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NATURAL HISTORY AND PROBABILITY OF SPONTANEOUS CLOSURE OF ARTERIOVENOUS FISTULAS AFTER RADIOFREQUENCY CATHETER ABLATION OF ATRIAL FIBRILLATION

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Aim. To evaluate the clinical outcomes of persistent arteriovenous fistulas (AVF) after catheter ablation (CA) of atrial fibrillation (AF), to determine potential predictors and the likelihood of self-resolution while taking anticoagulants.

Methods. Thirty-six patients with AVF after CA AF (14 men, age 59.9±8.4 years) were included. Pulmonary veins were isolated for everyone. Femoral vein catheterization was performed according to anatomical guidelines. Hemostasis was performed with a "figure of eight" type suture, a pouch suture or a compression bandage. With symptoms suggesting the presence of vascular access complications (VAC), ultrasound duplex scanning (UDS) was performed the next day after the CT. When AVF was detected, compression bandages were treated. While maintaining AVF, outpatient follow-up continued, including UDS, echocardiography, and questionnaires. Surgical treatment was performed with a combination of AVF with other VAC, with paired AVF, and with refusal of observation.

Results. The incidence of AVF was 1.19%. Compression therapy was effective in 8 (22.2%) patients, surgical treatment was performed in 7 (19.4%). In no case was AVF symptomatic, and there were no indications for immediate surgical treatment. Outpatient follow-up was continued 14. The duration of follow-up was 24 [12; 28] months. In 8 patients, AVF resolved on its own, in 1 previously closed AVF relapsed. Minor local symptoms were noted in 4 out of 7 patients with persistent AVF. In 15 (41.7%) of 36 patients, AVF resolved independently or with the help of compression therapy. The only independent predictor of self-closure of AVF in a single-factor logistic regression analysis was the age of patients (odds ratio (OR) 0.807; confidence interval (CI) 95% 0.651-1,000; p=0.050). Using ROC analysis, it was shown that the age over 65.5 years reduced the chance of self-closure of AVF by 93.7% (OR 0.067; CI 95% 0.007-0.614; p=0.017).

Conclusion. The frequency of spontaneous closure of AVF after AF was 57.1%. The only independent predictor of AVF persistence was the patient's age over 65.5 years. None of the patients with persistent AVF developed symptoms of heart failure and vascular symptoms that required immediate surgical closure.

Keywords: atrial fibrillation; catheter ablation; complications of vascular access; arteriovenous fistula; spontaneous resolution; ultrasound duplex scanning; compression therapy

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Vascular access complications (VAC) are the most common complications of catheter ablation (CA) for atrial fibrillation (AF). The incidence of VAC requiring observation is 1-7%, and those requiring surgical treatment range from 0.1% to 0.3% [1]. In all AF CA procedures, femoral venous access is used to insert diagnostic and ablation electrodes, and sometimes femoral arterial access is also used for invasive monitoring of blood pressure, blood gas analysis, and aortic visualization during transseptal puncture [2]. One of the complications of femoral vascular access is arteriovenous fistula (AVF). The incidence of AVF varies depending on the study design and diagnostic method, ranging from 0.006% to 6.9% [3, 4]. The clinical presentation of iatrogenic AVF ranges from asymptomatic to the development of congestive heart failure, lower limb ischemia, and bleeding [5-7]. There is no unified approach to the management of AVF, with each healthcare institution often following its own treatment protocol. Options include simple observation, compression therapy, endovascular closure methods, and surgical treatment [8, 9]. Surgical treatment is traditionally considered the standard approach but is associated with complications such as bleeding, infection, femoral artery stenosis, cosmetic defects, and economic burden for the healthcare institution [3, 10]. However, several studies have demonstrated that AVF following heart catheterization may resolve spontaneously in the absence of anticoagulant and antithrombotic therapy [11, 12]. Various studies have analyzed predictors of AVF occurrence after cardiac interventions. However, the likelihood of spontaneous AVF closure during prolonged an-

ticoagulant therapy and the complications associated with the long-term persistence of AVF after CA for AF have not been previously studied. Aim of the study: to evaluate the clinical outcomes of persistent AVF after CA for AF, identify potential predictors, and assess the likelihood of spontaneous resolution while taking anticoagulants.

