Early and midterm outcomes following open surgical conversion after failed endovascular aneurysm repair from the "Italian North-easT RegIstry of surgical Conversion AfTer Evar" (INTRICATE)

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ABSTRACT

Objective: To report the early and mid-term outcomes following open surgical conversion (OSC) after failed endovascular aortic repair (EVAR) using data from a multicentric registry.

Methods: A retrospective study was carried out on consecutive patients undergoing OSC after failed EVAR at eight tertiary vascular units from the same geographic area in the North-East of Italy, from April 2005 to November 2019. Study endpoints included early and follow-up outcomes.

Results: A total of 144 consecutive patients were included in the study. Endoleaks were the most common indication for OSC (50.7%), with endograft infection (24.6%) and occlusion (21.9%) being the second most prevalent causes. The overall rate of 30-day all-cause mortality was 13.9% (n = 20); 32 patients (22.2%) experienced at least one major complication. Mean length of stay was 13 ± 12.7 days. On multivariate logistic regression, age (odds ratio [OR], 1.09; 95% confidence interval [CI], 1.01-1-19; $P = .02$), renal clamping time (OR, 1.07; 95% CI, 1.02-1.13; $P = .01$), and suprarenal/celiac clamping (OR, 6.66; 95% CI, 1.81-27.1; $P = .005$) were identified as independent predictors of perioperative major complications. Age was the only factor associated with perioperative mortality at 30 days. Renal clamping time >25 minutes had sensitivity of 65% and specificity of 70% in predicting the occurring of major adverse events (area under the curve, 0.72; 95% CI, 0.61-0.82). At 5 years, estimated survival was significantly lower for patients treated due to aortic rupture/dissection (28%; 95% CI, 13%-61%), compared with patients in whom the indication for treatment was endoleak (54%; 95% CI, 40%-73%), infection (53%; 95% CI, 30%-94%), or thrombosis (82%; 95% CI, 62%-100%; $P = .0019$). Five-year survival rates were significantly lower in patients who received emergent treatment (28%; 95% CI, 14%-55%) as compared with those who were treated in an urgent (67%; 95% CI, 48%-93%) or elective setting (57%; 95% CI, 43%-76%; $P = .00026$). Subjects who received suprarenal/celiac (54%; 95% CI, 36%-82%) or suprarenal (46%; 95% CI, 34%-62%) aortic cross-clamping had lower survival rates at 5 years than those whose aortic-cross clamp site was infrarenal (76%; 95% CI, 59%-97%; $P = .041$). Using multivariate Cox proportional hazard, older age and emergency setting were independently associated with higher risk for overall 5-year mortality.

Conclusions: OSC after failed EVAR was associated with relatively high rates of early morbidity and mortality, particularly for emergency setting surgery. Endoleaks with secondary sac expansion were the main indication for OSC, and suprarenal aortic cross-clamping was frequently required. Endograft infection and emergent treatment remained associated with poorer short- and long-term survival. (J Vasc Surg 2022;75:153-61.)

Keywords: Endovascular aneurysm repair; Failure; Reinterventions; Open surgery conversion; Abdominal aortic aneurysm; Endoleak; Graft infection

Since its inception, endovascular aortic repair (EVAR) has become the preferred treatment modality for abdominal aortic aneurysms (AAAs) in most patients with suitable anatomy and reasonable life expectancy.[1] However, the long-term durability of EVAR remains a concern as the potential for adverse events during the long run cannot be completely eliminated and mandates lifelong follow-up. Although secondary procedures, when required, can usually be performed in endovascular fashion in the majority of these cases, open surgical conversion (OSC) may still be required in some instances.[2] Undoubtedly, OSC may be associated with significantly higher morbidity and mortality rates than those encountered with primary open aortic repair, a finding which has been shown in several contemporary series.

Nevertheless, large real-world evidence needs to be accumulated to define risk factors associated with immediate and late prognosis. The aim of this multicentric study was to report the early and midterm outcomes following OSC after failed EVAR using data from the "Italian North-easT RegIstry of surgical Conversion AfTer Evar" (INTRICATE), collected over a consecutive 15-year period.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of data of the Italian North-easT RegIstry of surgical Conversion AfTer Evar" (INTRICATE) registry
- **Key Findings:** Open surgical conversion after failed endovascular aneurysm repair (EVAR) in 144 patients resulted in a 13.9% 30-day mortality; 22.2% had at least one major complication, predicted by age, renal clamping time, and suprarenal/celiac clamping. Five-year survival was better with elective (57%) than with emergency treatment (28%; $P = .00026$). Age and emergency treatment predicted higher mortality ($P = .02$).
- **Take Home Message:** Open surgical conversion for failed EVAR carries high mortality and complications, with decreased 5-year survival for emergency treatment, for those with advanced age and if repair required superarenal or supraceliac aortic clamping. Prevention of failure at the initial EVAR procedure remains paramount.

