Endovascular treatment of penetrating atherosclerotic ulcers of the arch and thoracic aorta: In-hospital and 5-year outcomes

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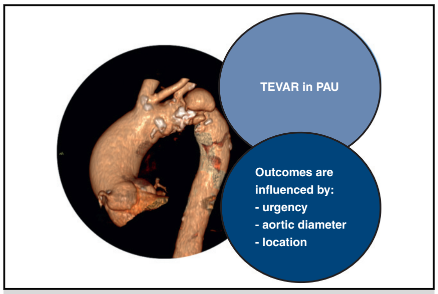
ABSTRACT

Objective: Thoracic endovascular aortic repair (TEVAR) is the treatment of choice for thoracic aorta diseases including penetrating aortic ulcer (PAU). The objective of this study was to analyze the results of TEVAR for the treatment of PAU in our population.

Methods: From January 1999 to January 2019, 830 patients with type B aortic syndromes were treated with TEVAR in our institution. Of these we selected 73 patients treated for a PAU. Clinical and radiologic follow-up was performed in all patients.

Results: Mean age of our population was 72 ± 8 years. Fifteen patients (20.5%) were treated in an emergency setting. The proximal landing zone was in arch zone 2 in 22 patients (30.1%). In-hospital mortality was 6.8% and was associated with acute presentation ($P = .005$). Distal arch delivery of the endograft was unrelated to mortality (Fisher exact test, $P = .157$). Survival at 1 and 5 years was 81.7% and 67.3%, respectively. Sixteen patients underwent reintervention of the thoracic aorta. Patients who underwent emergency surgery and older patients had a shorter survival (log rank test, $P < .001$). No difference in survival was shown according to the proximal landing zone (log rank $P = .292$) or the dimension of the thoracic aorta (log rank $P = .067$). In multivariable Cox regression analysis, only age older than 75 years was associated with 5-year mortality (hazard ratio, 6.60; 95% CI, 2.12-20.56); $P < .001$).

Conclusions: The use of TEVAR for treatment of aortic PAU is a safe procedure in an elective setting despite necessity of arch stent grafting. An early intervention performed at smaller aortic diameters of <55 mm might be beneficial in selected patients to improve late survival. (JTCVS Open 2022;10:12-21)



Factors that influence outcomes of patients with PAU treated with TEVAR.

CENTRAL MESSAGE

The use of TEVAR in patients with PAU is a safe and durable treatment in an elective setting whereas morbidity and mortality are higher in acute cases with signs of IMH or impending rupture.

PERSPECTIVE

An early endovascular intervention at smaller aortic diameter (<55 mm) should be considered in selected patients with specific ulcer characteristics.

▶ Video clip is available online.

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Penetrating atherosclerotic ulcer (PAU) is defined as an atherosclerotic plaque ulceration that penetrates the intima and then progresses into the tunica media. It was first described as a clinical entity in 1986.[1] These lesions occur almost exclusively in the descending thoracic aorta, where extensive atherosclerosis is more frequent than in the ascending aorta and the aortic arch.[2] Their real incidence is unknown, because in most cases PAUs are asymptomatic. Nevertheless, some studies reported that it could range between 2% and 11%.[3,4] Patients with PAU are older than those with classical dissection and risk factors such as

Abbreviations and Acronyms

CT = computed tomography
HR = hazard ratio
K-M = Kaplan–Meier
OR = odds ratio
TEE = transesophageal echocardiography

hypertension, hypercholesterolemia, or smoking tend to be more frequent than in classical dissection.[5] When PAU causes symptoms, these are usually similar to those of aortic dissection with chest or back pain and might be indistinguishable, although patients are less likely to suffer from malperfusion syndrome.[6] The main objective of PAU treatment is to prevent aortic rupture or progression to classic dissection. Recent studies revealed the malignant nature of PAU. It has been suggested that the presence of PAU in combination with intramural hematoma (IMH) is particularly ominous. The risk for aortic rupture during initial hospital admission might be higher in patients who present with PAU compared with that in patients with classic aortic dissection.[7] In particular, there is a general consensus about the high risk of disease progression in patients with recurrent thoracic pain, whereas asymptomatic ulcers may be managed conservatively.[8] The treatment of choice for symptomatic PAU located in the descending thoracic aorta is nowadays the use of endovascular stent graft repair, which seems to be a low-invasive and rational option for aortic ulcers and provides satisfactory perioperative and mid-term results with low rates of mortality and morbidity.[9-11] The objective of our study was to evaluate the early and late outcomes of stent graft implantation in the treatment of acute and chronic PAU in the descending thoracic aorta.

METHODS

Patient Characteristics

From April 1999 to January 2019, 830 thoracic endovascular aortic repairs (TEVARs) were performed at our institution in patients with acute and chronic type B aortic syndromes. Of these, 73 patients underwent TEVAR for a PAU in the thoraco-abdominal aorta between January 2001 and October 2018, and represented our study population. All open or hybrid procedures in the arch were excluded, as well as proximal landing zone in arch zone 0 or 1. We retrospectively analyzed the preoperative, postoperative, and follow-up clinical data of all patients, but also the radiological data with an angiographic computed tomography (CT) scan performed before surgery and then at discharge, 3 months, 1 year, and every year thereafter in our outpatient clinic.