METHODS

From 2018 to 2023, the Federal Center for Cardiovascular Surgery of the Ministry of Health of Russia (Penza) performed 3037 radiofrequency CA procedures for paroxysmal and persistent AF. The procedure was conducted under intravenous sedation with dexmedetomidine and fentanyl. During the procedure, heparin was administered intravenously at doses that maintained the activated clotting time (ACT) above 300 seconds. All patients received therapy with warfarin or new oral anticoagulants without interruption for the surgical treatment. No femoral arterial access was used in any case. Access to the femoral veins was performed either from one side, predominantly the right, or from both sides. Femoral vein catheterization was performed 2-3 cm below the inguinal ligament using anatomical landmarks and palpating the pulse on the femoral artery (FA), with no ultrasound visualization used. Non-guided introducers with diameters of 7 and 8 Fr were used to introduce diagnostic and ablation electrodes. The number of venous introducers used on one side ranged from 1 to 3. To neutralize the anticoagulant effect of heparin before the removal of the introducers, protamine sulfate was administered intravenously. Hemostasis was achieved on the operating table with a "figure-eight" suture or a purse-string suture. If excessive bleeding occurred after the introducer removal or if a hematoma appeared or increased in size, or if there were doubts about the quality of hemostasis, manual compression followed by the application of a compression bandage at the site of puncture was performed.

Table 1.

Clinical-demographic and instrumental parameters of patients with AVF included in the study (n=36)

Indicator	Value
Age, years, M±SD	59.9±8.4
Male gender, n (%)	14 (38.9)
BMI, kg/m^2	32.1±3.8
Arterial hypertension, n (%)	31 (86.1)
Diabetes mellitus, n (%)	2 (5.6)
Smoking, n (%)	8 (22.2)
HAS-BLED, score	2 [1; 2]
History of femoral catheterizations, n (%)	15 (41.7)
Warfarin, n (%)	18 (50)
INR before surgery, units	1.5 [1.1; 2.4]
Platelet count, x10^9/L	236.3±51.9
Creatinine level, µmol/L	91.8±23.6
Right atrial volume index, mL/m^2	29.2±8.7
Right ventricular size, mm	26.8+3.4
Left ventricular ejection fraction (n, %)*	59.3±8.9
TR grade 2-4, n (%)	2 (5.6%)

Notes: HAS-BLED - a scale for assessing the risk of bleeding; INR - international normalized ratio; * - by Simpson's method; TR - tricuspid regurgitation.

The duration of bed rest after hemostasis with a suture was 6 hours, and after applying a compression bandage, it was until 7 a.m. the following day. All patients, even those with minimal complaints and/or clinical symptoms suggesting the presence of VAC (pain, hematoma, swelling in the groin, bruit on auscultation at the puncture site, tremor over the vessel projection area), as well as patients who had a compression bandage applied for hemostasis, underwent screening with UDS the day after the procedure. In cases of difficulties with ultrasound diagnostics (e.g., diffuse hematomas, soft tissue edema in the leg, obesity, or individual anatomical features), computed tomography angiography (CTA) was performed.

When AVF was detected, the artery and vein involved in its formation were identified, and the diameter and linear blood flow velocity in the AVF were determined if possible. According to the treatment protocol adopted in our center, treatment started with compression therapy. Manual compression was performed in the area of the AVF marked on the skin by the ultrasound specialist for 20-30 minutes. Afterward, regardless of the presence of bruit on auscultation, tight bandaging with an ordinary bandage was applied, and an elastic bandage was placed on top. The elastic bandage was left in place for 4-6 hours. Due to leg swelling, which impaired venous outflow, local skin ischemia, and associated hematoma, painful sensations were noted, requiring the administration of analgesics. After the prescribed time, the elastic bandage was removed to avoid venous thrombosis and skin trophic disorders, and a tight pressure bandage was kept in place until 7 a.m. the following day. During this period, the patient was on strict bed rest. After the bandage was removed, a physical examination, auscultation for bruit at the puncture site, and follow-up UDS were performed. If no AVF was detected, compression therapy was discontinued. In case of persistent AVF, a repeated tight pressure bandage was applied. A total of 1-4 attempts at compression therapy were made, with the number of attempts often limited by the presence of painful inguinal hematomas and macerated skin, which made proper compression difficult, and in some cases, the patient refused due to pain and required bed rest.

