Late open conversions after endovascular abdominal aneurysm repair in an urgent setting

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ABSTRACT

Objectives: We report a multicenter experience of urgent late open conversion (LOC), with the goal of identifying the mode of presentation, technical aspects, and outcomes of this cohort of patients.

Methods: A retrospective analysis of endovascular aneurysm repair (EVAR) requiring LOC (>30 days after implantation) from 1996 to 2016 in six vascular centers was performed. Patients with aneurysm rupture or other conditions requiring urgent surgery (<24 hours) were included. Patient demographics, time interval between EVAR and LOC, endograft characteristics, previous attempts at endovascular correction, indications, operative technique, 30-day mortality and morbidity, and long-term survival were analyzed.

Results: There were 42 patients (88.1% men; mean age, 75.8 ± 9.0 years) included. Among the 42 explanted grafts, 33 were bifurcated, 1 tube, 6 aortouni-iliac, and 2 side-branch devices. Suprarenal fixation was present in 78.6%. Twelve patients (28.6%) underwent endovascular reintervention before LOC. Indications for urgent LOC were aneurysm rupture in 24 of the 42 cases (57.1%), endograft infection in 11 (26.2%), endoleak associated with aneurysm growth and pain in 6 (14.3%), and recurrent endograft thrombosis in 2 (4.8%). The proximal aortic cross-clamping site was infrarenal in 38.1% of cases, suprarenal in 19.1%, and supraceliac in 42.9%. Complete removal of the endograft was performed in 32 patients (76.2%) and partial removal in 10 (proximal preservation in 7 of 10). Reconstructions were performed with Dacron grafts in 33 of the 42 cases, cryopreserved arterial allografts in 5, and endograft removal associated with prosthetic axillobifemoral bypass in 4. The 30-day mortality was 23.8%; hemorrhagic shock was an independent risk factor of early mortality (odds ratio, 10.5; 95% confidence interval, 1.5-73.7; $P = .018$). During a mean follow-up of 23.9 ± 36.0 months, two late aneurysm-related deaths occurred. The estimated 1- and 5-year survival rates were 62.1% and 46.1%, respectively.

Conclusions: Urgent LOC after EVAR are associated with high postoperative mortality rates and poor long-term survival. Further studies are necessary to define the timing and the best treatment option for failing EVAR. (J Vasc Surg 2018;■:1-9.)

Keywords: Abdominal aortic aneurysm; Open surgical conversion; Endovascular repair; EVAR explantation; Failed EVAR

Endovascular aneurysm repair (EVAR) demonstrated an early morbidity and mortality advantage when compared with open repair of abdominal aortic aneurysms (AAA).[1] For this reason, EVAR has now become the first choice treatment for AAA, accounting for more than three-quarters of elective aneurysm repairs.[2,3] In contrast, EVAR is burdened by a higher rate of reinterventions.[4] As a result of the improvement of endovascular materials and techniques, these complications are usually managed by minimally invasive techniques. Nevertheless, a late open conversion (LOC) is still necessary in certain cases.[5,6] Additionally, because the number of patients undergoing EVAR is increasing, the number of LOC will realistically increase in the foreseeable future.

LOC after EVAR is associated with a considerably increased perioperative morbidity and mortality as compared with standard EVAR or open repair.[2,7] Particularly, LOC performed in an urgent setting are characterized by an early mortality rate that may reach 50% in some series published in the literature, whereas the elective LOC perioperative mortality rate is usually reported at less than 10%.[2,7,8] This considerable discrepancy suggests that EVAR complications that lead to urgent LOC should be thoroughly analyzed.

Herein we report a multicenter experience of urgent LOC, which has been organized after the results of a previously published single-center study,[5] with the goal of identifying the mode of presentation, technical aspects, and outcomes of this cohort of patients.

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METHODS

Patients, indications, and study design. Records of all patients who required LOC from January 1996 to December 2016 in six vascular centers were collected retrospectively into a specific, regional database. LOC was defined as a total or partial aortic endograft explantation followed by anatomic or extra-anatomic reconstruction, performed at least 30 days after the first EVAR.[2,5] Open surgical repairs without endograft removal (ie, aortic banding for type I endoleaks, or sacculotomy and collateral branches ligation) were not included into the database. For this study, we considered for analysis only LOC performed in a urgent setting. Specifically, patients presenting with aneurysm rupture or other conditions (such as graft thrombosis, life-threatening infection, or aneurysm growth associated with pain) that required urgent surgery (<24 hours from presentation) owing to the severity of the illness were selectively included.[9] Patient demographics (sex, age), clinical data (renal insufficiency, chronic obstructive pulmonary disease, and cardiovascular risk factors), time interval between EVAR and LOC, type and characteristics of the endograft, any previous attempt of endovascular correction, indication for LOC, operative technique (clamping site, partial or complete graft removal, type of reconstruction), and intraoperative data (operative time, blood loss, need for transfusions) were obtained for analysis.