Patient characteristics are listed in Table 1. The mean age of our population was 72 ± 8.1 years and 79.5% were male. The most frequent cardiovascular risk factor was hypertension (88.7%), whereas 15.5% suffered from diabetes, 24.7% from chronic obstructive pulmonary disease and 12.7% from peripheral artery disease, 5.6% had a positive family history for aortic events. Most patients showed good cardiac function (mean ejection fraction, 57.3 ± 8.3) and renal function (mean creatinine level, 1.22 ± 0.67). Symptom onset was variable even if the most frequent presentation was pain (chest pain 19.2% and infrascapular pain 15.1%). Previous surgery on the thoracic aorta had been performed in 10 patients (13.7%), all above arch procedures, and 47 patients (64.4%) had a descending thoracic aorta aneurysm estimated to be more than 55 mm. This retrospective study was approved by the local institutional review board and did not require the patient informed consent (number 109/2019/Disp/AUOBo). It was also conducted in accordance with the ethical principles established in the Declaration of Helsinki.

Surgical Indications

PAU was defined according to current recommendations[12] as ulceration of an aortic atherosclerotic plaque penetrating through the internal elastic lamina into the media, with or without intramural hemorrhage or limited parietal flap (Figure 1). Fifty-eight (79.5%) had elective procedures for chronic PAU. These patients were in angiographic CT scan follow-up for a known PAU that met criteria for surgery. Indications for surgical treatment were aortic diameter exceeding 55 mm, increase in diameter exceeding 10 mm per year, and ulcer characteristics (including diameter, location, neck etc) as indicated in current guidelines.[5,12] Fifteen patients (20.5%) were treated in an emergency setting, because of hemodynamic instability and imaging findings of an impending rupture. Signs of impending rupture were considered recurrent thoracic pain associated with periaortic hematoma, hemorrhagic pleural effusion, contrast media extravasation outside the adventitial wall, and rapid growth rate of the pseudo-aneurysm.

Operative Strategy

Our standard approach has been previously described.[10] Briefly, all patients underwent general anesthesia and received mechanical ventilation. Blood pressure was monitored using right radial artery cannulation. Cerebrospinal fluid drainage to reduce the risk of paraplegia was used in 8 patients (11.0%), usually in elective cases when a long aortic coverage was expected and in patients with a previous surgery on the abdominal aorta. Usually the common femoral artery was used as surgical access after exposure. Heparin (2500 IU) was generally administered, with the exception of patients who had active bleeding into the pleural and or mediastinal space. Angiography and transesophageal echocardiography (TEE) were used to identify the lesion, landing zones, and their relationship with the side branches. Intraoperative data are listed in Table 2. A median of 1 stent graft (range, 1-4) was used for each procedure (1 stent in 57.5% and 2 in 32.9% of our population). Stents were delivered using fluoroscopic and TEE control with induced hypotension (systolic pressure <90 mm Hg) to prevent the displacement of the stent graft during delivery. The most frequently used proximal landing zone for TEVAR was arch zone 3, but in 22 procedures (30.1%) the stent graft was deployed in arch zone 2 (Video 1). In these cases, a left carotid to left subclavian bypass was performed routinely in elective cases (19 patients), whereas in the emergency setting subclavian coverage by the stent graft was accepted and the arm carefully evaluated for any sign of ischemia. Distal landing zone was the mid-descending thoracic aorta in 65.7%, the distal thoracic aorta before the celiac trunk in 19.2%, and beyond the celiac trunk in 15.1% of cases (of these 3 received a branched endograft). Associated procedures were subclavian artery embolization in 5 patients (6.8%) and celiac truck embolization in 1 patient (1.4%). On the basis of angiographic CT scan measurement, an oversizing of 10% to 15% was applied in the choice of stent graft diameter. Mean fluoroscopy time was 19.8 minutes and the mean quantity of contrast necessary for the procedure was 122 cc. Postprocedural angiography and TEE control were performed to reveal the final result.

Statistical Analysis

Categorical variables are summarized as n (%) and continuous variables as mean ± standard deviation or median and interquartile range as appropriate. Shapiro–Wilk test was used to test the normality of the frequency

TABLE 1. Patient characteristics (n = 73)

Variable	Value	%
Mean age ± SD, y	72.0 ± 8.1	
Age ≥75 y	30	41.1
Male gender	58	79.5
Mean BMI ± SD	26.3 ± 3.6	
Hypertension	63	86.3
COPD	18	24.7
Diabetes	11	15.1
Mean creatinine ± SD, mg/dL	1.22 ± 0.67	
Peripheral artery disease	9	12.3
Coronary artery disease	23	31.5
Mean EF ± SD, %	57.3 ± 8.3	
Previous temporary neurologic events	2	2.8
Previous surgery, thoracic aorta	10	13.7
Descending thoracic aortic aneurysm ≥55 mm	47	64.4
Intramural hematoma	13	17.8
Ulcer number >1		
Infrascapular pain at admission	11	15.1
Syncope at admission	3	4.1
Status at in-hospital admission		
Elective	58	79.5
Urgent/emergent	15	20.5

Values are n except where otherwise noted. *BMI*, Body mass index; *COPD*, chronic obstructive pulmonary disease; *EF*, ejection fraction.

distribution of continuous variables. Categorical and continuous variables were compared between groups using χ^2 test or Fisher exact test and *t* test (or Mann–Whitney test for non-normal variables), respectively. The risk factor analysis for in-hospital mortality was performed using binary logistic regression. We tested the linearity of the relationship between continuous variables and the logit using Box–Tidwell transformation. Survival probabilities were estimated from hospital discharge to death or end of follow-up, whichever came first, using the Kaplan–Meier (K-M) method. The log rank test was applied to compare survival curves. Multicollinearity among variables was detected using Pearson correlation test or phi test for categorical variables. In the presence of strongly correlated variables (>0.50), only 1 was retained in the model. Variables that differed particularly between groups in K-M analyses were included in a multivariable Cox regression model. We tested the proportional hazard assumption underlying Cox regression models using Schoenfeld residuals. When variables did not meet the proportional hazard assumption, they were used as strata of the baseline hazard. Results are expressed as odds ratios (ORs; logistic regression) or hazard ratios (HRs; Cox regression), with 95% confidence intervals. SPSS statistics 27.0 (IBM Corp) and Stata 15.1 (StataCorp LLC) were used for statistical analyses.