In order to improve the success of treatment, anticoagulants were discontinued for 1-2 days during the compression therapy period, if there were no absolute indications for their use. If conservative treatment was unsuccessful, the patient was discharged with recommendations for consultation and follow-up UDS in 3 months or an unscheduled examination if clinical symptoms associated with VAC worsened. Further follow-ups were scheduled according to an individual timetable, with mandatory UDS performed at each visit. Surgical treatment was performed in patients with AVF associated with a pulsatile hematoma (PH) of the FA, unresponsive to compression therapy, in cases of expanding or paired AVFs, and if the patient refused passive observation.

This study is retrospective in nature, despite the prospective observational registry, and was approved

by the local ethics committee (protocol No. 103, dated 25.01.2024). The study included all cases of diagnosed AVF, either isolated or combined with other VAC, in 36 patients who underwent radiofrequency CA for AF between 2018 and 2023. Clinical and instrumental data were extracted from electronic medical records, and procedural data were obtained from the operative treatment protocols. Patient characteristics are presented in Table 1.

Paroxysmal AF was present in 25 (69.4%) patients, and in 23 (63.9%) patients, AF was recorded on the electrocardiogram (ECG) prior to CA. Fifteen patients (41.7%) had a history of diagnostic and interventional procedures. All previous access sites were femoral venous, ranging from 1 to 5 times. None of the patients received antiplatelet agents, and none had significant concomitant atherosclerosis of the lower extremity arteries or congestive heart failure. All patients underwent pulmonary vein isolation (PVI) using the standard technique, and in 8 (22.2%) cases, the procedure design included additional interventions in the left and/or right atria. Perioperative indicators for patients with AVF are presented in Table 2.

At the time of study completion, all patients with a history of AVF were invited for a follow-up consultation. In addition to physical examination and UDS, ECG was recorded, echocardiography (Echo) was performed, and patient questionnaires were completed to assess the clinical significance of AVF. The questionnaire included questions reflecting clinical symptoms of right heart overload (shortness of breath, weakness, reduced performance, etc.) and symptoms related to the lower extremities typical for AVF persistence, including those associated with arterial steal and venous hypertension (pain and "tremor" in the groin, vein expansion and lower extremity edema, weakness, and rapid fatigue in the lower extremity, etc.). The ECG registration evaluated rhythm characteristics, right heart overload symptoms, while Echo assessed the size and volumetric characteristics of the right atrium and right ventricle, the degree of tricuspid regurgitation, and left ventricular ejection fraction (LVEF). The standard UDS protocol included an assessment of the relative positioning of the FA and femoral vein and the degree of venous artery overlap in the transverse projection at the AVF level or 2 cm below the inguinal ligament in the absence of AVF.

Statistical analysis

The statistical analysis of the results was performed using IBM® SPSS® Statistics Version 23 (23.0). All quantitative variables were tested for distribution type using the Kolmogorov-Smirnov test. For symmetrical distributions, the results are expressed as the mean and standard deviation (M±SD). If the distribution was asymmetrical, values are presented as the median (Me) and interquartile range, which is the difference between the third and first quartiles. The Mann-Whitney test was used for analysis. For comparison of nominal scale variables, the Pearson $\chi 2$ test was used. The impact of potential predictors on the dependent variable (the probability of spontaneous closure of the AVF) was assessed using multivariate logistic regression analysis. To assess the sensitivity and specificity of predicting spontaneous closure of AVF based on the obtained indicators, ROC analysis was performed. The data are presented with the achieved significance level (p) and 95% confidence interval (CI 95%). A critical significance level was set at ≤0.05.

