Evaluation of Morphological and Clinical Factors Related to Failure of Percutaneous Treatment with Thrombin Injection of Femoral Pseudoaneurysms from Cardiac Catheterization

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Background: Ultrasound-guided thrombin injection (UGTI) has become the method of choice in the treatment of pseudoaneurysm caused by endovascular procedures because it is minimally invasive, costs less, and effective, with short hospitalization time. The objective was identify the morphological aspects of femoral pseudoaneurysms and clinical aspects of patients that may lead to the failure of UGTI in femoral pseudoaneurysms after cardiac catheterization.

Population and Method: From December 2012 to December 2016, 60 patients with pseudoaneurysms caused by cardiac catheterization were referred to the interventional radiology unit to be treated with UGTI. Medical charts were retrospectively reviewed for comorbidities, use of antiplatelet agents, anticoagulation, indication of cardiac catheterization, and so forth. Morphological aspects of the pseudoaneurysms such as volume, diameter (anteroposterior, laterolateral, and longitudinal), length, and diameter of the neck were analyzed.

Results: Technical success of UGTI was achieved in 100%. No clinical aspects of the patients were statistically significant for UGTI failure in occlusion of the pseudoaneurysms. For morphological aspects of pseudoaneurysm: anteroposterior ($P = 0.029$), longitudinal ($P = 0.020$), and neck diameters ($P = 0.004$) were statistically significant for UGTI failure. Logistic regression analysis for longitudinal diameter showed that for each centimeter, there was a 2.66 chance of failure of pseudoaneurysm thrombosis in a single thrombin injection session (95% confidence interval: 1.33−5.30). For longitudinal and neck diameters greater than 1.8 cm and 0.55 cm, respectively, there is a greater probability of needing more than one UGTI session for complete thrombosis.

Conclusions: Among variables, the longitudinal dimension was more significant, and in a larger diameter, the treatment with thrombin injection presented greater complexity.

Conflict of Interest: The authors state that they have no conflict of interest related to this article and that there was no sponsor related to it.

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INTRODUCTION

Since 1997, ultrasound-guided thrombin injection (UGTI) has been reported as an alternative approach for the treatment of iatrogenic pseudoaneurysms (PSAs).[1] The UGTI has emerged as an alternative to ultrasound (US)-guided compression repair with success rates of 91% to 100%. Complication rate of approximately 2% has been reported.[2,3] The UGTI has become the first-line treatment for PSAs, and it is increasingly popular for the treatment of iatrogenic PSAs in many institutions.

Femoral artery pseudoaneurysms (PSAs) are among the most frequent complications of angiography. Iatrogenic femoral PSAs occur in 0.2−0.5% of diagnostic angiography procedures and in up to 8% of percutaneous coronary interventions.[4−6] Many risk factors for the development of PSAs such as sheath size, increasing age, body mass index, improper technique (such as unsatisfactory manual compression or maldeployment of a closure device), female gender, chronic renal failure, puncture site access below the femoral bifurcation, hypertension, calcified arteries, fibrinolytic therapy, postinterventional anticoagulant, and antiplatelet therapies have been reported previously.[7−9] Complications of PSAs include local pain, rupture, distal embolizations, compression of adjacent neurovascular structures (neuropathy), and local skin ischemia. It may also result in local sepsis and abscess formation which may rupture and cause subsequent hemorrhage.[10]

In the literature, it is possible to find some studies describing the percutaneous treatment with thrombin injection in PSA after cardiac catheterization. However, we did not identify studies that analyzed the diameters of the PSAs individually, anteroposterior, laterolateral, and longitudinal; diameters and neck extension; and clinical aspects and related them with success or failure in the treatment with thrombin injection.

The aim of the study was to identify the morphological aspects of PSAs and clinical aspects of patients that may lead to the failure of UGTI in PSAs after cardiac catheterization. The present study and its protocols were approved by the ethics committee with the protocol number 86608218.5.0000.0068 Certificate of Presentation for Ethical Consideration.

MATERIALS AND METHODS

Database

A retrospective study was performed to investigate the clinical results of UGTI for the treatment of post-cardiac catheterization pseudoaneurysms (PCCPs) of the femoral and radial artery. Between December 2012 and December 2016, 65,382 cardiovascular percutaneous interventions were performed, of which 50,560 (77.33%) diagnostic angiography procedures and 14,822 (22.66%) percutaneous endovascular therapy procedures were performed for cardiovascular disease.

The study included all consecutive adult patients with PCCP, a total of 60 patients, who were sent for treatment with thrombin injection, corresponding to 0,00,091% of the overall cases. The patients had given written consent to receive UGTI.