METHODS

Data collection. A retrospective study was carried out on consecutive patients undergoing OSC after failed EVAR at eight tertiary vascular units from the same geographic area in the North-East of Italy, encompassing three regions (Veneto, Friuli Venezia Giulia, and Trentino Alto Adige) and serving roughly 7,000,000 people. All institutions met yearly caseload for aortic surgery as per current clinical practice guidelines.[1] All vascular centers retrieved their records from April 2005 to November 2019.

Preoperatively collected data included demographics and comorbidities, stent graft type and characteristics, time elapsed from initial EVAR and reason for OSC, and patients' condition at presentation. Intraoperative collected data included aortic cross-clamp site and time, extent of stent graft removal and type of reconstruction performed, operating time, and any adjunctive surgical procedure. Patients were included in the database if they received OSC after failed EVAR including either aortic endograft explantation (either total or partial) or endograft preservation (ie, the so-called semi-conversions), with or without arterial reconstruction (anatomic or extra-anatomic). No specific exclusion criteria were considered including surgical timing (elective, urgent, or emergent procedures), indications for OSC, or time from initial EVAR (within 30 days or later). Urgent setting was considered for procedures performed within 24 hours (mainly for symptomatic nonruptured AAA or graft thrombosis with nonthreatening lower limb ischemia). Emergency setting was considered for procedures performed immediately upon patients' presentation in case of those conditions that required expedited treatment (especially for ruptured AAA or symptomatic graft thrombosis with threatening lower limb ischemia).

According to prior literature, EVAR cases were defined as complex if they required concomitant femoral-femoral bypass, femoral endarterectomy, internal iliac artery coiling, iliac artery stent or bypass, renal artery stent, or other arterial bypass.[3] Otherwise, they were defined as standard. None of these cases were branched, fenestrated, or chimney procedures. Postoperative follow-up was performed according to local policies of care. Patients were excluded from the analysis if no data were made available for the in-hospital phase and/or they did not have at least one postoperative clinical or imaging examination available for follow-up following hospital discharge. Institutional Review Board requirements were waived for this descriptive and retrospective analyses of anonymized data, while written informed consent for data collection was obtained from all patients.

Study endpoints. Study endpoints included early (ie, 30-day or in-hospital) and late follow-up outcomes. Early outcomes included mortality, major complications, and length of stay. Perioperative complications were assessed using the standardized Clavien-Dindo classification of surgical complications.[4] According to this classification, classes III and IV refer to complications that require prolonged hospitalization, intensive care unit admission, or reinterventions and were collectively defined as major. The main outcome of interest during follow-up was overall survival. Causes of death were assessed by medical records search, review of death certificates when available, or by phone interview with the patient's general practitioner. A patient was considered lost to follow-up when available clinical data were older than 2 years, but death could not be confirmed.

Statistical analysis. Continuous variables were tested and presented as mean (±standard deviation) in case of normal distribution or as median (interquartile range) in case of skewed distribution. Binary outcomes were evaluated first by univariable methods, with results reported as odds ratio (OR) with 95% confidence intervals (CIs). A multiple logistic regression model was built including significant covariates and confounders. Survival analysis was carried out by Kaplan Meier method and reported with standard error <0.10; the log rank test was used to compare survival estimates. Patients lost to follow-up were censored at the date of their last verified clinical examination. Multivariable Cox proportional hazards was used to assess independent predictors for all-cause mortality with results reported as hazard ratio (HR) with 95% CIs. Covariates for these models were selected based on previously described risk factors and univariate screen of all available potential confounders, using backwards selection with a criteria of 0.25 to stay in the final models. The final models were tested for violation of proportional hazards assumptions using Schoenfeld residuals. The renal-visceral clamping cutoff time that was associated with the risk for major complications was identified after analysis of the frequency density distribution of renal clamping time (in minutes), stratified by occurrence of complications. A *P* value <.05 was considered statistically significant. The R 3.5.2 software (R Foundation for Statistical Computing, Vienna, Austria) was used for the analysis.