Outcomes analyzed were intraoperative and 30-day mortality, postoperative complications (myocardial infarction [MI], arrhythmia, acute kidney injury, pneumonia, prolonged ventilation, and duration of intensive care unit stay), duration of hospitalization, and long-term survival status. According to the RIFLE criteria (risk of renal failure, injury to the kidney, failure of kidney function, loss of kidney function, and end-stage renal failure), acute kidney injury was considered when the deterioration of renal function was significant (a more than twofold increase in serum creatinine concentration from baseline), sudden (1-7 days), and sustained (persisting >24 hours), or when it required permanent or temporary hemodialysis (HD).[10]

Written informed consent for treatment was obtained from all patients except for those who presented with hypovolemic shock and unconsciousness. The institutional review board approved this study, and consent for retrospective analysis of medical records was collected from all the patients who were alive during the data collection phase.

Follow-up. Follow-up protocols were different among the participant institutions, but included at least a yearly clinical and ultrasound examination to assess the patency of the graft, the status of surgical anastomoses (to exclude the presence of stenosis or aneurysmal degenerations), and the patients' long-term survival. Computed tomography (CT) angiography was not performed systematically, but only in selected cases as an adjunct to ultrasound examination. Causes of death were established by searching through medical records or by phone interview with relatives or the general practitioner (in case death did not occur during an hospitalization in a participating center).

HIGHLIGHTS

- **Type of Research:** Retrospective, multicenter cohort study
- **Take Home Message:** In a cohort of 42 patients who underwent urgent late open conversions after endovascular aneurysm repair, the 30-day mortality was high (23.8%) and the 1- and 5-year survivals were poor (62.1%. and 46.1%, respectively).
- **Recommendation:** Urgent conversions after endovascular aneurysm repair have excessive mortality and poor long-term survival, suggesting a need to develop new strategies to decrease urgent conversions.

Statistics. Data were entered into a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, Wash). The association between potential medical or surgical risk factors and 30-day mortality and morbidity were assessed first by univariate methods, and then by stepwise multivariate logistic regression analysis. Continuous measures were compared using Mann-Whitney U test or Kruskal-Wallis test, and presented as mean ± standard deviation in case of normal distribution, or as median with range in case of skewed distribution. Categoric factors were compared using χ^2 test or Fisher exact test and presented as number (percentage). Long-term survival was analyzed by Kaplan-Meier curves. Statistical significance was assumed at a *P* value of less than .05. Statistical analysis was performed with Epi Info 7.2.1.0 (CDC, Atlanta, Ga) or StatView 5.0 (SAS Institute Inc, Cary, NC).

RESULTS

Demographic data and indications. During the interval of the study, 140 LOC were performed in the six participating institutions. Among these, 42 patients were operated on within 24 hours from presentation in an urgent setting, and were therefore analyzed. The first urgent LOC was performed in 1999; since then, numbers increased slightly but steadily over time (correlation R = 0.71; $P = .0009$; coefficient of determination $R^2 = 0.51$, equation of the trendline $y = 0.184x + 0.588$). The mean age at LOC was 75.8 ± 9 years, and 37 patients (88.1%) were male. Chronic kidney disease was present in 16 of the 42 patients (38.1%), coronary artery disease in 15 (35.7%), chronic obstructive pulmonary disease in 21 (50%), and diabetes mellitus in 8 (19.1%). The great majority of the study cohort was represented by high-risk patients;

in fact, more than 50% of the patients were classified as American Society of Anesthesiologists 4 or 5. Preoperative clinical data, including risk factors and American Society of Anesthesiologists classification are summarized in Table I.