RESULTS

Early Outcomes

Overall in-hospital mortality was 6.8%, however, it varied according to the setting of the procedure. In fact, in elective procedures mortality was 1.8%, whereas in case of acute presentation it reached 26.7% (Fisher exact test, P = .005). Neurological injury rates were low, with only 1 case of paraplegia (1.4%), 2 cases of transient ischemic attack (2.7%), and no patients with permanent stroke. Five patients (6.8%) suffered from acute kidney injury, but only 3 of them required dialysis (4.1%). Postoperative angiographic CT scan, before discharge, showed a small incidence of early type 2 or type 4 endoleaks (approximately 16%) and none of them required interventions (Table 3). Result of univariate logistic regression using preoperative and postoperative variables for in-hospital mortality are provided in Table 4. None of the continuous variables failed to meet the linearity assumption. Early mortality was associated with acute presentation with the presence of an IMH (OR, 20.73 [95% CI, 2.11-203.54]; P = .005), presentation with infrascapular pain (OR, 21.75 [95% CI, 2.01-203.20]; P = .011], extension of aortic coverage (OR, 3.26 [95% CI, 1.06-10.07]; P = .040), and the postoperative onset of renal failure requiring dialysis (OR, 44.67 [95% CI, 3.11-641.50]; P = .011). On the contrary, other operative variables such as the proximal landing zone with coverage of the subclavian artery and consequent need for a carotid-subclavian bypass or the presence of an aortic aneurysm ≥55 mm were unrelated to in-hospital mortality.

Survival and Reintervention During Follow-up

The median length of follow-up after discharge was 51 (interquartile range, 22-85) months. Because of the small number of individuals at risk after 5 years, we focused on survival over the 5-year period after discharge. Overall survival at 1 year was 87.8% and at 5 years 72.4%. It was different when considering age older than 75 years (log rank P > .001; Figure 2). No significant difference in survival was observed according to the proximal landing zone (arch zone 2 vs descending thoracic aorta; log rank P = . 471; Figure 3). However, when patients were divided into 2 subgroups according to acute or chronic presentation, acute cases had a strongly worse prognosis with a higher follow-up mortality rate than elective cases (log rank P = .018; Figure 2). Still, when the population was classified according to the presence or absence of descending thoracic aorta aneurysm ≥55 mm at the time of TEVAR, patients with a more dilated aorta had a higher follow-up mortality rate (log rank P = .089; Figure 3).

A multivariable Cox regression analysis was then performed including age older than 75 years (yes/no) and acute presentation (yes/no). Both of these variables met the proportionality of hazard assumption, and were strongly but moderately correlated (phi test, 0.31; P = .01), because emergency procedures are more common among the elderly. Thus, acute presentation and age were retained in the Cox regression model. Only age older than 75 years was associated with mortality (HR, 6.60 [95% CI, 2.12-20.56]; P < .001), whereas acute presentation (HR,