Table I. Baseline characteristics

Variable	No. (%) or mean ± standard deviation
Demographics	
Age, years	75.1 ± 8.2
Male gender	129 (89.6)
Risk factors	
Hypertension	133 (92.4)
Diabetes	28 (19.4)
Smoking[a]	86 (59.7)
Ischemic heart disease[b]	75 (52.1)
CKD (Cr > 1.5 mg/dL)	43 (29.9)
COPD[c]	35 (24.3)
Perioperative risk assessment	
SVS cardiac score	0.72 ± 0.79
SVS pulmonary score	0.46 ± 0.69
SVS renal score	0.39 ± 0.69
SVS hypertension	1.61 ± 0.73
SVS age	2.07 ± 0.78
SVS score	0.80 ± 0.44

CKD, Chronic kidney disease; *COPD*, chronic obstructive pulmonary disease; *Cr*, creatinine; *SVS*, Society for Vascular Surgery.
[a]Includes current and former smokers.
[b]Defined as current angina pectoris, previous myocardial infarction, coronary artery bypass graft operation or percutaneous coronary intervention, or current or previous arrhythmia or heart failure.
[c]Requiring medications.

RESULTS

Study population. A total of 144 consecutive patients (mean age 75.1 ± 8.2 years; 89.6% males) were included in the study (Supplementary Table I, online only). Hypertension, current or past smoking, and history of ischemic heart disease were present in 133 (92.4%), 86 (59.7%), and 75 (52.1%) subjects, respectively (Table I). The median Society for Vascular Surgery score of the study cohort was 0.80 ± 0.44. Details of initial EVAR revealed that suprarenal fixation had been used in 87 patients (60.4%), whereas 18 patients (12.5%) had received stent graft implantation outside the manufacturer's instructions for use (IFU) (Table II). Complex EVAR procedures were carried out in 57 patients (39.6%). Overall, the majority of OSC procedures were performed >12 months after initial EVAR (111; 77.1%), and 86 (59.7%) were carried out in the elective setting (Table III). Endoleaks were the most common indication for OSC in 73 patients (50.7%), with endograft infection (n = 18; 24.6%) and endograft occlusion (n = 16; 21.9%) being the second most prevalent causes. Complete or partial endograft removal was performed in 83 (57.6%) and 46 patients (31.9%), respectively (Table IV). The most frequent types of reconstruction included aortobi-iliac in 84 patients (58.3%) and aortobifemoral in 25 patients (17.4%). The mean operating time was 267.7 ± 91.9 minutes, and suprarenal aortic cross-clamp was required in 88 patients (61.6%).

Perioperative morbidity. The overall rate of 30-day all-cause mortality was 13.9% (n = 20). Of these, 8 (5.5%) were aortic-related and included the following: 5 cases of intraoperative bleeding and hemorrhagic shock, 2 cases of aortic rupture, and 1 case of aortoenteric fisutla. In total, 32 patients (22.2%) experienced at least one major complication (Table V). Respiratory (10; 31.2%), renal (8; 25%), and cardiac (8; 25%) complications were the most prevalent perioperative adverse events. Mean length of stay was 13 ± 12.7 days. On multivariate logistic regression, age (OR per year, 1.09; 95% CI, 1.01-1.19; *P* = .02), renal clamping time (OR, 1.07; 95% CI, 1.02-1.13; *P* = .01), and suprarenal/celiac clamping (OR, 6.66; 95% CI, 1.81-27.1; *P* = .005) were identified as independent predictors of perioperative major complications (Supplementary Table II, online only). Older age (OR, 1.09; 95% CI, 1.01-1.19; *P* = .035) was the only factor associated with all-cause mortality at 30 days (Supplementary Table III, online only). A renal

Table II. Aneurysm morphology, endograft planning, and EVAR procedure

Variable	No. (%) or mean ± standard deviation
AAA characteristics	
AAA diameter, mm	57.8 ± 11.8
Neck diameter, mm	23.0 ± 3.4
Endograft details	
Medtronic Endurant	48 (33.3)
Gore Excluder	27 (18.7)
Cook Zenith	14 (9.7)
Jotec	12 (8.3)
Endologic Nellix	9 (6.3)
Vaskutek Anaconda	8 (5.6)
Endologic Ovation	6 (4.2)
Cordis Incraft	5 (3.5)
Altura	1 (0.7)
Other endograft	14 (9.7)
Endograft fixation, sizing, and IFU	
Suprarenal	87 (60.4)
Infrarenal	47 (32.6)
Proximal neck oversizing, %	21.0 ± 8.9
Extra IFU implantation	18 (12.5)
Complex EVAR procedures	57 (39.6)
Sac embolization	30 (52.6)
Proximal extension	12 (21.1)
Distal limb extension	10 (17.5)
Embolectomy/femoro-femoral bypass	6 (10.5)
Relining due to type III EL	6 (10.5)
Chimney	2 (3.5)
Endoanchors	1 (1.7)
IBD	1 (1.7)