The median interval between the initial EVAR and the LOC was 37 months (range, 1.6-132.1 months). Indications for urgent LOC were aneurysm rupture in 24 of the 42 cases (57.1%), selected cases of endograft infection in 11 (26.2%), endoleaks associated with aneurysm growth and pain in 6 (14.3%), and recurrent endograft thrombosis in 2 (4.8%). One patient presented with concomitant aneurysm rupture and EVAR device infection. Specifically, the remaining 10 cases of EVAR infection underwent urgent surgery for the following reasons: two cases of aortoenteric fistula, two cases of EVAR infection associated with abdominal pain, two cases associated with back pain and spondylodiscitis, and four cases with sepsis signs (high fever or hypothermia, tachycardia and hypotension) associated with clear CT findings (two cases of perigraft air and two cases of intrasac collections). In the latter cases, patients underwent urgent surgery after a consensus was reached among the vascular surgeon, the infectious disease specialist, and the anesthesiologist. Regarding infected endografts, in the four cases of abdominal or back pain, and in the case of rupture, diagnosis of endograft infection was confirmed intraoperatively, after extensive perigraft purulence was revealed. Fourteen patients (33.3%) presented with hemorrhagic shock.

Endoleak was present in 30 of 42 patients. Type I endoleak was the most frequently occurring, representing the 71.4% of total endoleaks, followed by endotension (13.3%), type II (10%), and type III (6.7%). Endotension was defined as sac enlargement without an identifiable endoleak, neither on preoperative imaging nor intraoperatively. Indications for LOC are shown in Table II.

Twelve patients (28.6%) underwent one or more endovascular reinterventions before LOC. These secondary procedures did not represent a risk factor for endograft infection development ($P = .51$), or rupture on presentation ($P = .20$). Attempts to repair the failing EVAR included five aortic cuff extensions for type Ia endoleaks, five iliac leg extensions for type Ib or type III endoleaks, two aortouni-iliac endograft deployments inside a preexisting EVAR device, one CT-guided percutaneous embolization of the aneurysm sac with coils and glue of a type II endoleak, one relining performed for a type Ia endoleak with a Nellix endograft (Endologix, Irvine, Calif) associated with a double renal chimney graft, and four cases of intra-arterial thrombolysis for iliac leg occlusion followed by percutaneous transluminal angioplasty in two cases. Four patients underwent multiple endovascular attempts to repair the endoleak before LOC. Specifically, one patient underwent bilateral iliac limb extension in two different stages, the second patient a proximal aortic extension and afterward an iliac leg extension, and the third patient CT-guided embolization and iliac leg extension. The four cases of thrombolysis and the two percutaneous transluminal angioplasties were carried out on the same patient. Therefore, this failing graft was explanted. To note, one patient underwent aortouni-iliac endograft deployment inside a preexisting bifurcated endograft for a ruptured aneurysm; on the first postoperative day, a leakage was still present; thus, the patient underwent urgent LOC. The 39% of newly diagnosed endoleaks at the time of acute presentation did not regularly follow the post-EVAR surveillance protocol (≥2 years without undergoing any abdominal imaging).[9]

Table I. Preoperative data of patients undergoing urgent late open conversion (*LOC*)

Variables	(N = 42)
Age at initial EVAR, years	71.9 ± 8.4
Age at LOC, years	75.8 ± 9
LOC interval,[a] months, median (range)	37 (1.6-132.1)
Male sex	37 (88.1)
Risk factors	
Obesity[b]	7 (16.7)
Chronic kidney disease[c]	16 (38.1)
CAD	15 (35.7)
Atrial fibrillation	9 (21.4)
COPD	21 (50)
Hypertension	41 (97.6)
Smoking (ongoing)	9 (21.4)
Diabetes mellitus	8 (19.1)
Dyslipidemia	16 (38.1)
ASA score	
2	2 (4.8)
3	17 (40.5)
4	18 (42.9)
5	5 (11.9)

ASA, American Society of Anesthesiologists; *CAD*, coronary artery disease; *COPD*, chronic obstructive pulmonary disease; *EVAR*, endovascular aneurysm repair.
Continuous data are presented as mean ± standard deviation and categoric data as number (%), unless otherwise stated.
[a]LOC interval is defined as the interval between the initial EVAR and LOC.
[b]Obesity is assumed as a body mass index of ≥30.
[c]Chronic kidney disease is defined as serum creatinine concentration ≥1.5 mg/dL. No patient was on chronic haemodialysis before LOC.