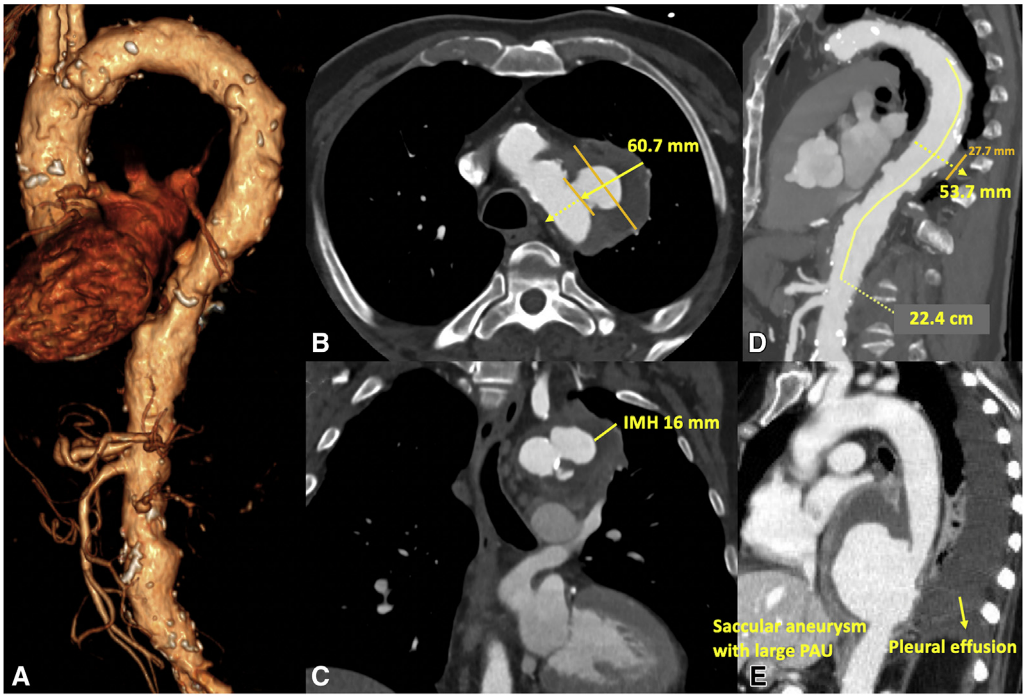


FIGURE 1. Angiographic-computed tomography scans showing different type of penetrating aortic ulcers (*PAUs*). A, 3-D reconstruction of multiple ulcers of the thoraco-abdominal aorta. B, Axial view of a distal arch PAU. C, Coronal view of an aortic isthmus PAU with presence of intramural hematoma. D, Sagittal view showing preoperative planning of stent graft implantation. E, Sagittal view of an acute PAU with saccular aneurysm and pleural effusion.

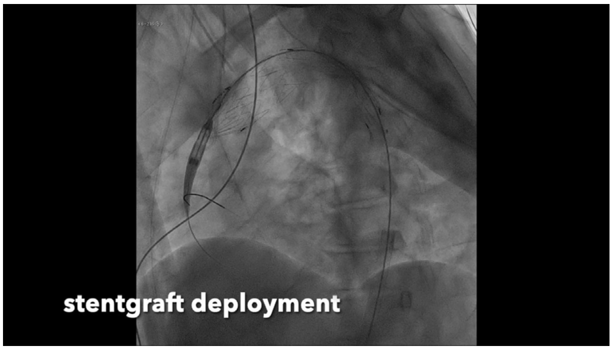
TABLE 2. Operative data (n = 73)

Variable	Value	%
Proximal landing zone (Ishimaru zone)		
Zone 2	22	30.1
Zone 3	46	63.0
Zone 4	5	6.9
Distal landing zone		
Descending thoracic (zone 4)	48	65.7
Distal descending (zone 5)	14	19.2
Supra-renal (zone 6-7)	4	5.5
Infra-renal (zone 8-9)	7	9.6
Carotid-subclavian bypass	19	26.0
Cerebrospinal fluid drainage	8	11.0
Associated procedures		
Subclavian artery embolization	5	6.8
Celiac trunk embolization	1	1.4
Endograft		
Valiant (Medtronic)	72	
Talent (Medtronic)	17	
Endurant (Medtronic)	2	
Bolton Relay (Terumo Aortic)	12	
bEVAR (Jotec)	6	
Gore TAG (W. L. Gore & Associates)	2	
Zenith (Cook Medical)	1	
Mean stents used ± SD, n	1.53 ± 0.71	
Fluoroscopy time ± SD, minutes	19.8 ± 18.9	
Mean contrast medium ± SD, cc	122.2 ± 49.6	

Values are n except where otherwise noted.

2.42 [95% CI, 0.82-7.13]; $P = .109$] was no longer associated (Table 5).

Sixteen patients underwent thoracic aorta reintervention over 5 years from discharge. Of them, 14 received a second endovascular procedure because of endoleak formation in 7 or aneurysm progression in other aortic segments in 7 patients, whereas open repair was necessary in the remaining 2 of 16 patients. The freedom from reintervention in K-M analysis was 92.5% at 1 year and 74.9% at 5 years.



VIDEO 1. Repair of the thoracic aorta in a patient with chronic PAU using a custom made stent graft delivered in the arch. Video available at: https://www.jtcvs.org/article/S2666-2736(22)00128-0/fulltext.

TABLE 3. In-hospital outcomes (n = 73)

Variable	Value	%
In-hospital mortality	5	6.8
Elective (n = 58)	1	1.7
Neurological Injury		
Transient ischemic attack	2	2.7
Stroke	0	0
Paraplegia	1	1.4
Myocardial infarction	0	0
Acute kidney injury	5	6.8
Dialysis	3	4.1
Respiratory failure	4	5.5
Limb ischemia	1	1.4
Mean length of stay ± SD, d	11.0 ± 17.8	
Early endoleaks type II	4	5.5
Early endoleaks type IV	8	11
Early endoleaks type II-IV	4	5.5

Values are n except where otherwise noted.

TABLE 4. Variables associated with in-hospital mortality

Variable	In-hospital mortality *P* value	In-hospital mortality OR (95% CI)
Age, y	.109	1.13 (0.97-1.31)
Age ≥ 75 y	.077	6.88 (0.73-65.02)
Female gender	**.056**	**0.14 (0.02-0.95)**
BMI	.617	0.93 (0.71-1.23)
Diabetes	.498	1.90 (0.18-20.14)
COPD	.591	2.17 (0.33-14.13)
Creatinine	.920	1.07 (0.27-4.18)
Acute presentation	**.005**	**20.73 (2.11-203.54)**
Infrascapular pain	**.011**	**21.75 (2.01-203.20)**
Syncope	1.00	0.94 (0.89-1.00)
Coronary artery disease	.656	1.43 (0.22-9.20)
Peripheral artery disease	.503	1.81 (0.18-18.31)
Previous surgery on thoracic aorta	1.00	0.92 (086-1.00)
Previous surgery on abdominal aorta	.107	4.88 (0.75-31.79)
CSF drainage	1.00	0.93 (0.87-1.00)
Aortic aneurysm ≥55 mm	.655	2.18 (0.23-20.64)
Proximal extension arch zone 2	.157	3.87 (0.60-25.00)
Carotid-subclavian bypass	.60	2.00 (0.31-13.00)
Endovascular branch embolization	**.051**	**10.67 (1.37-83.24)**
Stents used, n	**.040**	**3.26 (1.06-10.07)**
Postoperative TND	1.00	0.93 (0.87-1.00)
Postoperative SCI	1.00	0.93 (0.87-1.00)
Postoperative dialysis	**.011**	**44.67 (3.11-641.50)**

Bold are strongly related variables. *OR*, Odds ratio; *BMI*, body mass index; *COPD*, chronic obstructive pulmonary disease; *CSF*, cerebrospinal fluid; *TND*, transient neurological deficits; *SCI*, spinal cord injury.