Exclusion criteria were active bleeding, expanding pulsatile masses, hemodynamic instability, local infection, skin necrosis, distal limb ischemia, or neurological deficits. No patient refused consent for the UGTI. No patient was excluded for the criteria mentioned previously.

The following parameters were documented retrospectively before the UGTI:

1) Demographic and clinical data of patients: age, sex, diabetes, systemic arterial hypertension, dyslipidemia, obesity, peripheral arterial disease, smoking, previous acute myocardial infarction, previous cardiac catheterization, previous heart surgery, cardiac insufficiency, renal function (clearance), hematimetry.

2) Data related to cardiac catheterization: indication of procedure (diagnostic versus therapeutic), location of the puncture site, caliber of the introducer used, use of anticoagulation and platelet antiaggregation, length of hospital stay after catheterization.

3) Data related to the PSA treatment: volume of thrombin used (in milliliter); time elapsed between cardiac catheterization and diagnosis of PSA (in days); time interval between the diagnosis of PSA and thrombin injection (in days); PSA volume (cm^3); architectural classification of PSA (simple versus complex); measured diameters: longitudinal, laterolateral, and anteroposterior PSA (in cm); length and width of the neck (in cm).

Endpoints

The primary endpoint was the initial success rate to occlude the PSA, and the secondary endpoints were the recurrence rate, surgical conversion rate, and complications.

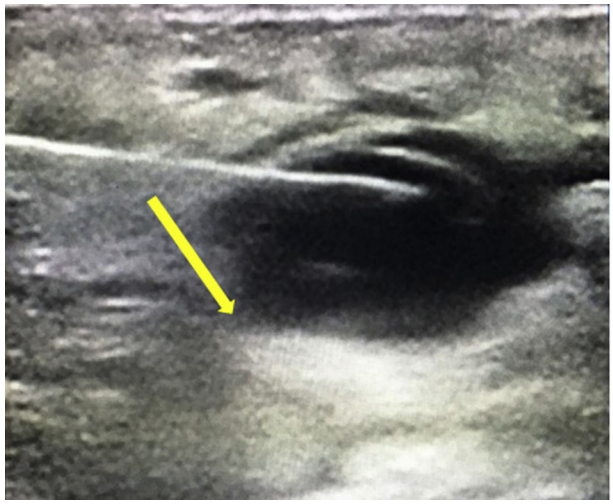

Fig. 1. Needle puncture, 22 Gauge, at the periphery of the pseudoaneurysm under US orientation, as far from the colon as possible. Pseudoaneurysm neck (yellow *arrow*).

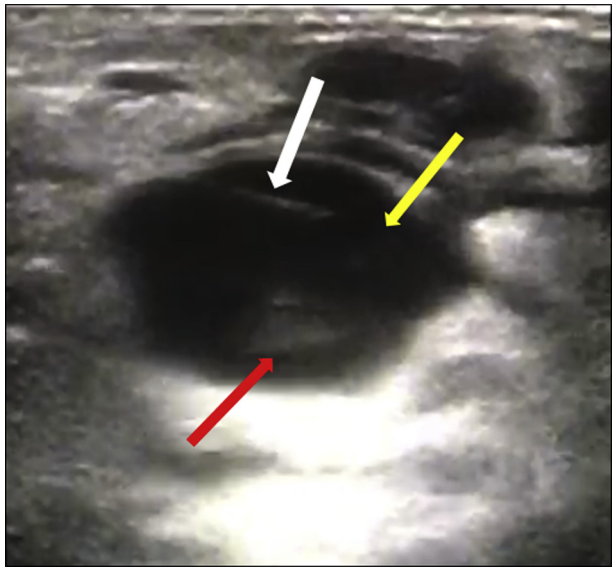

Fig. 2. Injection of thrombin inside pseudoaneurysm with 22-Gauge needle. Needle 22-Gauge (white *arrow*), pseudoaneurysm (yellow *arrow*), and injection of thrombin with clot formation inside the pseudoaneurysm (red *arrow*).

Diagnosis Confirmation

The US device used to guide the percutaneous treatment with thrombin injection in PSAs was Toshiba Aplio XG (Tokyo, Japan) with linear 4–8 MHz or 3–6 MHz convex transducers. Furthermore, US was used to confirm the PSA in interventional radiology room. The PSA and associated defect in the underlying native artery were assessed in both transverse and longitudinal planes. Measurements of the false cavity were calculated in three dimensions, in addition to the length and size of the neck. Besides, blood flow was confirmed on peripheral arterial pulsation or by using a Doppler flowmeter if pulsation was not palpable.