Endograft characteristics and operative data. Multiple types of endografts have been removed: 33 of the 42 bifurcated endografts, 1 tube, 6 aortouni-iliac, and 2 iliac side-branch devices. These EVAR devices were Talent in 9 cases, AneuRx in 5 cases, and Endurant in 3 cases (Medtronic, Santa Rosa, Calif); Zenith (Cook, Bloomington, Ind) in 9 cases (among these, two iliac side branch devices); AFX in 9 cases, and Nellix in 1 case (Endologix); Anaconda (Vascutek, Inchinnan, United

Table II. Indications for urgent late open conversions (LOC)

Indication	n/N (%)
Endoleaks with rupture	24/42 (57.1)
Type I[a]	19/24 (79.2)
Type II	2/24 (8.3)
Type III	1/24 (4.2)
Endotension	2/24 (8.3)
Symptomatic endoleaks[b]	6/42 (14.3)
Type I	2/6 (33.3)
Type II	1/6 (16.7)
Type III	1/6 (16.7)
Endotension	2/6 (33.3)
EVAR device infection[a,c]	11/42 (26.2)
Sepsis	4/11 (36.4)
Aortoenteric fistula	2/11 (18.2)
Abdominal pain	2/11 (18.2)
Back pain	2/11 (18.2)
Rupture	1/11 (9.1)
Graft failure[d]	2/42 (4.8)

EVAR, Endovascular aneurysm repair.
[a]One patient presented with concomitant EVAR device infection and aneurysm rupture for a type I endoleak.
[b]Endoleaks associated with aneurysm growth and pain.
[c]EVAR infection includes only patients who required LOC within 24 hours after hospitalization.
[d]Graft failure corresponds to graft thrombosis or recurrent limb thrombosis.

Table III. Types and characteristics of the explanted endovascular aneurysm repair (*EVAR*) devices

EVAR device	No. (%) (N = 42)
Talent, Medtronic	11 (26.2)
Bifurcated	8 (19.1)
Aortouni-iliac	3 (7.1)
Zenith, Cook	9 (21.4)
Bifurcated[a]	5 (11.9)
Aortouni-iliac	2 (4.8)
Iliac branch	2 (4.8)
AFX, Endologix	7 (16.7)
AneuRx, Medtronic	5 (11.9)
Endurant, Medtronic	3 (7.1)
Bifurcated	2 (4.8)
Aortouni-iliac	1 (2.4)
Anaconda, Vascutek	2 (4.8)
Vanguard,[b] Boston Scientific	2 (4.8)
Stentor, MinTec	1 (2.4)
Excluder, Gore	1 (2.4)
Nellix, Endologix	1 (2.4)
Fixation	
Suprarenal[c]	33 (78.6)
Infrarenal	9 (21.4)
Presence of hooks/barbs	18 (42.9)

[a]Including two low-profile devices.
[b]Including one Vanguard aortic tube.
[c]Including the Nellix endograft used to perform the double renal chimney graft.

Kingdom) in 2 cases; Vanguard (Boston Scientific, Marlborough, Mass) in 2 cases; Stentor (MinTec, La Ciotat, France) in 1 case; and Excluder (W. L. Gore & Associates, Flagstaff, Ariz) in 1 case. Suprarenal fixation was present in 78.6% of stent grafts explanted. Hooks or barbs were present in 42.9% of the cases. The type of removed stent grafts and their characteristics are summarized in Table III.

A transperitoneal approach was used in 36 patients (85.7%), usually through a midline incision (only one case of bilateral subcostal incision). A retroperitoneal approach was performed in 6 of the 42 cases (14.3%). Proximal aortic cross-clamping site was infrarenal in 38.1% (16 of 42) of the cases, suprarenal in 19.1% (8 of 42), and supraceliac in 42.9% (18 of 42). Complete removal of the stent graft was performed in 32 of 42 patients (76.2%), partial removal in the remaining 10 of 42 cases (23.8%). Proximal preservation of the EVAR device was performed in 6 of 10 cases, distal preservation in 3 of 10, and proximal and distal preservation in 1 case. Overall, the proximal portion of the endograft was preserved in 7 of 42 patients (16.7%).

Reconstructions were performed with Dacron grafts in 33 of the 42 cases (11 aorto-aortic tubes, 19 aortobi-iliac grafts, and 3 aortobifemoral bypass grafts), cryopreserved arterial allografts in 5 of 42, and endograft removal associated with prosthetic axillobifemoral bypass in 4 of 42. Specifically, infected grafts were treated with several methods: 5 of 11 explantations followed by reconstruction with a cryopreserved allograft, 4 of 11 endograft removals associated with suture of the aortic stump and prosthetic axillobifemoral bypass graft, and 2 of 11 cases of replacement of the infected device with a silver-coated Dacron graft. Overall, adjunctive procedures were necessary in four cases: two bowel resections in patients with aortoenteric fistula, one left renal artery reimplantation, and one left renal artery Dacron bypass graft.