AAA, Abdominal aortic aneurysm; *EL,* endoleak; *EVAR,* endovascular aneurysm repair; *IBD,* iliac branch device; *IFU,* instructions for use.

Table III. Time, setting, and indications for open surgical conversion

Variable	No. (%) or mean ± standard deviation
Conversion time after EVAR, months	53 ± 43.4
0-30 days	12 (8.3)
1-12 months	21 (14.6)
>12 months	111 (77.1)
Setting	
Elective	86 (59.7)
Urgent (24-48 hours)	20 (13.9)
Emergent (<24 hours)	38 (26.4)
Conversion indications	
EL (total number of patients)[a]	73 (50.7)
Type I	43 (58.9)
Type II	33 (45.2)
Type III	4 (5.5)
Type IV	1 (1.4)
Number of patients who presented more than one type of EL	8 (10.9)
Aortic rupture	28 (19.4)
Graft Infection	18 (12.5)
Graft occlusion	16 (11.1)
Graft migration	6 (4.2)
Failure deployment	3 (2.1)

EL, Endoleak; *EVAR,* endovascular aneurysm repair.
[a]Some patients had multiple endoleak types at the same time.

clamping time >25 minutes had sensitivity of 65% and specificity of 70% in predicting the occurring of major adverse events (area under the curve, 0.72; 95% CI, 0.61-0.82) (Supplementary Fig, online only).

Late follow-up outcomes. The mean duration of follow-up was 29.9 ± 37.3 months for patients who survived >30 days after their index OSC. The long-term mortality rate (all-cause) during the follow-up was 38.9% in the whole study cohort, with an overall long-term complication rate (including both medical and surgical complications) of 9.7%. Three cases (2.1%) of aortic-related complications were recorded during the follow-up, including two cases of aortic pseudoaneurysm and one case of recurrent graft infection. At 5 years, estimated survival was significantly lower for those that were treated due to aortic rupture/dissection (28%; 95% CI, 13%-61%) as compared with patients in whom the indication for treatment was endoleak (54%; 95% CI, 40%-73%), infection (53%; 95% CI, 30%-94%), or thrombosis (82%; 95% CI, 62%-100%; $P = .0019$) (Fig 1). Similarly, 5-year survival rates were significantly lower in patients who received emergent treatment (28%; 95% CI, 14%-55%) as compared with those who were treated in the urgent (67%; 95% CI, 48%-93%) or elective setting (57%; 95% CI, 43%-76%; $P = .00026$) (Fig 2). Lastly, subjects who received suprarenal/celiac (54%; 95% CI, 36%-82%) or suprarenal (46%; 95% CI, 34%-62%) aortic cross-clamping had lower survival rates at 5 years than those whose aortic-cross clamp site was at the infrarenal level (76%; 95% CI, 59%-97%; $P = .041$) (Fig 3). Using multivariate Cox proportional hazard, older age (HR, 1.07; 95% CI, 1.03-1.12; $P = .001$) and emergency setting (HR, 2.03; 95% CI, 1.10-3.74; $P = .02$) were independently associate with higher risk for overall 5 years mortality (Supplementary Table IV, online only).

DISCUSSION

Despite its reduced invasiveness and better short-term results, an increasing rate of complications requiring secondary procedures has been associated with EVAR as