UGTI Protocol

The groin and fist were prepared and draped in the usual sterile fashion. Local anesthesia was administered (Lidocaine Hydrochloride Induction 2%; Mercury Pharma International Ltd., Dublin, Ireland). Lyophilized thrombin (500 UI/ml) was reconstituted in calcium chloride solution (2 ml) (Tissucol; Baxter, Deerfield, IL) to produce the thrombin solution component. Before application, the syringe was attached to a 22-G needle that was advanced into the PSA under US guidance parallel to the transducer. Puncture of the PSA neck was avoided (Fig. 1). The needle tip was placed in the midpoint of the PSA lobe, and thrombin was injected slowly at doses of 0.1–0.2 ml under color-coded US guidance at a low-pulse repetition frequency (Fig. 2). The flow in the sac was checked on color Doppler US, and if there was persistent flow in the sac, an additional dose of thrombin was injected. The thrombin injection was terminated when there was no flow to the color mode, final US imagings were performed to confirm obliteration of flow within the PSA and patent native artery, and the peripheral blood flow was confirmed on pulsation or by using a Doppler flowmeter (Fig. 3). The thrombin dose was recorded.

Patients with femoral PSA were kept on bed rest for 24 h. The initial success of PSA repair was defined as complete obliteration of the PSA, as seen at follow-up performed 24 h after the initial UGTI, and recurrence of PSA was defined as reperfusion of the PSA sac after the initial success. If there was still evidence of blood flow in the PSA sac, additional thrombin was injected, as described.

Adverse Events and Complications

The following complications associated with UGTI were assessed: thromboembolic complications, defined as direct visualization of a thrombus within the lumen of the feeding femoral or radial artery; disappearance of pulsation in the anterior or posterior tibial artery in femoral PSA or the disappearance of the radial PSA; infection or an allergic reaction. Color Doppler US was performed one day after successful repair of the PSA, and the extent of thrombosis in the PSA sac and the patency of the feeding

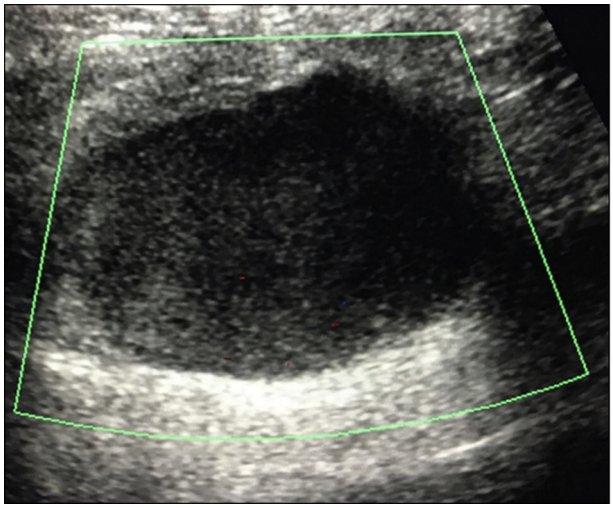

Fig. 3. Ultrasonographic control in Doppler mode, performed soon after an injection of thrombin, to ensure the persistence of pseudoaneurysm thrombosis, as well as a patency of the artery that originated it. Hyperechoic image within the pseudoaneurysm corresponding to the group formed by thrombin injection (red *arrows*).

artery were examined again. During the follow-up period, we also documented any symptoms reported by the patients, including local pain, signs of inflammation, and new occurrence or aggravation of claudication symptoms.

Statistical Analysis

A statistical analysis was performed using a computer software program (Statistical Package for Social Sciences version 18.0; SPSS Inc., Chicago, Illinois, USA). Categorical variables were presented descriptively with absolute (*n*) and relative (%) frequencies. The association with failure was assessed using the chi-square test, Fisher's exact test, or likelihood ratio test. The Shapiro-Wilk test was used to evaluate the normality of the quantitative variables. The comparison with respect to failure was made with the Student's t-test or nonparametric Mann-Whitney test. They were described as mean and standard deviation or median and interquartile range. The variables that presented statistical significance in the univariate analysis were used in the multiple logistic regression model with stepwise procedure of variable selection. The receiver operating charateristic curve was used to verify the cut-off value of the dimension and colon variables. The tests were two-tailed, and the values of $P < 0.05$ were considered statistically significant.

RESULT

Between December 2012 and December 2016, of 60 patients diagnosed with PSA and referred to the interventional radiology unit, 40 cases were identified (66.66%) in the right common femoral artery, six (10%) in the right superficial femoral artery, seven (11.66%) in the left common femoral artery, four (6.66%) in the left superficial femoral artery, and three (5%) in the right radial artery after cardiac catheterization and treated with US-guided thrombin injection. Of these cases, 19 (31.77%) were diagnostic angiography cases and 41 (68.3%) were percutaneous endovascular therapy cases.