DISCUSSION

According to the progressive increase of elderly patients and atherosclerotic burden in western countries, the diagnosis of aortic ulcers has become much more frequent. Compared with other acute aortic syndromes, PAU are a multifaceted disease; they can be chronic, asymptomatic, and isolated, or diffuse and extended to the entire thoracoabdominal aorta, otherwise the presentation can be acute with chest pain and signs of impending rupture or fresh hematoma. There are no controlled studies regarding the natural history of PAU in different settings, but reports have shown that PAU can result in the development of a true aortic aneurysm, IMH, or an aortic dissection.[12,13]

This study extends our previous 2008 report on the early experience with PAUs at the University Hospital of Bologna. The earlier report included a total of 19 patients; in the current study, we expanded our patient cohort to 73 patients that represented approximately 10% (73/830) of patients we treated with TEVAR in the past 20 years. However, we observed an increased number of PAU and treatment of chronic lesions. The onset of PAU occurred in patients older than those with classic dissection.

Indications for treatment in asymptomatic patients have been driven mostly by aortic diameter and then by ulcer characteristics,[12,14] however, during the past years we changed our policy in favor of a more aggressive treatment approach on the basis of ulcer anatomy instead of diameter. In particular, preoperative angiographic CT scan analysis was performed by the aortic team (cardiac surgeon and interventional radiologist) on the basis of measurements of PAU neck, PAU depth, PAU location, and total aortic diameter (Figure 1). Larger PAUs (diameter >15 mm and neck >10 mm) should be considered for repair in patients with an aortic diameter <55 mm. Ulcer progression and enlargement or pain onset were other relevant factors in patients that we follow-up with routine examination. According to these parameters we report in Figure 4 an algorithm showing our decision-making process.

Similar observations came from other series. Nathan and colleagues[13] from the University of Pennsylvania analyzed 388 PAUs, the largest series available, and reported that maximum aortic diameter does not predict subsequent radiographic disease progression. In fact, even if initially treated conservatively with resolution of pain, 36% of symptomatic PAUs eventually required repair versus 7.8% of asymptomatic ones, and 43% of symptomatic PAUs had radiographic progression versus 16.7% of asymptomatic PAUs. They concluded that size-related criteria might not be helpful in predicting PAU behavior. In a more recent study, Yang and colleagues[15] reported long-term imaging evolution and prognosis in 109 PAUs and showed that patients with an ulcer diameter >12.5 mm (HR, 3.8; $P = .003$) or an ulcer depth