Table IV. Open surgical conversion: intraoperative details

Variable	No. (%) or mean ± standard deviation N = 144
Graft removal technique	
Complete endograft removal	83 (57.6)
Partial endograft removal	46 (31.9)
No graft removal (graft suture, aortic banding, lumbar artery ligation)	5 (3.5)
Type of reconstruction	
Aortobisiliac	84 (58.3)
Aortobifemoral	25 (17.4)
Aorto-aortic	12 (8.3)
Aorto femoral/iliac	7 (4.9)
Other	6 (4.2)
Type of new graft	
Dacron Silver	75 (52.1)
Dacron	45 (31.2)
Homograft	7 (4.9)
Procedure time, minutes	267.7 ± 91.9
Suprarenal aortic clamping	88 (61.1)
Supraceliac aortic clamping	21 (14.6)
Renal clamping time, minutes	23.7 ± .9.1
Other intraoperative procedure	35 (24.3)
Internal iliac artery bypass	13 (37.1)
Renal bypass	8 (22.8)
Femoral endarterectomy	6 (17.1)
Duodenum repair	5 (14.3)
Splenectomy	3 (8.6)
Aortic endarterectomy	2 (5.7)
TEVAR	1 (2.8)
Renal artery chimney	1 (2.8)
Other procedures	3 (8.6)

TEVAR, Thoracic endovascular aneurysm repair.

Table V. Early outcomes (≤30 days)

Variable	No. (%) or mean ± standard deviation N = 144
Length of stay, days	13 ± 12.7
30-day major complications	32 (22.2)
Respiratory	10 (31.2)
Renal	8 (25.0)
Cardiac	8 (25.0)
Intraperitoneal bleeding	5 (15.6)
MOF	5 (15.6)
Sepsis	4 (12.5)
Neurological	2 (6.2)
Aortic rupture	2 (6.2)
Intestinal occlusion	2 (6.2)
AEF	1 (3.1)
30-day any-cause mortality	20 (13.9)
30-day aortic-related mortality	8 (5.5)

AEF, Aortoenteric fistula; *MOF,* multiorgan failure.

compared with open surgical repair of AAAs, thereby making the effective overall benefit of endovascular techniques in terms of mid- and long-term survival still controversial.[5,6] Although many of these complications can be successfully salvaged by endovascular means, OSC still remains the preferred approach under specific circumstances or when failure recurs despite secondary endovascular procedures.[7] The inferior long-term outcomes of EVAR could be due to lack of durability; this consideration is especially important given that EVAR patients are surviving longer with advances in health care, and maintaining consistent long-term outcomes is a contemporary priority.[8] In the present report, performing OSC after failed EVAR was associated with substantially high rates of early morbidity and mortality, particularly when the operation was carried out under emergent circumstances, as consistently shown by previously published clinical studies[9-12] and systematic reviews.[13,14] Two-thirds of study subjects required suprarenal aortic cross-clamping, where duration represented a risk factor for perioperative morbidity, and endograft infection also remained associated with poorer long-term survival (as compared with patients with noninfective indications to OSC).These results appear comparable to those from prior studies. Indeed, Perini et al[10] (n = 232) showed a similar dramatic increase in the perioperative death rate from 4.9% in the elective setting to 26.1% in the urgent setting, whereas Chastant et al[15] (n = 62) reported survival rates at 1 and 5 years as high as 97% and 71% when excluding OSC procedures done for rupture or infection. Also, Dubois et al[16] (n = 111) reported that patients who have an indication should be offered surgery, when indicated, before symptoms or rupture occurs. In the present study, we found that the most prominent decrease in survival in cases done for infection or rupture was noted in the first 6 months after the surgical procedure, thereby likely reflecting the increased severity of underlying illness. The most frequent cause for OSC in the present series were endoleaks with secondary sac expansion, a finding which is well-confirmed from prior reports.[17-19] Although type II endoleaks are still the subject of much debate,[20-22] type I endoleaks represent failure of proximal/distal sealing, thereby potentially casting doubts as to whether more liberal use of EVAR over the recent years has led to an increase in the incidence of EVAR failure.[23] Indeed, it is well known that EVAR performed in suboptimal anatomy and/or outside the manufacturer's IFU may lead to loss of early benefits during follow-up.[24] This underlines the

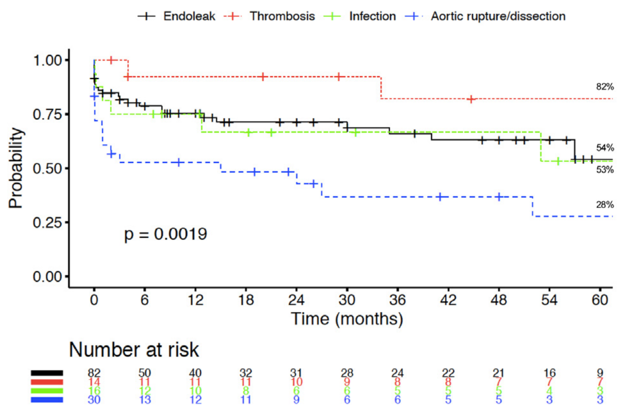

Fig 1. Kaplan-Meier survival estimates stratified by indication for open surgical conversion.