Table I summarizes the demographics analysis and cardiovascular risk factors, which were typical for patients with PSA. There were no statistically significant differences between the risk factors and demographics, but there were in preprocedural antiplatelet therapy. The median time of cardiac catheterization to the diagnosis of PSA was three days (1−5), and it can extend until the thrombin injection at 5.5 days (3−7.75). The median diameter of the PSAs in the laterolateral dimensions was 2.95 cm (2.1−4.4), in the anteroposterior dimension 1.95 cm (1.43−2.9), and in the longitudinal dimension 1.7 cm (1.3−2.2). The median diameter of the neck was 0.5 cm (0.3−0.8), and the extension was 1.1 cm (0.6−1.5), being multilocated in 8.3% of the patients. The median PSA volume was 9.29 cm^3 (4.83−25.38) and statistically significant ($P = 0.034$). The therapy used is already established in the literature. The median volume of thrombin injected into the PSA was 1.5 ml, although the rates of thrombin injection are not well established (1−2) (Table II).

Regarding the dimensions of the PSA, two of the three dimensions evaluated, anteroposterior and longitudinal diameters, were statistically significant for the failure of the percutaneous treatment with thrombin injection. Among these two variables, the longitudinal dimension was more significant, and in a larger diameter 1.8 cm, the treatment with thrombin injection presented greater complexity, with sensitivity and specificity of 75% and 58%, respectively, and area under the curve of 0.71 (confidence interval [CI]: 0.53−0.9) (Fig. 4). When the diameter of 1.8 cm was analyzed punctually, the probability of a failure of 15% with only one thrombin injection session was observed (Fig. 5). Thus, the larger the longitudinal diameter, starting at 1.8 cm, the worse the treatment result, often requiring multiple sessions for total PSA thrombosis.

Table I. Demographic, clinical, and laboratory data

	Primary success			
	No	Yes	Total	
Variable	12 (20%)	48 (80%)	60	*P*
Sex[a]				0.735
Female	3 (15.8%)	16 (84.2%)	19 (31.7%)	
Male	9 (22.0%)	32 (78.0%)	41 (68.3%)	
Caliber of the introducer[b]				0.697
6F	6 (18.2%)	27 (81.8%)	33 (55.0%)	
7F	6 (22.2%)	21 (77.8%)	27 (45.0%)	
Laterality[a]				0.677
Right	9 (18.4%)	40 (81.6%)	49 (81.2%)	
Left	3 (27.3%)	8 (72.7%)	11 (18.3%)	
Body mass index (kg/m^2; mean/SD)[c]	28 ± 4	28 ± 4	28 ± 4	0.810
Obesity[d]				0.965
Normal	3 (18.8%)	13 (81.2%)	16 (26.7%)	
Overweight	4 (19.0%)	17 (81.0%)	21 (35%)	
Obesity	5 (21.7%)	18 (78.3%)	23 (38.3%)	
Smoking[b]				0.050
No	8 (32.0%)	17 (68.0%)	25 (41.7%)	
Yes	4 (11.4%)	31 (88.6%)	35 (58.3%)	
Diabetes[b]				0.121
No	4 (12.5%)	28 (87.5%)	32 (53.3%)	
Yes	8 (28.6%)	20 (71.4%)	28 (46.7%)	
Systemic arterial hypertension[a]				0.670
No	1 (10.0%)	9 (90.0%)	10 (16.7%)	
Yes	11 (22.0%)	39 (78.0%)	50 (83.3%)	
Dyslipidemia[a]				0.713
No	2 (14.3%)	12 (85.7%)	14 (23.3%)	
Yes	10 (21.7%)	36 (78.3%)	46 (76.7%)	
Previous acute myocardial infarction[a]				1.000
No	9 (21.4%)	33 (78.6%)	42 (70%)	
Yes	3 (16.7%)	15 (83.3%)	18 (30%)	
Cardiac insufficiency[a]				0.153
No	11 (25.0%)	33 (75.0%)	44 (73.3%)	
Yes	1 (6.3%)	15 (93.8%)	16 (26.7%)	
Previous cadiac catheterization[b]				0.513
No	6 (17.1%)	29 (82.9%)	35 (58.3%)	
Yes	6 (24%)	19 (76%)	25 (41.7%)	
Previous heart surgery[a]				1.000
No	10 (21.3%)	37 (78.7%)	47 (78.3%)	
Yes	2 (15.4%)	11 (84.6%)	13 (21.7%)	
Peripheral arterial disease[a]				1.000
No	8 (21.1%)	30 (78.9%)	38 (63.3%)	
Yes	4 (18.2%)	18 (81.8%)	22 (36.7%)	
Indication of procedure[a]				0.306
Diagnostic	2 (10.5%)	17 (89.5%)	19 (31.7%)	
Therapeutic	10 (24.4%)	31 (75.6%)	41 (68.3%)	
Anticoagulation[b]				0.896
No	7 (20.6%)	27 (79.4%)	34 (56.7%)	
Yes	5 (19.2%)	21 (80.8%)	26 (43.3%)	
Acetylsalicylic acid[a]				0.099
No	0 (0%)	11 (100%)	11 (18.3%)	
Yes	12 (24.5%)	37 (75.5%)	49 (81.7%)	
Clopidogrel[b]				0.071
No	3 (10.3%)	26 (89.7%)	29 (48.3%)	