The mean operative time was 264 ± 94 minutes. The median estimated blood loss was 2000 mL (range, 500-4500 mL). The median transfused red blood cell units during surgery were 2.5 (range, 0-10 units). Regarding the 26 patients who underwent suprarenal or supraceliac aortic cross-clamping, the mean suprarenal clamp time was 49 ± 36 minutes.

Early results. Five patients of the 42 (11.9%) died intraoperatively (3 cases of aneurysm rupture, 1 EVAR infection, and 1 case with both aneurysm rupture and EVAR infection). Five more patients died in the postoperative period during intensive care unit stay of multiorgan failure, which likely resulted from MI in 2 cases, pulmonary infection in 1 case, acute kidney injury secondary to hypotension in another case, and the latter from bowel ischemia. Thus, overall 30-day mortality was 23.8% (10 of 42 patients).

The 30-day mortality rate was 27.3% in patients with infection of the endograft, 33.3% in patients with aneurysm rupture, and 0% in patients with symptomatic endoleak or graft failure. A suprarenal clamping site was associated with a statistically significant higher mortality rate of 38.5% ($P = .003$). Presentation with hypovolemic shock was found to be a risk factor for 30-day mortality (42.9% mortality; $P = .04$). No other risk factors for 30-day mortality were found on univariate analysis (Table IV). When factors with a P of .10 or less in univariate analysis were computed into the stepwise multivariate logistic regression model, only hemorrhagic shock (odds ratio, 10.5; 95% confidence interval, 1.5-73.7; $P = .018$) determined to be an independent predictive factor of early mortality. Suprarenal clamping site was not significant ($P = .96$).

The 30-day morbidity rate was analyzed after exclusion of intraoperative deaths (n = 37). The overall early morbidity rate was 67.6% (25 of 37 patients). This included 16 cases of acute kidney injury (including a case of bilateral renal artery thrombosis treated with thromboaspiration), prolonged ventilation of more than 4 days during intensive care unit stay in 14 patients, 5 cases of bowel ischemia (of which 3 required relaparotomy and bowel resection), 4 MIs, and 1 reintervention for hemorrhagic shock on postoperative day 1, which needed surgical revision of the anastomosis between the infrarenal aorta and the cryopreserved arterial allograft. Among the 16 patients who suffered from acute kidney injury, nine required HD (permanent HD in two cases). Only a preexisting renal insufficiency predicted postoperative morbidity ($P = .01$). The presence of a suprarenal fixation of the endoprosthesis ($P = .09$), infection ($P = .12$), or a suprarenal clamp position ($P = .20$) did not affect this end point (Table V). When factors with a P of .10 or less on univariate analysis were analyzed with the multivariate logistic regression model, only preexisting renal insufficiency (odds ratio, 10.8; 95% confidence interval, 1.2-99.4; $P = .036$) proved an independent risk factor of postoperative morbidity after urgent LOC. The presence of a suprarenal fixation of the endograft ($P = .20$) was nonsignificant. The median duration of stay was 14 days (range, 1-71 days).

Table IV. Univariate analysis (end point: Early mortality)

Variable	30-Day mortality, No. (%)	P
Age at LOC, years, mean ± SD	81.4 ± 6.9	.06
Male sex	9/37 (24.3)	.83
Preoperative risk factors		
Obesity[a]	2/7 (28.6)	.75
Chronic kidney disease[b]	4/16 (25)	.89
CAD	5/15 (33.3)	.28
Atrial fibrillation	2/9 (22.2)	.90
COPD	6/21 (28.6)	.72
Hypertension	9/41 (21.9)	.24
Smoking (ongoing)	2/9 (22.2)	.90
Diabetes mellitus	2/8 (25)	.93
Dyslipidemia	6/16 (37.5)	.14
Endograft characteristics		
EVAR infection	3/11 (27.3)	.75
Suprarenal fixation	9/33 (27.3)	.42
Hooks or barbs	4/18 (22.2)	.75
Endovascular reinterventions[c]	4/12 (33.3)	.43
Intraoperative variables		
Suprarenal clamping site	10/26 (38.4)	.004
Ruptured aneurysm	8/24 (33.3)	.15
Hemorrhagic shock	6/14 (42.9)	.04

CAD, Coronary artery disease; *COPD,* chronic obstructive pulmonary disease; *EVAR,* endovascular aneurysm repair; *LOC,* late open conversion; *SD,* standard deviation.
Continuous data are presented as mean ± standard deviation and categoric data as number (%), unless otherwise stated.
[a]Obesity is assumed as a body mass index of ≥30.
[b]Chronic kidney disease is defined as serum creatinine concentration ≥1.5 mg/dL.
[c]Any kind of endovascular reintervention for endoleak repair or graft stenosis/thrombosis before LOC.