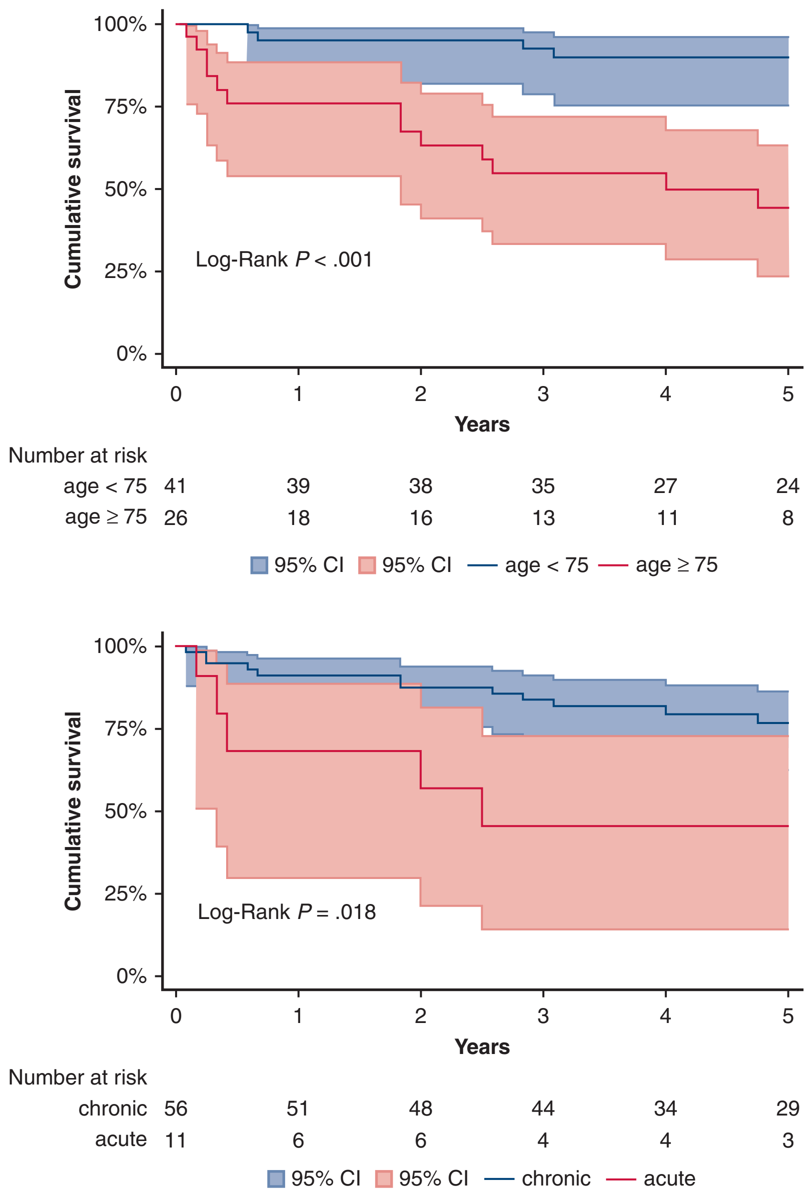


FIGURE 2. Kaplan–Meier survival curves for age (*top*) and clinical presentation (*bottom*).

>9.5 mm (HR, 3.4; $P = .003$) have a higher risk for disease progression. According to Chou and colleagues,[16] between medically managed patients with PAU the lesion rarely resolved and persisted or worsened in 85% of cases, with 30% requiring late operation.

Unlike acute aortic dissection, a PAU is usually a focal, localized lesion representing an ideal anatomic target for self-expandable stent graft. According to the results of this study, also the lesions involving the distal aortic arch and isthmus necessitating a carotid-subclavian bypass (used in 30% of the procedures) or custom-made prosthesis (fenestrated or scallop endograft) do not seem to be related to early and late outcomes. Instead, the PAU treatment at larger aortic diameter (>55 mm) was associated with a lower survival in the K-M analysis compared with patients with smaller diameters. Actually, age might have influenced this result because patients with an aortic diameter <55 mm were slightly younger compared with the population with larger aortic diameters (68.9 years vs 72.7 years).

Despite improvements in operative techniques, stent grafts, and postoperative care, the treatment of PAU in the acute setting is still associated with high morbidity and a mortality rate of 26.7%. According to the Yale experience,[16] incidence of rupture state at PAU presentation was 32%, considerably high if compared with rates of rupture of typical aortic dissection (type A and B), confirming the especially malignant nature of a penetrating ulcer. Moreover, patients are usually elderly (the mean age of our

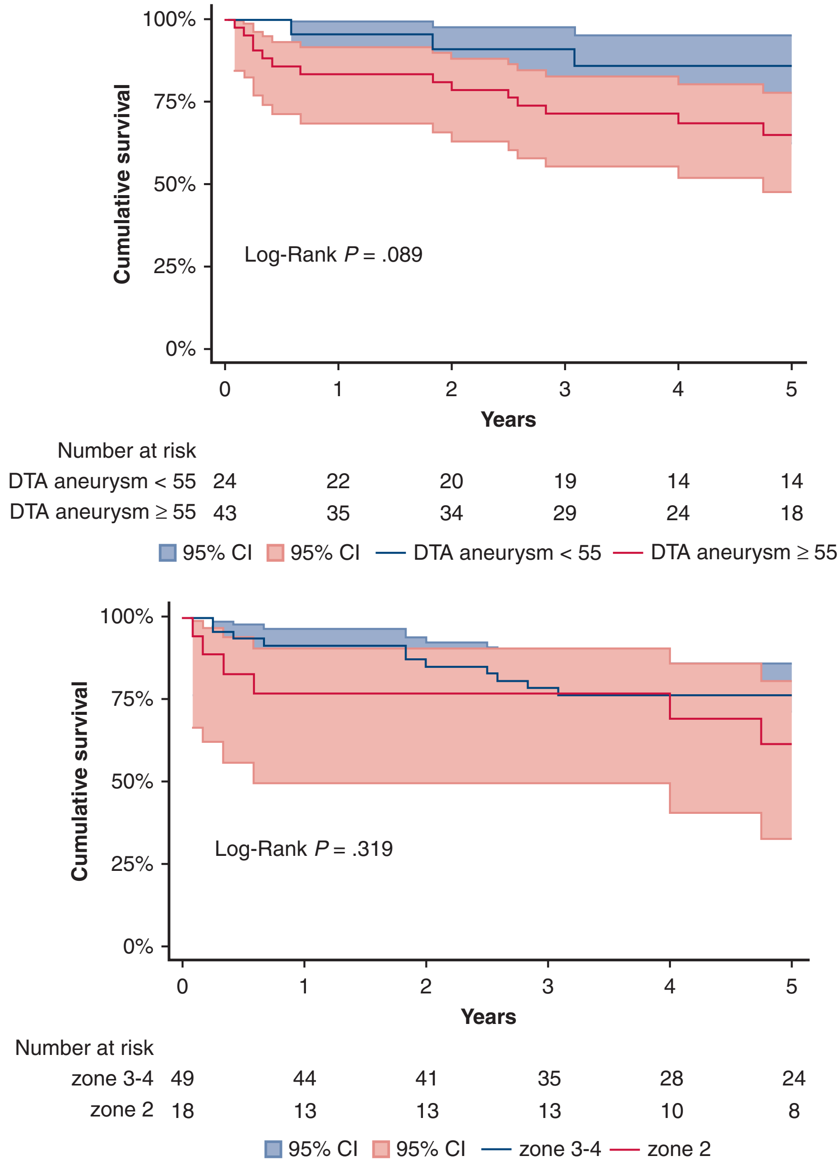


FIGURE 3. Kaplan–Meier survival curves for descending thoracic aorta aneurysm greater than or less than 55 mm (*top*) and proximal landing zone in arch or descending thoracic aorta (*bottom*). *DTA*, Descendinng thoracic aorta.

population was 72.0 years), with a variety of comorbidities and even if they do not show any sign of organ malperfusion at admission, postoperative care is usually slow and often requires chest tube drainage for recurrent pleural effusion or dialysis.