(*Continued*)

Table I. Continued

	Primary success			
	No	Yes	Total	
Variable	12 (20%)	48 (80%)	60	*P*
Yes	9 (29.0%)	22 (71.0%)	31 (51.7%)	
Morphology[a]				1.000
Single	11 (20.0%)	44 (80.0%)	5 (8.3%)	
Multilobed	1 (20.0%)	4 (80.0%)	55 (91.7%)	
Death[a]				1.000
No	12 (20.7%)	46 (79.3%)	58 (96.7%)	
Yes	0 (0%)	2 (100%)	2 (3.3%)	
Age (years; mean/SD)[c]	62 ± 10	65 ± 15	64 ± 14	0.490
Ejection fraction (%; median/IQR)[e]	60 (55–69)	6 (50–64)	6 (51–65)	0.349
Hb (mg/dl; median/IQR)[e]	10.3 (9.75–12.6)	11.6 (9.83–13.18)	11.55 (9.83–13.1)	0.500
Ht (mg/dl; median/IQR)[e]	31.1 (29.83–37.8)	34.3 (28.05–38.15)	34 (29.1–38)	0.890
Clearance (ml/min; median/IQR)[e]	87 (75.5–100.25)	82 (69.5–94.75)	85.5 (71–95.75)	0.385
Hospitalization time (days; median/IQR)[e]	8.5 (5.5–13.5)	10 (6–22)	9 (6–21.75)	0.464

IQR, interquartile range; SD, standard deviation; Hb, hemoglobin; Ht, hematocrit; mg/dl, milligram per deciliter; ml/min, milliliter per minute.
[a]Fisher's exact test.
[b]Chi-squared test.
[c]Student's t-test.
[d]Likelihood ratio test.
[e]Mann-Whitney test.

In the multiple logistic regression analysis for the longitudinal diameter, it was observed that for each centimeter, there is a 2.66-fold chance of PSA thrombosis failure in a single thrombin injection session (primary success) (95% CI: 1.33–5.30) (Table III). Thus, if the PSA volume is greater than 22 cm^3, there will also be a greater chance of treatment failure in a single session.

Regarding the neck of the PSA, it was observed that, between the variables length and diameter, only diameter showed statistical significance for the failure of the treatment with thrombin injection. That is, PSAs having neck diameters greater than 0.55 cm require more than one thrombin injection session to close. Primary failure demonstrated sensitivity and specificity of 75% and 68%, respectively, with area under the curve of 0.76 (CI 0.64–0.88) (Fig. 6).

The primary success rate of percutaneous US-guided thrombin injection in the treatment of PSAs was 80% (48 patients) of all patients. In 12 of the 60 patients with a remaining PSA, additional UGTI was successful. The total success rate was 100%. There were no complications, such as thromboembolic, allergic, or infectious events related to UGTI. There were two deaths in the studied population, due to cardiogenic shock and osteomyelitis, after myocardial revascularization, without a correlation with the thrombin injection procedure. In the successfully treated patients, there were no recurrences after an average follow-up of 24 hours.

DISCUSSION

Most PSAs occur in the inguinal region because cardiac catheterization arteries involve the common femoral artery in most cases. The common femoral artery is chosen because of ease of access, adequate caliber for puncture, superficial topography, comfort for the interventionist to work, and ease of compression after the procedure. However, PSAs can occur at any site used as arterial access.

The overall success rate of thrombin injection for PSA treatment in the present study was 100% (60 of 60 patients). The primary therapeutic success, using a single injection, rate was 80% (48 of 60 patients) for all PSAs.

Most patients who undergo cardiac catheterization have numerous comorbidities and risk factors for cardiovascular disease. Among the risk factors for cardiovascular disease and comorbidities as well as clinical and laboratorial aspects of the patients evaluated in the present study, there was no statistical significance for failure to treat PSA with thrombin injection. Although these risk factors are related to the formation of PSAs. Regarding the data related to the catheterism, only the use of antiplatelet agents, clopidogrel and acetylsalicylic acid, showed a tendency to be significant, respectively, 0.071 and 0.099.