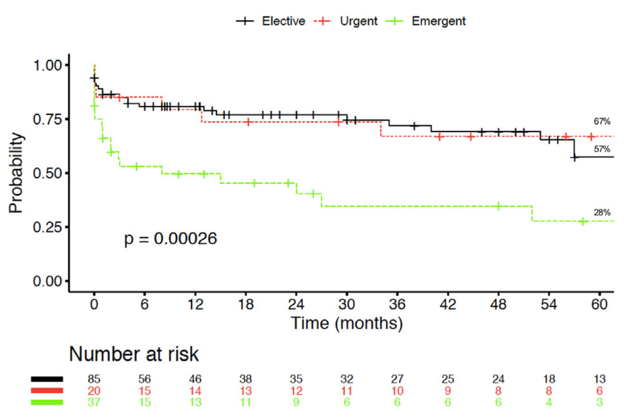

Fig 2. Kaplan-Meier survival estimates stratified by timing of open surgical conversion.

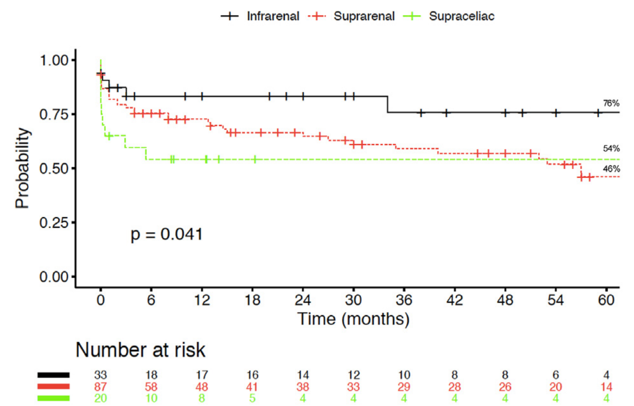

Fig 3. Kaplan-Meier survival estimates stratified by aortic cross-clamping site.

importance of strict adherence to postoperative follow-up protocols, especially as previous studies have showed that follow-up protocols should be tailored based on risk factors for failure as identified during the early postoperative phase.[25,26] As noted above and already shown in prior publications, postoperative morbidity and mortality are primarily driven by patient- and procedure-related factors including age, emergency of the procedure, and duration of suprarenal aortic cross-clamping.[27] Indeed, patients undergoing OSC are older and have more comorbidities as compared with those receiving primary aortic treatment. Suprarenal clamping during OSC is frequently required for many reasons, one being that many stent grafts have suprarenal fixation mechanisms, and a threshold of 25 minutes was associated with a significant increase in the rate of early major complications. However, the question still remains as to whether the duration in clamping time itself causally contributed to the increased risk of morbidity, or it simply represents an indirect marker of more challenging presentation, similarly to what is usually observed for acute repair of ruptured AAAs.[28] Nevertheless, all these findings should alert the surgeon that anticipated need for prolonged suprarenal aortic cross-clamping be considered during the decision-making process for remedial treatment of failed EVAR, thereby highlighting the necessity for careful postoperative observation of these patients, particularly during the early postoperative period. Despite its feasibility and the flexibility of tailoring treatment to individual needs by using several different technical approaches,[29] OSC remains a complex operation needing careful preparation.[30] More recently, fenestrated-branched EVAR has emerged as a safe and effective complementary tool to address EVAR failures,[31-33] because it can maintain the minimal invasiveness of original endovascular treatment. However, this should not be seen as justification to push further the boundaries on conventional infrarenal EVAR devices, as the ultimate goal for patients with AAAs must remain for the first operation to be the right one.[34] Indeed, secondary fenestrated-branched EVAR procedures are more technically demanding than primary interventions as additional anatomical challenges are to be expected. Furthermore, they are not advisable as definitive treatment in cases of infection as they are unable to eradicate the bacterial focus, and the time required for customization usually limits their applicability to elective cases.[35,36] Although alternative complex techniques could all expand the endovascular armamentarium to treat EVAR failures in the urgent setting,[37] their outcomes are still sparse, and they should be employed only in patients without other reasonable options by adequately trained physicians.