Follow-up data and long-term results. Mean follow-up was 23.9 ± 36 months. The actual number of patients available for follow-up after 30 days was 29. The survival rate was estimated by means of the Kaplan-Meier method at 65.4% after 6 months, 62.1% at 1 year, and 46.1% after 5 years of follow-up (Fig). Perioperative deaths were included in this analysis.

During follow-up, we recorded 14 deaths, of which two were aneurysm related. The first was due to the rupture of an aortic stump in a patient who underwent endograft explantation associated with an axillobifemoral bypass graft for an infected EVAR device; it occurred approximately 11 months after LOC. The latter was caused by the rupture of a false aneurysm, which developed at the level of the proximal aortic anastomosis 18 months after LOC. Two LOC-related complications were recorded during follow-up: the thrombosis of a renal bypass and the occlusion of a reimplanted renal artery. These complications both occurred approximately 6 to 8 weeks after surgery.

DISCUSSION

Despite advances in endovascular techniques and improvements in technology, late failure remains an important issue after EVAR. Even though most of late EVAR complications are amenable to endovascular treatment, LOC is sometimes required.[11] According to a recent review, the average LOC rate is 3.7% (range, 0.9%-22.8%).[2] In the literature, LOC are usually carried out in an elective manner; anyhow, a not negligible

Table V. Univariate analysis (end point: Postoperative complications)

Variable	30-day morbidity,[a] No. (%)	P
Age at LOC, years (mean ± SD)	74.6 ± 7.8	.92
Male sex	21/32 (65.6)	.52
Preoperative risk factors		
Obesity	6/6 (100)	.14
Chronic kidney disease	13/14 (92.9)	.01
CAD	10/12 (83.3)	.16
Atrial fibrillation	5/7 (71.4)	.81
COPD	13/18 (72.2)	.56
Hypertension	24/36 (66.7)	.48
Smoking (ongoing)	5/8 (62.5)	.73
Diabetes mellitus	4/6 (66.7)	.96
Dyslipidemia	8/13 (61.5)	.56
Endograft characteristics		
EVAR infection	8/9 (88.9)	.12
Suprarenal fixation	21/28 (75)	.09
Hooks or barbs	12/16 (75)	.40
Endovascular reinterventions	8/10 (80)	.33
Intraoperative variables		
Suprarenal clamping site	16/21 (76.2)	.20
Ruptured aneurysm	14/20 (70)	.73
Hemorrhagic shock	7/11 (63.6)	.74

CAD, Coronary artery disease; *COPD,* chronic obstructive pulmonary disease; *EVAR,* endovascular aneurysm repair; *LOC,* late open conversion; *SD,* standard deviation.
[a]Early morbidity is defined as any postoperative major complication, including myocardial infarction (MI), arrhythmia, acute kidney injury, pneumonia, prolonged ventilation (>4 days during intensive care stay), bowel ischemia, and reinterventions.

portion of LOC are performed in a urgent setting. In fact, the average urgent LOC rate reported in literature is 22.5% (range, 7.8%-38.7%).[2,8,12] In this current experience, urgent LOC represented the 30% of late surgical conversions after EVAR. Despite improvements in endoleak detection, prevention, and treatment, the number of urgent LOC steadily increased during the 20 years of this study.[13-16] One of the possible explanation for this increase is that an important portion of patients do not regularly follow the post-EVAR surveillance protocol. In fact, in our experience, 39% of newly diagnosed endoleaks were found in noncompliant patients; thus, urgent LOC could have possibly been prevented in these patients. Urgent LOC are characterized by significant higher rates of intraoperative and postoperative mortality and morbidity when compared with elective conversions. Except for a few reports, mortality rates in the literature were clearly different between elective and nonelective patients (3.2% vs 29.2% in the abovementioned review).[2,17] In a recent article, renal and respiratory complication rates were significantly higher in nonelective settings (42% vs 5% [$P = .02$] and 42% vs 0% [$P = .005$], respectively).[12]

For these reasons, we believe that urgent LOC should be considered as a different entity and, therefore, analyzed separately.

