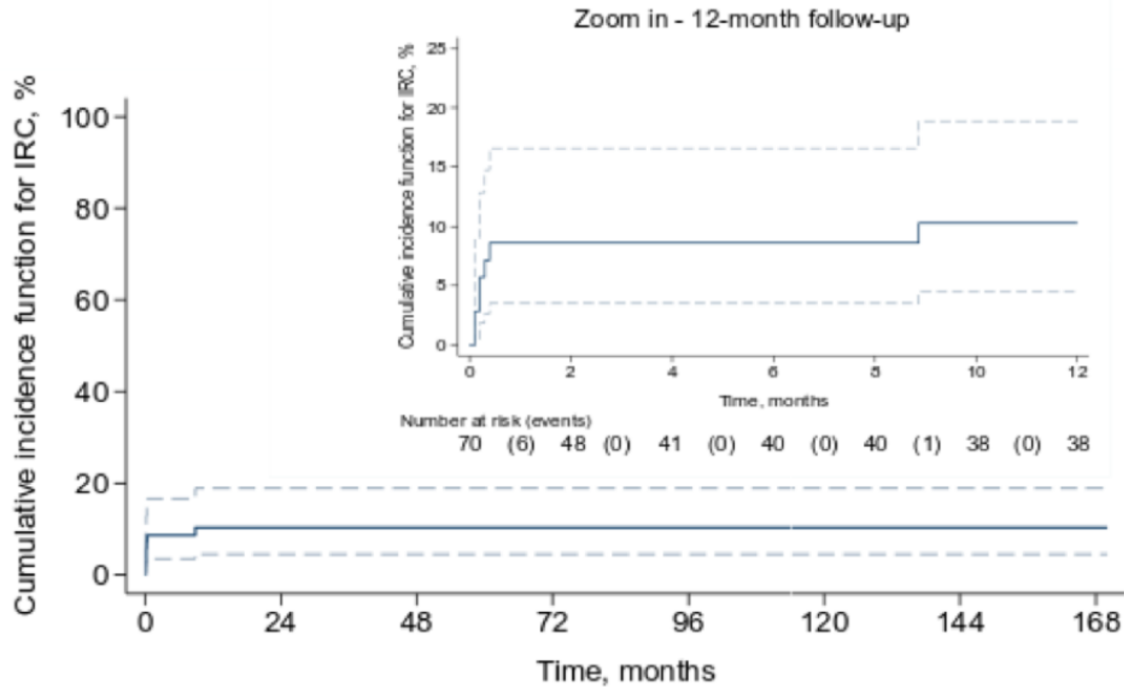


Number at risk (events)
 70 (24) 26 (1) 16 (1) 10 (0) 4 (1) 3 (0) 3 (0) 0

95% CI Survivor function

IRC indicates infection related complication

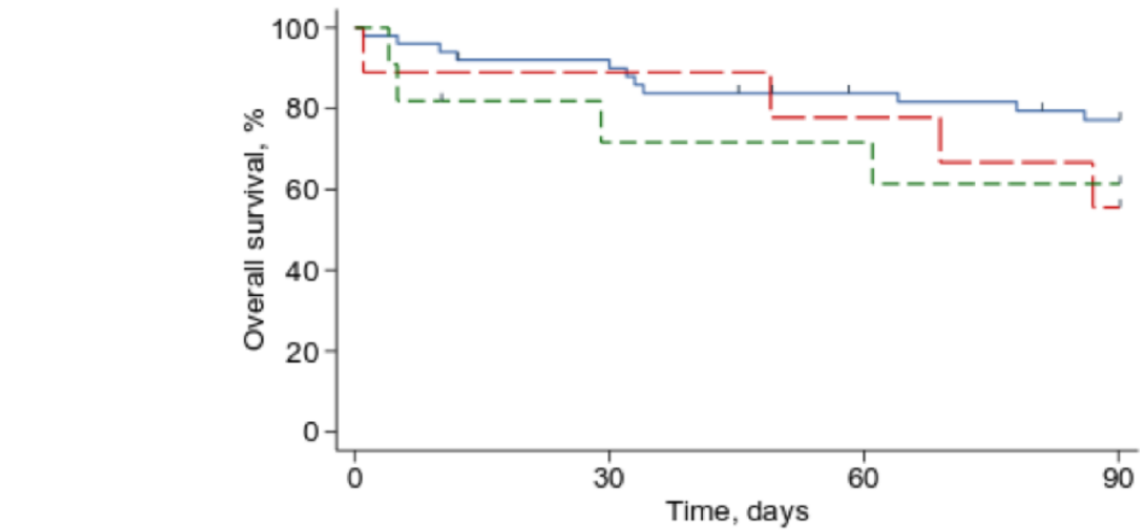
B



Number at risk (events)
 70 (7) 26 (0) 16 (0) 10 (0) 4 (0) 3 (0) 3 (0) 0

95% CI Cumulative incidence function

C



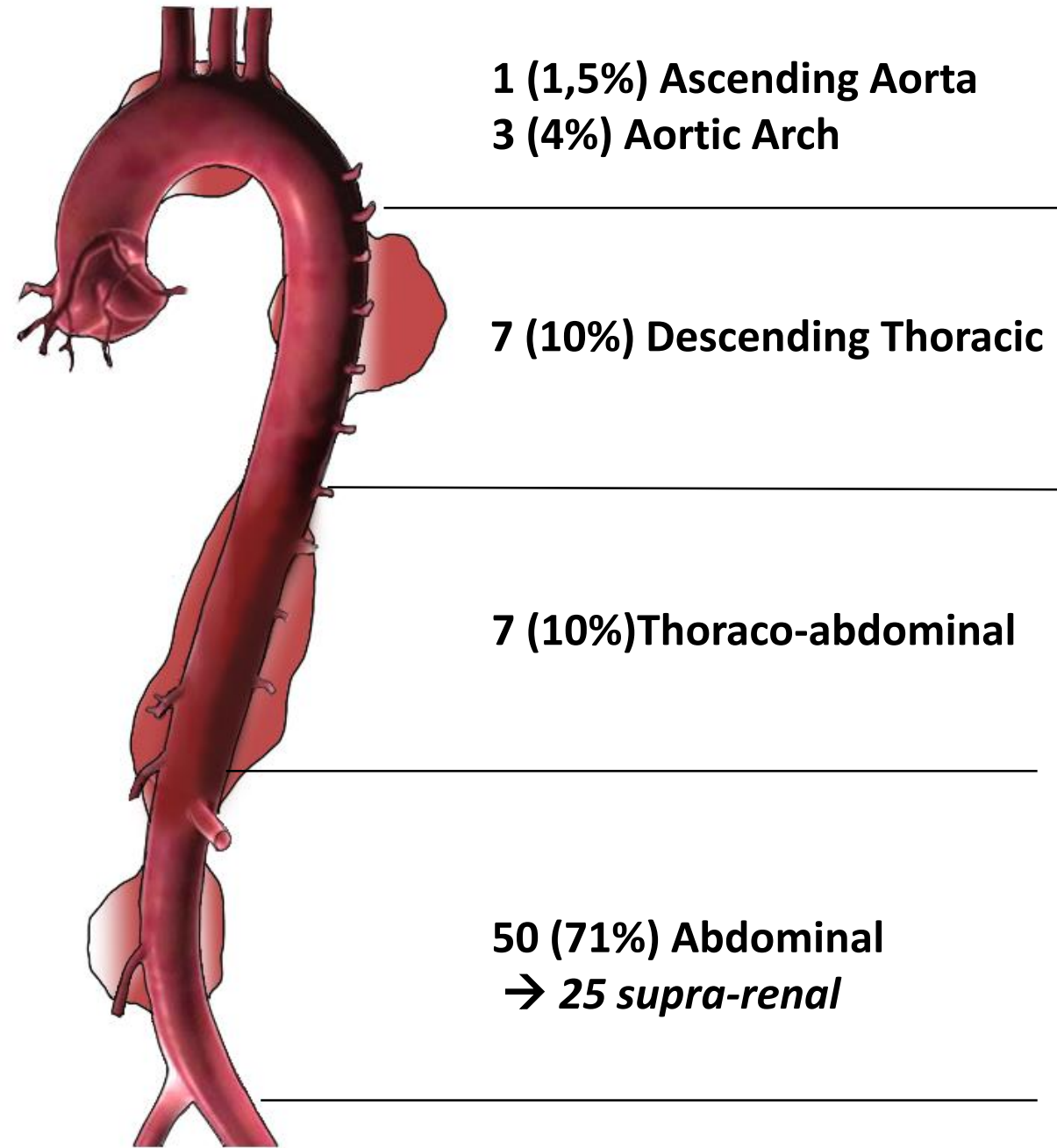
Number at risk (events)

<i>Abdominal</i>	50	(4)	45	(4)	38	(3)	34
<i>Thoraco-abdominal</i>	9	(1)	8	(1)	7	(2)	5
<i>Thoracic</i>	11	(3)	7	(0)	7	(1)	6

Abdominal Thoraco-abdominal Thoracic

D

70 INFECTIVE NATIVE AORTIC ANEURYSMS



+ 2 (3%) concomitant abdominal + thoracic INAAs

20 (29%) RUPTURED AT PRESENTATION

61 (87%) + 5 (=94%)
OPEN REPAIR
96% *Cyropreserved arterial allografts*

3 (4%) **HYBRID SURGERY**

5 (7%) **EMERGENT EVAR**

1 **PALLIATIVE EVAR**

Early reinfection

87%
30-days survival

72%
90-days survival

10%
Infection-related complication rate

Predictors for mortality

Age ≥ 70 (OR 10.8, 95% CI 1.1-107.8)

ASA score 3-4 (OR 6.0, 95% CI 1.1-33.9 and 14.9, 95% CI 1.7-129.3)

Chronic kidney disease (OR 32.0, 95% CI 1.2-821.5)