TABLE 5. Multiple Cox regression analysis for survival after discharge in patients with penetrating aortic ulcer

Variable	Follow-up mortality	
	P value	HR (95% CI)
Age ≥75 y	**.001**	**6.60 (2.12-20.56)**
Acute presentation	.109	2.42 (0.82-7.13)

Bold are strongly related variables. *HR*, Hazard ratio.

Like in other series,[15-18] in-hospital mortality after endovascular repair is approximately 4% to 15% and results of TEVAR in PAU patients compare favorably with TEVAR for other indications, with a high rate of technical success (98%-100%), few neurologic complications (0-5%), and few requirements for reinterventions (0-20%). In our experience postoperative angiographic CT revealed early endoleaks in approximately 16% of the population but most were type IV and none of them required intervention.

At follow-up, survival of treated patients was satisfactory with 87.7%, 72.3%, at respectively, 1 and 5 years. After

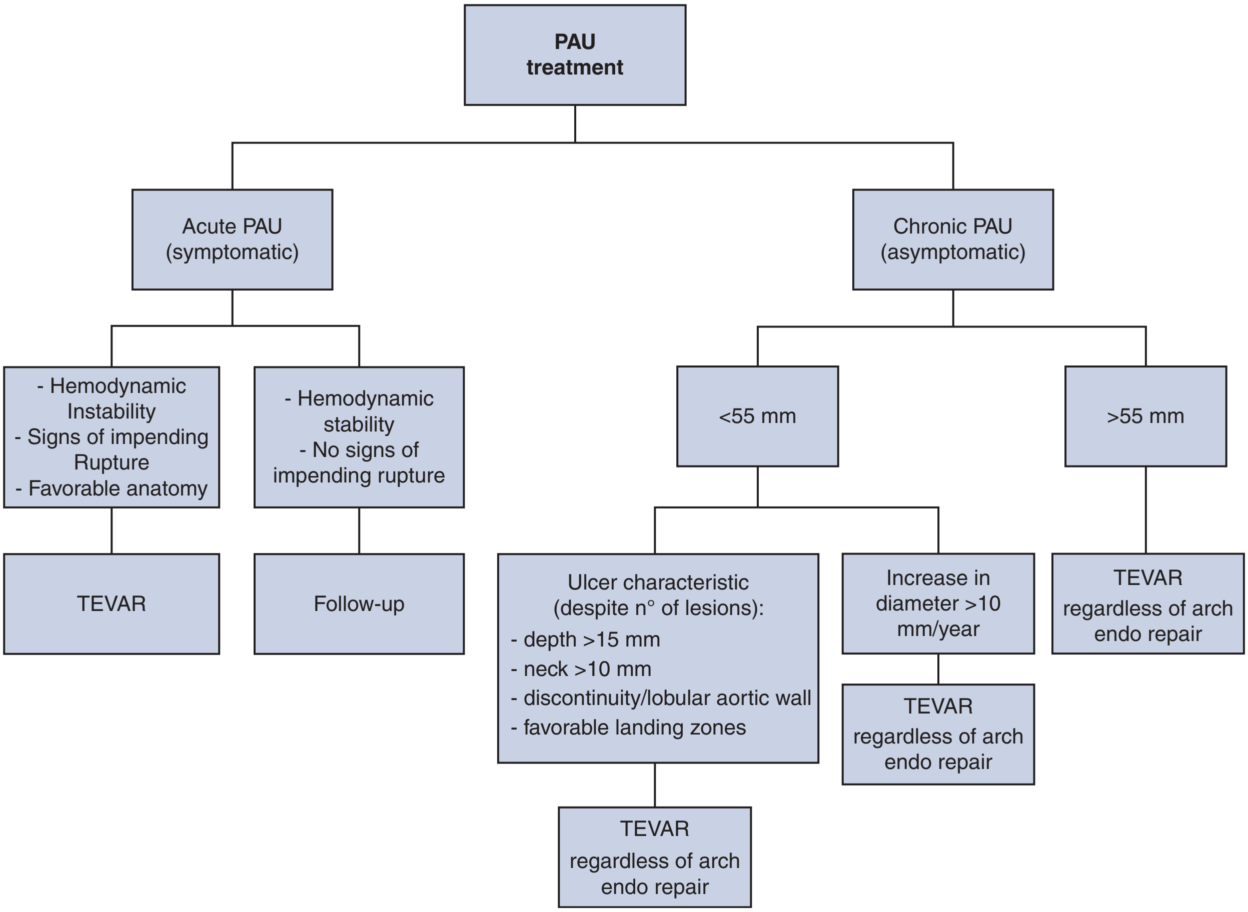


FIGURE 4. An algorithm showing the decision-making process for acute and chronic penetrating atherosclerotic ulcers (*PAUs*). *TEVAR*, Thoracic endovascular aortic repair.

endovascular treatment this population has a similar life expectancy to that of the elderly population. Indeed, Cox regression analysis for patient characteristics, operative data, and postoperative complications showed that only the age older than 75 years was associated with mortality, whereas the acute presentation was related to it. This seems to be related to the localized nature of this particular aortic disease, because for which endovascular therapy is durable and the incidence of reintervention is lower than it is in cases of more extensive aortic pathologies such as residual aortic dissection and degenerative aneurysm. A future study focused on late aortic growth including a larger population is necessary to strengthen this hypothesis.