Patients undergoing urgent LOC are typically frail with multiple comorbidities, as demonstrated by the fact that, in our series, more than 90% had an American Society of Anesthesiologists score of three or higher (Table I). Endoleak represented the main indication for LOC in our series (>70%), in accordance with the literature.[2,6,18,19] In all six participant centers, LOC was reserved for cases not amenable to endovascular repair or after one or more unsuccessful minimally invasive attempts (in fact, 12 patients underwent endovascular reintervention before LOC, of which four underwent multiple endovascular repair in addition to initial EVAR).

The incidence of endograft infection in our series (26.2%) was higher than the average of 9.5% reported in literature.[2,20] This finding may indicate that infected endografts are more likely to present in an urgent setting. LOC in case of an infected endograft may be more technically challenging when compared with noninfected EVAR device explantation. Specific issues that can be encountered are related to the need of complete removal of the infected endograft (which may need a supraceliac clamp, exposing the kidney to injury); aortic reconstruction, which cannot benefit from the use of standard prosthetic grafts (cryopreserved allografts and/or silver/antibacterial-coated grafts must be available in urgency); and the potential presence of a frail arterial wall—weakened by the infection—that can make aortic suture challenging. In fact, the two aneurysm-related deaths we recorded during follow-up (the rupture of an aortic stump and the rupture of a proximal aortic false aneurysm) both occurred in patients who presented with EVAR infection.

In the literature, graft or limb thrombosis is a rare indication for LOC, representing approximately the 6% of the cases.[2,18] Also in our series, recurrent graft thrombosis is the least represented reason for endograft removal (4.8%). This may be because limb thrombosis or kinkings are usually easily managed by low-risk percutaneous (eg, thrombolysis and/or percutaneous transluminal angioplasty) or surgical procedures (eg, femorofemoral crossover bypass graft), and LOC is usually left for recurrent cases after numerous minimally invasive attempts.

Many different surgical techniques are described in literature. They vary mainly in terms of type of approach (transperitoneal vs retroperitoneal), proximal cross-clamping site (infrarenal, suprarenal, or supraceliac), and extent of graft removal (complete vs partial). These choices are typically guided by both clinical factors (such as the presence of a suprarenal fixation, the reason for removal, or previous abdominal surgery), and surgeon's preference and/or customs. In our series, similar to what is reported in the literature, transperitoneal access through a midline incision is the most common

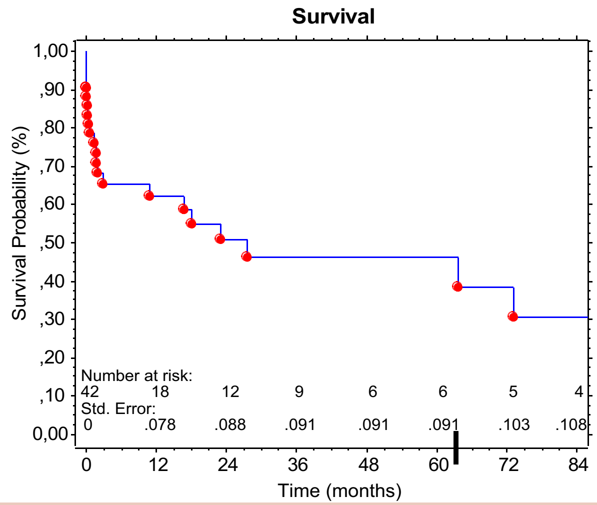

Fig. Seven-year estimated survival for the patients who underwent urgent late open conversion (LOC) after endovascular aneurysm repair (EVAR). The standard error exceeds 10% after 64 months of follow-up.

approach (>80% of cases).[2] Nevertheless, some investigators seem to prefer the retroperitoneal approach.[18] In the majority of the experiences published in literature, the proximal clamp is usually positioned in a suprarenal or supraceliac fashion, with reported rates of up to 87%.[8,18] In our series, the proximal aorta was clamped in a suprarenal position in 26 of the 42 patients (61.9%). The rationale is to avoid direct clamping of the endograft, which may cause alterations of the metallic structure or aortic mechanical lesions. However, a recent single-center study reported a series of patients who underwent LOC with 100% infrarenal clamp positioning, suggesting that in most cases requiring endovascular aortic graft explantation, suprarenal or supraceliac clamping is unnecessary.[5] Furthermore, suprarenal or supraceliac cross-clamping seems to be associated with significantly increased postoperative mortality,[6,21] and with higher rates of visceral complications and renal injuries.[20,22,23] In our study on urgent LOC, suprarenal clamp was associated with a higher mortality rate (38.4%), which was significant on univariate analysis ($P = .004$; Table IV). On multivariate analysis, only presentation with hemorrhagic shock was found to be an independent risk factor for early mortality. This, in our opinion, may indicate that a shocked patient is more likely to undergo suprarenal clamping to facilitate hemodynamic stabilization, but the clamping site is not a mortality risk factor by itself.