RESULTS

The incidence of AVF in our study was 1.19%. In 8 (22.2%) of 36 cases, AVF was associated with PH, and in 21 (58.3%) cases with soft tissue hematomas. Soft tissue hematomas were defined as visible changes in tissue in the projection of the femoral vein puncture site over a distance >5 cm. In 15 (41.7%) patients, there were no complaints or visible symptoms of VAC; the reason for the examination was the presence of bruit at the puncture site or intraoperative hemostasis with a tight compression bandage. In half of the cases, UDS was used as a diagnostic method, while in the other half, it was supplemented by computed tomography angiography.

Compression therapy was effective in 8 (22.2%) patients. Surgical treatment was performed in 7 (19.4%) patients. In no case was there an indication for immediate surgery. No case of symptomatic AVF was observed. Indications for surgery included paired AVF in 3 cases, the combination of PH with AVF in 1 case, and AVF in young patients whose work was physically demanding and who preferred surgical treatment over observation, in 3 cases. The postoperative period in one patient was complicated by the development of a seroma and stenosis of the superficial femoral artery up to 50%.

Of the 21 patients discharged with AVF, 14 continued outpatient follow-up. Seven patients, who did not attend in-person visits, explained their refusal by feeling well and the absence of typical VAC symptoms when contacted by phone. The follow-up duration was 24 [12; 28] months. In 8 of 14 patients, AVF resolved spontaneously. In 1 patient, a previously closed AVF recurred. Four of 7 patients with persistent AVF complained of local discomfort and pulsation in the groin (n=2), swelling of veins, edema, and weakness in the lower limb (n=2). Two patients underwent surgical treatment due to local complaints, and five patients continued follow-up (Fig. 1). None of the patients reported hemodynamic symptoms associated with the progression of heart failure. According to the ECG data, all patients maintained sinus rhythm, and no signs of right heart overload were detected. Echocardiography revealed no statistically significant differences in the right atrial volume

Table 2.

Perioperative characteristics of patients with AVF (n=36)

Indicator	Value
Duration of surgery, min	97.6±28.1
Heparin dose, thousand units	20.7±7.8
Activated clotting time, s	342 [316; 413]
Number of introducers*, n (%)	28 (77.8)
Left femoral access, n (%)	4 (11.1)
Hemostasis with tight compression bandage, n (%)	16 (44.4)
INR after surgery, units	1.9 [1.4; 3.2]

Note: * - 2 or more on one side; INR - international normalized ratio.

index, right ventricular size, degree of tricuspid regurgitation, or LVEF before the procedure and at the end of the observation period.

In 30 (83.3%) cases, the common femoral vein was involved in the formation of AVF, and in 32 (88.9%) cases, the superficial femoral artery was involved. In all cases, duplex ultrasound showed some degree of overlap between the artery and vein: complete overlap in 66.7% and partial overlap in 33.3%, either at the level of AVF or 2 cm below the inguinal ligament if the AVF had resolved.

In 15 (41.7%) of 36 patients, AVF resolved spontaneously or with the help of compression therapy. Possible independent predictors of spontaneous closure of AVF were considered, including clinical-demographic, instrumental, and perioperative factors: sex, age, body mass index (BMI), hypertension, diabetes, smoking, platelet count, creatinine level, HAS-BLED score (for bleeding risk assessment), warfarin anticoagulation, combined with other VAC (PH and soft tissue hematomas), previous femoral catheterizations, duration of the procedure, heparin dosage, ACT, 2 or more introducers on one side, hemostasis with tight compression bandage, and the international normalized ratio before and after surgery. The only independent predictor of spontaneous AVF closure in univariate logistic regression analysis was the patient's age (odds ratio (OR) 0.807; 95% confidence interval (CI) 0.651-1.000; p=0.050).