There are important limitations to be considered when interpreting the results of this study. First, it is a single-center experience with a retrospective nature. Second, the sample size of PAUs was relatively small, even if patients were selected from a large TEVAR population over approximately 20 years' experience and other single-center experiences on the same topic reported similar or smaller number of patients. Moreover, diagnosis and subsequent clinical and radiologic follow-up was meticulous and complete. However, according to the limited number of patients and the rarity of the events we acknowledge large confidence intervals and perhaps model overfitting.

In summary, as reported in Figure 5, the results of endovascular repair of PAUs are limited and derived from a small series; natural history of chronic lesions is still controversial and despite presentation they are often malignant lesions requiring treatment. What we learn from this study is that treatment of elective patients can be achieved with excellent results despite location (including the arch) and distribution of ulcers, although attention is necessary to select acute symptomatic patients for treatment.

CONCLUSIONS

The use of TEVAR for the treatment of PAU is a safe procedure if performed in an elective setting whereas a higher early and late mortality has to be expected in acute cases with signs of IMH or impending rupture. A proximal endograft deployment in the distal arch (zone 2 vs descending thoracic aorta) were unrelated to outcomes. However, an

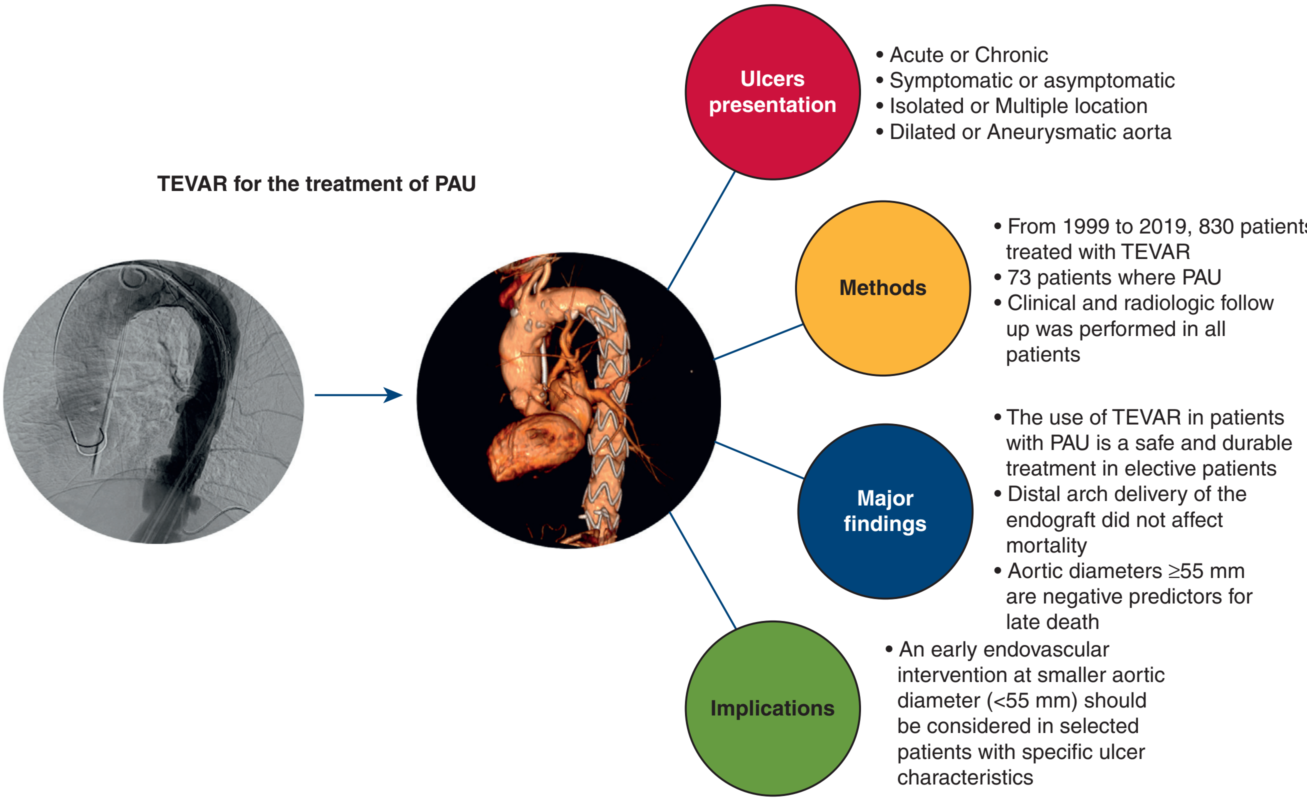


FIGURE 5. A visual summary of the main findings of our study. In a total of 73 patients treated with endograft for penetrating atherosclerotic ulcers (*PAUs*) results showed better outcomes in elective patients despite location of the ulcer, extensions of endograft coverage, but not according to maximum aortic diameters. *TEVAR*, Thoracic endovascular aortic repair.

early intervention at smaller aortic diameter (<55 mm) seems to be associated with better late survival in selected patients with specific ulcer characteristics.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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