Several maneuvers assisting in successful removal of the EVAR device can be found in the literature: in addition to the traditional clamp-and-pull method, collapsing the proximal bare metal stent into a 20-mL syringe or the use of iced saline poured on nitinol stents to help collapse and facilitate removal have also been described.[20,22,24,25] In contrast, numerous techniques have been described to perform partial endograft explantation, such as the direct infrarenal endograft clamping or the surgical infrarenal neoneck technique.[5,26,27] Preserving a significant portion of the endograft may limit aortic dissection, decrease clamp time, and lower the incidence of visceral or renal ischemia, thus decreasing intraoperative and postoperative morbidity and mortality.[5,20,27] In the current series, complete endograft removal was performed in the great majority of the cases (76.2%). This, in our opinion, may be related to (i) the remarkable amount of endograft infections (26.2%), which imposes a complete explantation of the endoprosthesis, and (ii) the high number of suprarenal and supraceliac aortic clamping (61.9%), which eases complete endograft removal.

Urgent LOC are characterized by high early mortality and morbidity rates. In fact, in our series, 11.9% patients died intraoperatively and the overall 30-day mortality was 23.8%. Low mortality rates in the subgroup of symptomatic patients indicates that LOC have better outcomes if performed before rupture occurs, even if carried out in a urgent setting.[9] Our early mortality rates are in accordance with the recent review of the literature, which identified an early mortality of 29.2%.[2] Some investigators reported even higher mortality rates, up to 37% in nonelective cases, and reaching 56% mortality for ruptures.[18,24] Among patients who survived ($n = 37$), the early morbidity rate was 67.6% in our series. These complications were often severe, including three interventions for bowel ischemia, four MIs, one reintervention for hemorrhagic shock, and nine cases of renal insufficiency requiring HD (of which two were permanent). Early morbidity seemed to be affected only by preexisting renal insufficiency in our experience.

The 5-year estimated survival rate of 46.1%, which was heavily affected by perioperative mortality, is significantly lower if compared with the main randomized controlled trial on AAA, indicating that urgent LOC, in contraposition with EVAR or standard open repair, is a severe condition characterized by poor early and long-term outcomes.[28] Close surveillance, which may allow planned LOC is crucial to achieve better outcomes after EVAR failure.[9]

Despite the potential limitations of a retrospective study, this article analyses for first the specific subgroup of patients who required urgent LOC. Another potential limitation is that the six vascular centers involved in this study may have different practices, in terms of both indication for LOC (including additional endovascular attempts before open conversion) and surgical technique. Nevertheless, considering the low incidence of urgent LOC, the management of this subset of patients is not currently standardized. However, differences in surgical management (ie, clamping site, extent of endograft removal), or a history of multiple previous endovascular procedures did not affect outcomes in our series. A potential additional limitation is that urgent LOC corresponds with a heterogeneous group, because it includes both stable and unstable patients; however, according to the Society for Vascular Surgery guidelines, a symptomatic AAA is best treated urgently.[9] Finally, EVAR devices and endovascular techniques have improved over the last few years. First-generation endografts are no longer available and, in contrast, new devices such as fenestrated EVAR expanded anatomic suitability and allowed repair of most type Ia endoleaks. So, it is can be assumed that, in the foreseeable future, LOC will be even more technically challenging, because it may be reserved for infected endografts or in case of complete degeneration of the proximal aortic neck with subsequent development of a juxtarenal, pararenal, or thoracoabdominal aneurysm.

CONCLUSIONS

Urgent LOC after EVAR is associated with very high postoperative mortality and morbidity rates and poor long-term survival. Worse outcomes are associated with hemorrhagic shock on presentation and preexisting renal insufficiency. Endoleak remains the main indication for open conversion, but endograft infection represented an important portion of urgent LOC. To improve outcomes, better compliance with the post-EVAR surveillance protocol should be achieved, because it may prevent a portion of urgent LOC. Moreover, further studies are eagerly awaited to standardize timing and treatment options for failing EVAR.

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AUTHOR CONTRIBUTIONS

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