Indications for the surgical repair of PSAs include the following factors: rapid expansion, especially in

Table II. Morphological data of pseudoaneurysms and primary success

	Primary success			
	No	Yes	Total	
Variable	12 (20%)	48 (80%)	60	*P*
Embolizing agent—thrombin (ml; median/IQR)[a]	1.5 (1.13–2)	1.5 (1–2)	1.5 (1–2)	0.402
Time interval 1 (days; median/IQR)[b,a]	5 (3.25–13)	6 (3–7)	5.5 (3–7.75)	0.656
Time interval 2 (days; median/IQR)[c,a]	2.5 (1–8.75)	3 (1.25–5)	3 (1–5)	0.940
Diameter laterolateral (cm; median/IQR)[a]	3.90 (2.23–4.40)	2.85 (2.03–4.25)	2.95 (2.1–4.4)	0.346
Diameter anteroposterior (cm; median/IQR)[a]	2.75 (2.10–3.63)	1.80 (1.40–2.48)	1.95 (1.43–2.9)	0.029
Diameter longitudinal (cm; median/IQR)[a]	2.50 (1.60–3.95)	1.50 (1.20–2.10)	1.7 (1.3–2.2)	0.020
Volume (cm^3; median/IQR)[a]	22.81 (8.99–56.87)	8.13 (4.13–19.95)	9.29 (4.83–25.38)	0.034
Length of the neck (cm; median/IQR)[a]	1.5 (0.85–1.8)	1.05 (0.53–1.3)	1.1 (0.6–1.5)	0.127
Width (cm; median/IQR)[a]	0.75 (0.53–0.8)	0.4 (0.3–0.6)	0.5 (0.3–0.8)	0.004

IQR, interquartile range; cm, centimeters; ml, milliliter; cm^3, cubic centimeter.
[a]Mann-Whitney test.
[b]Time interval between the diagnosis of pseudoaneurysm and thrombin injection (in days).
[c]Time elapsed between cardiac catheterization and diagnosis of pseudoaneurysm (in days).

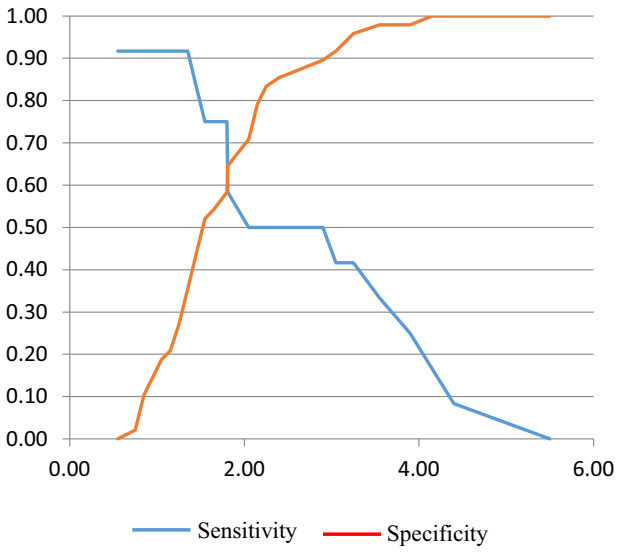

Fig. 4. Receiver operating characteristic curve of sensitivity and specificity of the longitudinal dimension.

an unstable patient, distal ischemia due to femoral artery compression, infection of the PSA, neuropathy, overlying soft tissue or skin ischemia, impending compartment syndrome, and the failure of percutaneous treatment.[10–13]

Some authors argue that the first option in small PSAs in patients who are not anticoagulated is to wait and follow the PSAs for spontaneous thrombosis while limiting the patient's activity. Toursarkissian et al. reported that small PSAs less than 3 cm in diameter (approximate volume of 14 cm^3) spontaneously thrombosed at an average of 23 days in 87% of patients.[3,13] The mean size of the PSAs in the present study was smaller than that in the previous reports of a laterolateral, anteroposterior, and longitudinal size of the PSA, respectively, 2.95 cm, 1.95 cm, and 1.7 cm. However, the volume was smaller than that in one previous report.

In small PSAs that have not thrombosed spontaneously, compression may be a treatment option.[14] Compression is relatively safe and effective, but its limitations include an often lengthy and painful procedure, and a success rate of approximately 63% to 88%, which is lower in patients under anticoagulation.[12,15–18] Among large PSAs, those lasting more than two weeks, sheath size, multilobulated PSAs, body mass index, and anticoagulants may show a lower thrombosis success

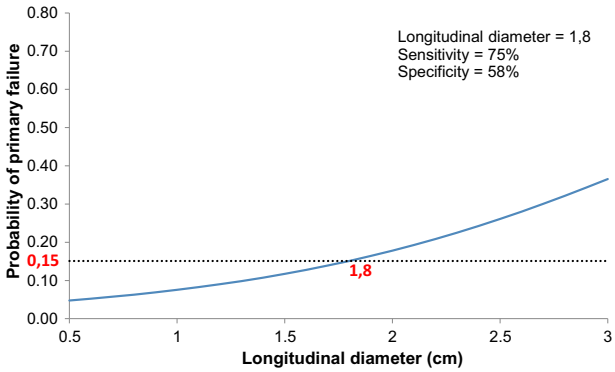

Fig. 5. Probability of primary failure related to longitudinal diameter.