The diagnostic significance of age for predicting spontaneous AVF closure was assessed using ROC curve analysis (Fig. 2). The area under the curve was 0.832, and the optimal cut-off age was found to be 65.5 years (sensitivity 71.4%, specificity 85.7%). Age over 65.5 years reduced the chance of spontaneous AVF closure by 93.7% (OR 0.067; 95% CI 0.007-0.614; p=0.017). Thus, patients over 65.5 years have a minimal chance of spontaneous AVF obliteration.

DISCUSSION

The absence of recommendations regarding the management strategy and indications for surgery in patients with iatrogenic AVF prompted us to conduct this study. According to published data, surgical treatment is considered the "gold standard" for managing patients with acquired AVFs. Based on this opinion, we previously referred all patients with diagnosed AVFs and unsuccessful compression therapy directly to surgery. However, significant edema, soft tissue imbibition, skin maceration, and active anticoagulation posed certain difficulties for surgical intervention and created conditions for the development of complications. Endovascular methods, while offering advantages such as early mobilization, a shorter hospital stay, and a lower risk of infectious complications, also have potential drawbacks. These include the possibility of thrombosis, stent kinking in active patients, and the closure of collateral arterial branches [6, 13, 14].

We adhered to an active surgical approach until the case of spontaneous obliteration of AVF in a young patient with a recommendation for surgical closure, where the operation was postponed for 3 months until the resolution of a large inguinal hematoma. The natural course of AVF has been studied in a small number of patients following coronary angiography and coronary angioplasty. The potential for spontaneous obliteration of AVF in the context of prolonged anticoagulation therapy after CA of AF had not been previously investigated. On the contrary, in some studies, prolonged anticoagulation was considered an indication for surgical treatment of AVF [11, 12]. Furthermore, the prognosis of long-term AVF persistence is unknown, as published reports describe only isolated high-symptom cases of AVF that required surgical closure.

The frequency of arteriovenous fistulas after catheter ablation of atrial fibrillation

In this study, the incidence of iatrogenic AVF was 1.19%. The true frequency of AVF development after CA of AF remains unknown. The detection rate is influenced by the study design and the method used for validating VAC. As demonstrated in a systematic review of complications in CA for AF (192 studies, n=83,236), the frequency of VACs is higher in prospective studies than in retrospective ones [15]. When the frequency of AVF was assessed based on surgical intervention data, it ranged from 0.006% to 0.14% [3, 16]. In a study similar to ours, where UDS was used as the primary diagnostic tool for minimal complaints such as pain and local hematomas, the frequency of AVF was higher, at 4.8% [4]. This study included patients (n=479) who received continuous anticoagulant therapy and underwent CA for supraventricular (AF ablation, n=293, 68%) and ventricular tachycardia. In the study by K. Bode et al. (2019), the incidence of AVF after CA for AF (n=1152) was 1.22%, with 14 cases of AVF [10], which is comparable to our findings. According to B. Aldhoon et al. (2013), small AVFs were diagnosed in 7 patients (0.59%) after CA for AF (n=1192) [17]. In a small study by T.F. Kresowik et al. (1991), where UDS was routinely performed for all patients to assess VACs, 114 patients underwent coronary angioplasty, and all had femoral artery (FA) and femoral vein punctures on