Study limitations. The findings from this study must also be interpreted in light of its shortcomings, mainly that the analysis was retrospective without a standardized follow-up protocol with the inherent risks for recall or attrition bias, as are all studies on this topic currently available in the literature. Another potential limitation may be the initial selection bias owing to the fact that perioperative management of these patients may have been heterogeneous for the eight participating centers in terms of indications and techniques of OSC. Because many of the original EVAR interventions were performed at outside institutions other than those where the OSC procedures were carried out, we cannot offer any meaningful insights into whether the frequency of these cases changed over time or whether it was related to more liberal repair indications outside of stent graft IFU. Nevertheless, our study provides a contemporary, large, real-world essay of OSC for failed EVAR, and its findings are concordant to those of previously published series.

CONCLUSIONS

Secondary open reoperation after failed EVAR was associated with relatively high rates of early morbidity and mortality, particularly when the operation was carried out under emergent circumstances. Endoleaks with secondary sac expansion were the main indication for OSC, and suprarenal aortic cross-clamping was frequently required. Endograft infection and emergent treatment remained associated with poorer short- and long-term survival.

AUTHOR CONTRIBUTIONS

Conception and design: AX, MD, FS, SL
Analysis and interpretation: AX, MD, FS, MA, FG, SB, DM, PF, DC, GV, RP, LG, AJ, SL
Data collection: AX
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Critical revision of the article: AX, MD, FS, MA, FG, SB, DM, PF, DC, GV, RP, LG, AJ, SL
Final approval of the article: AX, MD, FS, MA, FG, SB, DM, PF, DC, GV, RP, LG, AJ, SL
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AX and MD contributed equally to this article and share co-first authorship.

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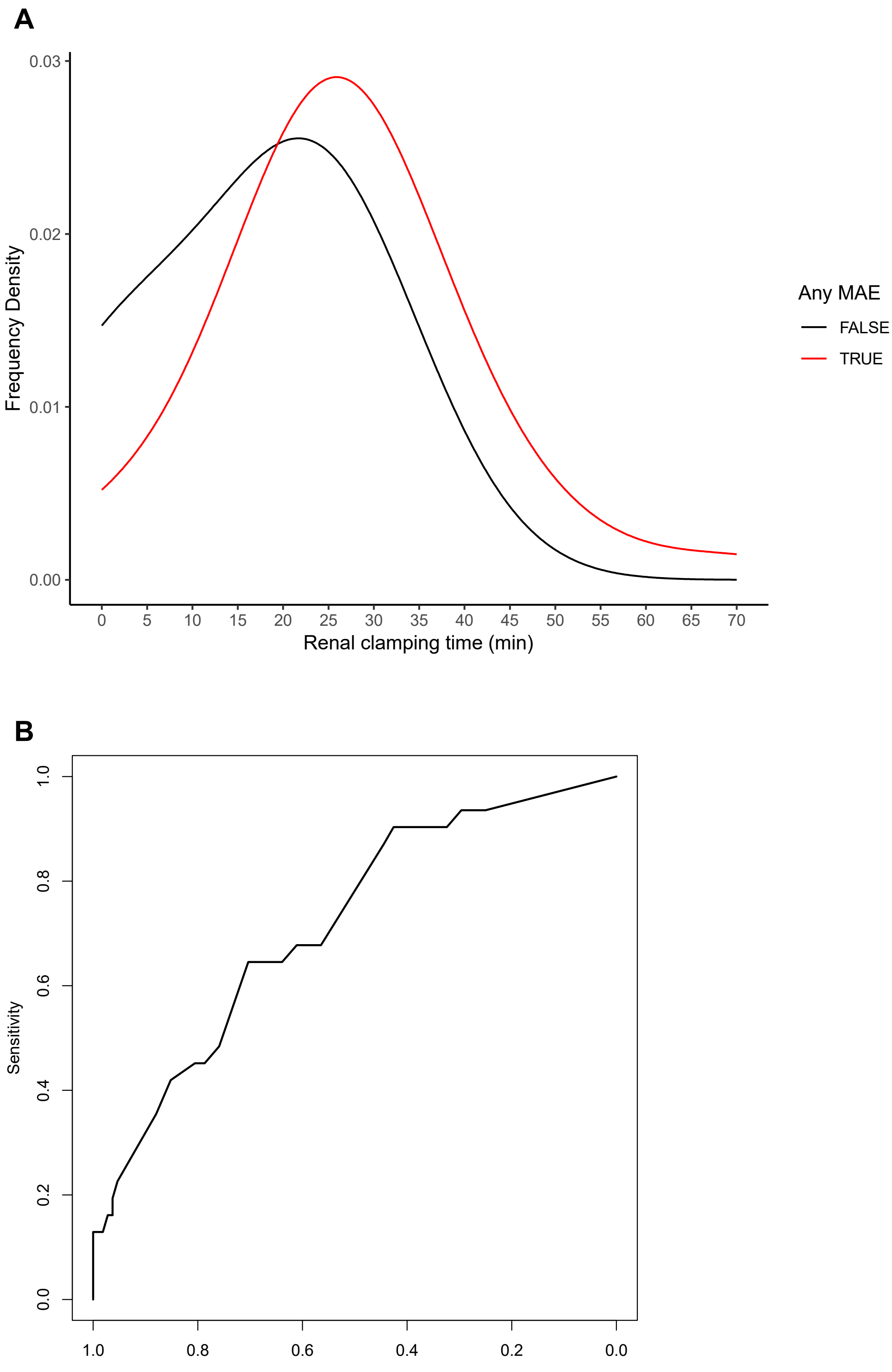
APPENDIX