Table III. Multiple logistic regression for primary failure-related longitudinal diameter (cm)

Variable	Estimated parameter	Standard error	OR (95% CI)	P
Diameter longitudinal (cm)	0.98	0.35	2.66 (1.33–5.30)	0.006
Constant	−3.48	0.89		

OR, odds ratio; CI, confidence interval.

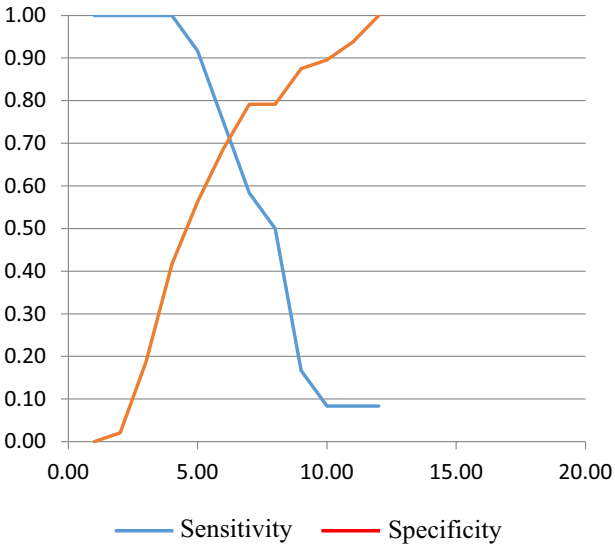

Fig. 6. Receiver operating characteristic curve of sensitivity and specificity of the neck diameter.

rate.[19] Finally, some PSAs are not amenable to compression, including PSAs in which arrest of the flow in the PSA neck is impossible, PSAs associated with exquisite groin tenderness, and PSAs that arise above the inguinal ligament.[20,21]

Our interventional radiology service adopted the protocol for small aneurysms, that is, less than 2 or 3 cm, the conservative treatment, with a weekly evaluation close to the patient, as there is the possibility of spontaneous thrombosis. If spontaneous thrombosis or aneurysms greater than 3 cm or PSAs leading to local pain do not occur within one or two weeks, then percutaneous treatment with thrombin injection is indicated.

US-guided injection of thrombin is an alternative to US-guided compression repair. Anticoagulation does not interfere with the result, and thrombin injection is safe and reliable because the final path of blood coagulation is the generation of thrombin.[22] Unlike compression repair, anticoagulation does not affect the success of thrombin injection. The thrombin injection procedures are extremely quick compared with compression repair. According to the literature survey, success rates range from 92 to 100%.[5,23–27] Mohler et al. reported that a second, third, or fourth injection is required during the initial treatment session in 15%, 5%, and 1% of patients, respectively.[23] Reported thrombosis rates after a single injection were 63% to 79%. In the present study, the primary success rate (single injections) was 80% (48 of 60 PSAs). Although the primary success rate was 80%, the secondary success rate (100%) was similar to that in previous reports. On the basis of the results of the current and previous studies, we are convinced that thrombin injections should be the treatment of choice for PSAs.

The originality of this study is due to the individual analysis of each diameter of the PSA, the diameter and extension of the neck, and, beyond that, clinical factors involved in failure of percutaneous treatment with thrombin injection of PSAs from cardiac catheterization. We did not identify studies that analyzed the rates of thrombin injection failure in PSAs after cardiac catheterization taking into consideration clinical and morphological aspects. Thus, it was identified that the anteroposterior and longitudinal diameters showed statistical significance for failure with only a thrombin injection session, respectively, 0.029 and 0.020. Similarly, the diameter of the neck, 0.004, also showed significance for failure with the same technique. Although several studies report that there is a high chance of spontaneous thrombosis for diameters smaller than 3 cm, we observed that they did not take into consideration which diameter should be considered. However, the diameters in the present study were smaller than those in one previous report.