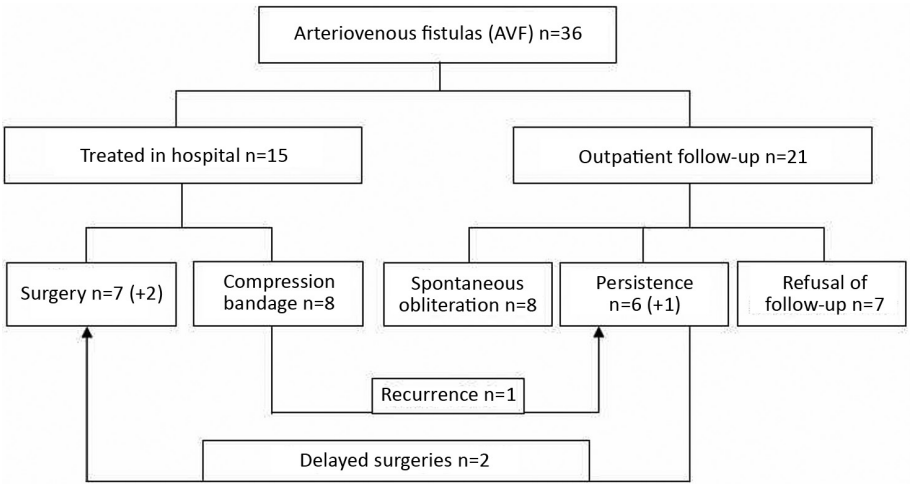

Fig. 1. Course and outcomes of arteriovenous fistula after radiofrequency ablation of atrial fibrillation.

one side. The incidence of AVF was 2.8% (n=4) [18]. In no study of VACs after CA for AF was UDS performed routinely, which likely means that some asymptomatic small AVFs were not diagnosed. Additionally, most studies did not analyze the frequency of AVF separately from other VACs, or only analyzed symptomatic AVFs that required blood transfusions, interventions, or prolonged hospitalization [19, 20].

The characteristics of the progression and outcomes of arteriovenous fistulas after catheter ablation of atrial fibrillation

The key event in AVF closure is the formation of a thrombus. The fact that all patients after AF CA are on anticoagulant therapy reduces the likelihood of spontaneous obliteration and the effectiveness of compression therapy. In the study by B. Toursarkissian et al. (1997), the natural history of 81 isolated and 9 combined AVFs with PH after cardiac catheterization for diagnostic (56%) and therapeutic purposes was analyzed. Spontaneous obliteration occurred in 81% of AVFs, and 90% resolved within 4 months, with an average time of 28 days. None of the patients with spontaneous closure received anticoagulants. The need for prolonged anticoagulant therapy was the most common indication for surgical treatment [12]. In the study by M. Kelm (2002), 10,271 patients who underwent cardiac catheterization were followed prospectively for 3 years. Femoral artery puncture was performed in all cases, unlike femoral vein puncture. Of 88 patients with AVF, 79 received long-term therapy with 100 mg/day of aspirin. Within 12 months, 38% of AVFs closed spontaneously. In the first 4 months, 69% of AVFs closed spontaneously, and the rest closed within a year [5]. Clinical outcomes of 6 AVFs after femoral artery catheterization were evaluated in the prospective study by K.C. Kent (1993). Spontaneous resolution occurred in 4 of 6 AVFs [11]. In contrast, in the study by T.F. Kresowik et al. (1991), no spontaneous closure occurred in any of the 3 AVFs during an 8-week follow-up [18]. According to the results of this study, 8 (57.1%) of the 14 patients with AVF who continued follow-up had spontaneous obliteration of the AVF.

To date, no predictors have been found to predict the likelihood of spontaneous closure and the timeline for AVF resolution. According to the study by M. Kelm (2002), none of the factors (sex, age, body mass index, hypertension, intraoperative high doses of heparin, warfarin therapy, puncture site, number and diameter of introducers) affected the frequency and speed of spontaneous AVF thrombosis. A trend towards prolonged AVF persistence was observed with high procedural doses of heparin (p=0.065) and warfarin therapy (p=0.091) [5]. It would be logical to assume that the linear blood flow velocity in the AVF and the shunt volume would influence obliteration. Asymptomatic AVFs with low flow have a higher chance of spontaneous resolution [12]. This correlates with studies on AVF closure for hemodialysis, where a reduction in flow volume below 500 ml/min and a decrease in the fistula vein diameter to less than 2 mm increases the likelihood of thrombosis [5, 21]. However, in the study by M. Kelm et al. (2002), the shunt volume measured by UDS was 310 ml/min (250-350) in closed AVFs and 350 ml/min (160-510) in persistent AVFs (p=NS) [5]. The blood flow velocity (30-150 cm/s) in the AVF and the size of the initial arterial puncture did not correlate with spontaneous thrombosis [11].