INTRICATE Collaborators. Riccardo Bozza, Operative Unit of Vascular and Endovascular Surgery, Vicenza San Bortolo Hospital, Vicenza, Italy; Alessandra Ferrari, Operative Unit of Vascular and Endovascular Surgery, "S. Bortolo" Hospital, Vicenza, Italy; Federico Furlan, Vascular Surgery Department, University Hospital of Udine, Udine, Italy; Filippo Gorgatti, Division of Vascular and Endovascular Surgery, Cardiovascular Department, University of Trieste Medical School, Trieste, Italy; Davide Mastrorilli, Vascular Surgery Unit, University Hospitals in Verona, Verona, Italy; Luca Mezzetto, Vascular Surgery Unit, University Hospitals in Verona, Verona, Italy; Tommaso Miccoli, Department of Vascular Surgery, IRCCS Sacro Cuore Don Calabria, Negrar, Verona, Italy; Marco Pipitone, Thoracic and Vascular Department, General Hospital, Bolzano, Italy; Maila Trillini, Vascular Surgery Department, "S. Bassiano" Hospital, Bassano del Grappa, Italy; Valentina Wasserman, Department of Vascular Surgery, Santa Chiara Hospital, Trento, Italy; and Federico Zani, Vascular Surgery Department, University Hospital of Udine, Udine, Italy.



Supplementary Fig (online only). Density plot **(A)** and receiver operating characteristic curve **(B)** for determination of the renal clamping time threshold associated with the highest predicted probability of perioperative major complications. *MAE,* Major adverse events.

Supplementary Table I (online only). Number of cases treated per participating center

Center	No. (%) (n = 144)
Bassano	14 (9.7)
Bolzano	10 (6.9)
Padova	33 (22.9)
Trento	22 (15.3)
Verona – Negrar Hospital	7 (4.9)
Verona – Borgo Trento Hospital	13 (9.0)
Vicenza	30 (20.8)
Udine	15 (10.4)

Supplementary Table II (online only). Multivariate logistic regression for independent predictors peri-operative major complications

Variable	OR	95% CI	*P*
Age, years	1.09	1.01-1.19	.02
Other procedure after EVAR	0.66	0.66-6.31	.22
Infection	3.13	0.56-15.8	.16
Renal clamping time, min	1.07	1.02-1.13	.01
Suprarenal/celiac clamping	6.66	1.81-27.1	.005

CI, Confidence interval; *EVAR,* endovascular aneurysm repair; *OR,* odds ratio.

Supplementary Table III (online only). Multivariate logistic regression for independent predictors of perioperative mortality

Variable	OR	95% CI	*P*
Age, years	1.09	1.01-1.19	.035
Emergent setting	1.55	0.44-5.19	.472
Infection	2.54	0.46-11.36	.239
Renal clamping time, min	1.03	0.97-1.08	.288
Suprarenal/celiac clamping	0.64	0.12-4.12	.619

CI, Confidence interval; *OR,* odds ratio.

Supplementary Table IV (online only). Multivariate Cox proportional hazard for independent predictors of all-cause long-term mortality

Variable	HR	95% CI	*P*
Age, years	1.07	1.03-1.12	.001
Emergency setting	2.03	1.10-3.74	.02
Renal clamping time	1.01	0.97-1.03	.09

CI, Confidence interval; *HR,* hazard ratio.