Thromboembolic complications with thrombin injection for PSA are rare (0–4%) but have serious

side effects.[2,5,24,28,29] Thromboembolic complication could occur when an inadvertent injection of thrombin into the artery or an injection too close to the PSA neck is performed. To avoid this complication, the tip of the needle must be well visualized and appropriately located within the PSA lumen, far away from the neck as possible. Poor visualization of the needle should be considered a relative contraindication to the procedure. A wide PSA neck is listed as a contraindication to thrombin injection because it predisposes patients to thromboembolic complications.[30]

For this reason, the distal pulses must be checked before the procedure and periodically rechecked after the procedure. No complications were experienced in the present study. Anaphylactic reactions are due to aprotinin. We did not use aprotinin in our technique, only thrombin and calcium. Therefore, we had no case of allergic reaction. These results demonstrate the safety of this procedure. The other reported complications include allergic and anaphylactic reactions due to the use of the bovine thrombin, deep venous thrombosis due to compression, development of abscess at the site of the PSA, requiring surgical drainage, skin cellulitis on the puncture site, rupture of the PSA, pulmonary embolism when there is an association of the PSA with an arteriovenous fistula, and groin pain after thrombin injections in some patients.[5,23,31,32]

Different methods for the closure of a postcatheterization PSA have been described, such as use of mechanical closure devices,[33] injection of saline guided by US and compression (has a high failure rate),[34] and occlusion of the PSA neck by balloon placement into the feeding artery during a fibrin adhesive injection—this method is substantially more invasive, costly, and time-consuming and has only been performed in isolated cases.[35]

The technological evolution of vascular access devices will favor the change of location from femoral to radial. In view of this, the European Society of Cardiology already advocates radial access as the first option because there is evidence of reduction of complications, such as bleeding and morbidity and mortality, despite increasing the dose of radiation for the patient and the physician.[36]

The natural history of PSA in the radial artery is unknown, and management principles are from experience with femoral artery lesions despite the anatomic differences from the upper extremity. Rupture of a femoral artery false aneurysm may have life- and limb-threatening consequences such as shock, infection, abscess, and ischemia. It is unclear whether the same risks are present for the radial artery.

Radial artery PSA neck diameters ranged from 0.1 to 0.3 cm and had at least one known risk factor for PSA, including placement of large-bore catheters, need for urgent or treatment interventional procedures, and anticoagulation. Although our study has only 3 cases of PSA in the radial artery, we can demonstrate that it is possible to have complications in this access as well as that the percutaneous treatment with thrombin injection is feasible and safe.

The ultrasound window in the inguinal region may be more complex, especially in obese patients. On the other hand, in the wrist, this difficulty is lower because the radial artery is more superficial, and consequently the percutaneous technique of thrombin injection becomes easier. Therefore, increasing the number of procedures using radial access is a worldwide reality, and we alert that the complication can happen and that the treatment has satisfactory results.

Our team argues that the surgical indication would be indicated in situations such as pain, size, the presence of ischemia, infection, nerve compression, compartment syndrome, or shock. On the other hand, surgery can trigger nerve damage, paresthesia in the hand, abscess, and tendon injury. In this way, it is now possible for the operator to choose the form of PSA treatment.

The literature is scarce comparing manual compression and use of hemostatic devices. There are meta-analyses that demonstrated no statistically significant difference, but there were marginally fewer complications with pooled arterial closure devices than with manual compression (odds ratio, 0.87; 95% CI: 0.52−1.48, $P = 0.13$).[37] Besides, there is a recent study with a sex-specific analysis of 1395 women enrolled in a large-scale, randomized, multicenter trial, in which patients undergoing transfemoral diagnostic coronary angiography were randomly assigned in a 1:1:1 ratio to arteriotomy closure with an intravascular vascular closure devices, extravascular vascular closure devices, or manual compression. The primary objective was to assess the safety and efficacy of 2 different vascular closure devices compared with manual compression regarding vascular access-site complications at 30 days. In women undergoing diagnostic coronary angiography via the common femoral artery, vascular closure devices and manual compression provided comparable safety while time to hemostasis and hematomas was reduced with vascular closure devices.[38,39]

Our study has several limitations. It is a retrospective study with its inherent limitations such as absence of a control group and no comparison with other therapeutic methods.

This is a pioneering study in demonstrating the success or failure of thrombin injection in the treatment of PSAs after cardiac catheterization when analyzing clinical and morphological aspects. However, its observational nature, the absence of a control group for comparison purposes, as well as the small number of patients do not allow us to make definitive and comprehensive conclusions on the subject, with a greater number of patients being necessary for randomized trials.

CONCLUSIONS

Ultrasound-guided percutaneous injection of thrombin is successful and safe in the management of femoral and radial PSAs after cardiac catheterization. Morphological aspects of PSA such as anteroposterior, longitudinal, and neck diameters are involved in UGTI failure in one single session. Among these variables, the longitudinal dimension was more significant, and in a larger diameter, such as 1.8 cm, the treatment with thrombin injection presented greater complexity.

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