In the present study, age over 65.5 years was the only predictor of AVF persistence. Age-associated changes in the arteries include increased stiffness and thickening of the walls, which is linked to an increase in collagen, a decrease in elastin, and the deposition of calcium and other substances. Similarly, in veins, the number of muscle fibers in the middle layer decreases, while the number of elastic fibers increases [22]. Clinically and histologically, it has been confirmed that the main cause of thrombosis in AVFs formed for hemodialysis is neointimal hyperplasia of the anastomosis or the fistula vein [23]. It can be assumed that younger patients have a greater chance of spontaneous AVF closure after AF CA due to a more active lifestyle, more movement in the hip joint, which causes transient extravascular compression of the AVF, and more active neointimal hyperplasia. According to numerous publications, advanced age is a predictor of complications after AF CA [1, 17, 19]. Naturally, it can be assumed that older age will also be associated with AVF persistence.

The effectiveness of compression therapy in this study was 22.2%. Compression therapy with or without ultrasound guidance is considered effective in two-thirds of cases of all complications after AF CA [10], but it is less successful in patients with AVF (33-50%) [24]. In several studies, compression therapy was ignored after AVF diagnosis, and a passive wait-and-see approach was chosen [10, 17, 25]. In the study by M.T. Massie et al. (1998), it was shown that there was no effect of compression therapy under ultrasound control for 60 minutes in patients with linear AVFs with high flow velocity (128 to 500 cm/s, with an average of 331 cm/s), whereas for non-linear AVFs with low flow velocity, compression was likely to be successful [26]. In our study, not all patients could have their linear blood flow velocity in the shunt assessed by ultrasound, so its impact on AVF persistence could not be determined. In the study by F. Schaub et al. (1994), 3 out of 9 AVFs were obliterated with compression in 80 minutes under ultrasound control [27]. The only limiting factor for the effectiveness of compression therapy is insufficient compression time to induce thrombosis in the AVF. This is related to fatigue in both the doctor and the patient, the overall

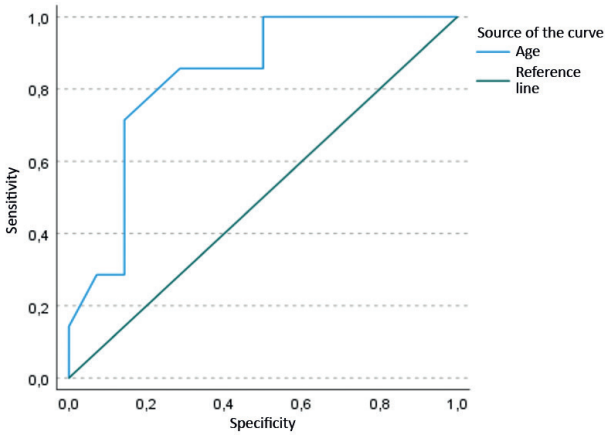

Fig. 2. ROC curve showing sensitivity and specificity for predicting spontaneous closure of AVF based on patient age.

busyness of the medical staff, severe pain, and vasovagal reactions [24]. In the original study by T. Zhou et al. (2007), 16 patients with AVF were treated with prolonged compression bandages using either a standard (n=12) or elastic bandage (n=4). The patients continued to receive clopidogrel 75 mg/day if clinically needed. The bandage was removed daily for 45 minutes to evaluate the compression result, and the patients performed minor everyday activities. All AVFs resolved as a result of compression within 4 to 46 days (on average 15±10 days). Despite the 100% effectiveness, the method is not without potential complications such as pneumonia, thromboembolic events, and skin ulceration [3]. Given the above, we believe that attempting compression therapy for AVF is justified.

Clinical manifestations of arteriovenous fistulas after catheter ablation

The clinical manifestations of AVF typically include symptoms related to both central and peripheral hemodynamics. These manifestations depend on factors such as the size of the shunt, the duration of persistence, and the diameter of the vessels involved. An arteriovenous fistula represents a connection between a high-pressure, high-resistance vessel (artery) and a low-pressure, low-resistance vessel (vein). According to hemodynamic principles, blood will flow from the artery into the vein. Significant shunting of blood from the arterial to the venous system increases the load on the right heart chambers, leading to heart failure. Distal to the AVF, arterial "steal" occurs due to decreased blood perfusion, potentially leading to arterial thrombosis and limb ischemia, especially in the presence of atherosclerotic damage. On the venous side, increased pressure further impairs capillary blood flow, leading to ectasia and even aneurysmal transformation of the venous wall, which increases the risk of rupture and bleeding [6, 28].

Clinical manifestations typically characterize AVFs resulting from trauma, vascular surgeries, or those created for hemodialysis [28, 29]. These AVFs are usually highly symptomatic and require interventional or surgical treatment. The natural course and management of post-traumatic AVFs cannot be extrapolated to AVFs that occur due to catheterization. Most iatrogenic AVFs are asymptomatic and are often detected incidentally [6, 30, 31]. However, recent years have seen an increase in publications reporting severe outcomes of AVFs following catheter-based diagnostic and interventional procedures [32-35].

In our study, 4 out of 7 patients with persistent AVFs exhibited minor peripheral symptoms. None of the patients with persistent AVFs showed signs of heart failure. In the study by M. Kelm et al. (2002), none of the patients with persistent AVFs (n=88) showed signs of heart volume overload or limb damage. In cases of interatrial or interventricular septal defects with left-to-right shunting, right ventricular function deteriorates only if the shunt volume exceeds 30% of cardiac output (normal resting cardiac output is 4-6.5 L/min). In mature AVFs for hemodialysis, the shunt volume ranges from 600-1200 ml/min [36]. In M. Kelm's study (2002), the shunt volume was much lower, ranging from 160-510 ml/min, which likely accounts for the asymptomatic course of AVFs in that cohort [5]. However, in some patients, clinical manifestations develop, and surgical treatment becomes necessary. In the study by M.A. Ohlow et al. (2009), 11% of all AVFs (n=107) required surgery due to the development of symptoms during an average follow-up of 48±10 months [37]. In another study, 2 out of 6 iatrogenic AVFs ultimately required surgical intervention due to the onset of peripheral symptoms [11]. Among 23,291 patients following heart catheterization, 6 AVFs required surgical treatment due to progression of heart failure, swelling, varicose veins in the lower limbs, claudication, or a combination of these symptoms [38].

It is worth noting that no prognostic indicators have yet been identified to predict which patients with persistent AVFs will develop clinical symptoms. It has been decided that AVFs with a diameter of 3 mm or more, formed after coronary angiography, should be surgically treated even in the absence of symptoms due to the potential risk of complications later on, if the AVF does not close within a year [13]. Complicated AVF course (heart failure, limb ischemia, nerve compression, bleeding, groin infection, etc.), the inability to continue observation or patient refusal, and the need for surgical treatment on the limb for other reasons are the most common indications for surgical treatment of AVF [6]. In our view, it is justified to observe patients for up to one year after unsuccessful compression therapy, with regular check-ups and ultrasound monitoring, in the unlikely event of developing heart failure or vascular complications.

Study limitations

Only patients with symptoms or clinical signs suggesting the presence of VAC and those who had hemostasis with a tight compression bandage underwent ultrasound examination. It is likely that some AVFs in asymptomatic patients were not diagnosed, meaning the true incidence of this complication may be higher than reported. The data on AVFs were obtained from only a subset of patients, which reduces the initial sample size. In 7 cases, surgical treatment was performed, which also limits the ability to evaluate the natural course of this complication. The results analyzed were from a single center, which restricts the generalizability of the findings.

CONCLUSION

The incidence of spontaneous closure of AVF after radiofrequency CA for AF was 57.1%. The only independent predictor of AVF persistence was the patient's age above 65.5 years. None of the patients with persistent AVF developed symptoms of heart failure or vascular symptoms that required immediate surgical closure. For AVFs with a diameter of less than 3 mm, it is reasonable to start treatment with compression therapy. In the absence of success with asymptomatic AVF, observation for one year is justified with the expectation of spontaneous obliteration. After this period, and for AVFs with a diameter greater than 3 mm, the decision regarding surgical treatment should be made.

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