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Ultrasound guided angioplasty of arteriovenous fistulas for hemodialysis: Benefits and limitations

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ABSTRACT

Background: Ultrasound-guided percutaneous angioplasty of arteriovenous fistulas (AVFs) makes it possible to avoid contrast agents and X-rays, to optimize the puncture site and to locate some stenoses on the fistulography, but is it really useful? Our objective was to report the results of our experience.

Material and methods: Between November 2012 and November 2017, all the patients treated according to this method in our center were collected retrospectively. The surgical indications were an insufficient maturation of the AVF, an increase in the venous pressure, an inadequate outflow, difficulties in puncture, a prolonged bleeding time, a flow drop, or an aneurysmal evolution.

Results: During this period, 50 patients had 72 ultrasound-guided (UG) angioplasties, 64 on native AVFs (88.9%) and eight on prosthetic AVFs (11.1%). The technical success rate was 100%. The average preoperative flow of AVFs was 506.8 ± 302.2 mL/min vs 955.9 ± 371.4

mL/min after angioplasty. The mean duration of follow-up was 13.4 ± 12.9 months. The cumulative rates of primary, assisted primary and secondary patency were 43.5%, 68.8%, 81.5% at one year and 31.7%, 63.9%, 76.8% at two years, respectively.

Conclusion: AVF angioplasty under ultrasound guidance only is feasible, effective and represents an interesting alternative. A controlled study comparing ultrasound guidance with angioplasties performed under conventional angiographic guidance as the reference technique would better clarify the value of this technique.

INTRODUCTION

Percutaneous angioplasty of arteriovenous fistulas (AVFs) is classically carried out during a dialysis fistulogram with injection of iodinated contrast medium, whether the vascular access is used or not. It can also be performed under ultrasound guidance, making it possible to escape the risk of nephrotoxicity and allergy and to avoid irradiation. We report here the results of our experience of UGA of AVFs. The objective of this study was to describe the technique, to evaluate the results and to discuss its advantages and disadvantages.

MATERIAL AND METHODS

This was a retrospective monocentric study which included all the patients treated by AVF UG angioplasty between November 2012 and November 2017 in our center. Data were collected from operative reports and pre- and postoperative ultrasound duplex examinations (UDE). Follow-up was carried out by consulting the computerized files of the patients (DxCare[®] software). The data were collected in a Microsoft Office Excel[®] 2016 spreadsheet, and then analyzed using the IBM SPSS Statistics[®] version 21 software. Primary patency was defined by the interval of time between UG angioplasty and the thrombosis of the fistula or any intervention carried out to maintain its patency. Assisted primary patency was defined by the interval of time between the UG angioplasty and the thrombosis of the fistula, including the interventions carried out to maintain the patency, and excluding the surgical operations

that were associated with the closure of the access. Secondary patency was defined by the time between the angioplasty and the stop of the use of the AVF, the thrombosis of the access or its surgical revision.¹

The indications of the procedure were defects of maturation (i.e. any AVF that cannot be used six weeks after its creation) diagnosed by a systematic UDE, an increase in the venous pressure, an insufficient drainage, difficulties of puncture during dialysis, an increased bleeding time, a drop of flow of the AVF, or the development of aneurysms. The localization as well as the degree and the repercussion of the stenoses were diagnosed by UDE. In the same way, central venous thromboses were highlighted by UDE, directly if they were located in an accessible zone or indirectly in the presence of evocative remote data. The diagnosis was then confirmed during the fistulogram or by an angio-CT when needed. The cases that were untreated with ultrasound only were central venous stenoses, patients with calcified arterial lesions or venous stenoses longer than 5 cm.

All the procedures were performed in a surgical unit under local anesthesia, possibly supplemented by a neuroleptanalgesy. The surgeon was accompanied by our contact angiologist in charge of AVFs, and both were gowned in sterile dressing for the procedure (Fig. 1). The angiologist first researched the lesions before puncturing the vessel under local anesthesia. A 4F-6F sheath was then placed in an antegrade or retrograde way according to the location of the lesion. A bolus of 50 UI/Kg of heparin was then injected intravenously. A 0.035 or 0.018 guidewire was used to cross the stenoses, sometimes with the help of a straight Impress[®] catheter (Merit[®]) or of a Ber 2[®] catheter (Boston Scientific Corporation[®]).

The size of the balloon was defined with UDE, according to the diameter of the adjacent vessel and the length of the stenosis. We used Paseo-18[®] balloons (Biotronik[®]) with 0.018 wires, Armada[®] balloons (Abbott[®]) with 0.035 wires and Mustang[®] balloons (Boston[®]) for resistant lesions requiring a high pressure of inflation. The length of the lesions was 20-60

mm and their diameter was 5-8 mm. Inflation was systematically carried out during three min. After angioplasty the balloon was withdrawn and the wire was left in place. The angiologist measured the size of the vessel after angioplasty, searched for a residual stenosis and evaluated the flow of the AVF whenever possible (Fig. 2). After withdrawal of the material, a manual compression was applied for 10 minutes.

RESULTS

Between November 2012 and November 2017, 50 patients had 72 interventions for UG AVF angioplasty, 17 women (34%) and 33 men (66%). Mean age was 66.1 ± 12 years (median 64.5 years). Sixty-four procedures were carried out on native AVFs (88.9%) and eight on prosthetic AVFs (partial or total; 11.1%). Thirty-one of the native FAVs were radiocephalic AVFs (43.1%), 20 were humerocephalic AVFs (27.8%), five were cubitocubital AVFs (6.9%), four humerobasilic AVFs (5.6%), two radiobasilic AVFs (2.8%) and two cubitobasilic AVFs (2.8%). Twenty-three angioplasties were carried out for an insufficient maturation (31.9%). The average time between the creation of the fistula and UG angioplasty was 18 ± 36.7 months ([1-249 months], median six months).

Overall, 108 stenoses were treated. The locations of the dilated sites are described in Tables I and II. Six patients underwent three angioplasties, five underwent two procedures and thirty-eight were dilated only once. One patient underwent six procedures on the same AVF, which was associated twice with a thrombectomy. The average time between the first and the second dilation was 9 ± 8 months ([1-23 months], median 6.5 months), and between the second and the third, it was 7.7 ± 5 months ([1-12 months], median nine months).

In total, eight stents were implanted. Four patients received one stent (two in the inflow artery [Prokinetic[®] stents, Biotronik[®]], and two in the drainage vein (Optimed[®] and Boston[®] stents), and two patients received two stents (Boston[®] Express[®] and Pulsar[®] Biotronik[®] stents, in the outflow vein of the AVF). In ten cases, the UG angioplasty was

associated with an open surgical procedure: three ligations of collateral veins located with UDE, three thrombectomies, two replacements of a venous segment, one repair of an arteriovenous anastomosis and one aneurysmorrhaphy.

Technical success and complications

The technical success rate of the angioplasties was 100%. Nine complications (12.5%) occurred, with three hematomas of the venous wall and one rupture treated by a prolonged low pressure inflation, three dissections on the dilated site (one treated with an additional prolonged angioplasty, one by the implantation of one stent and another requiring the realization of a short venous bypass to treat the occlusion of the dissected zone), one peroperative thrombosis leading to the abandonment of the fistula, and another thrombosis treated by thrombolysis and a new prolonged angioplasty. Wall hematomas could be diagnosed quickly by UDE (much more difficult with a fistulogram), which allowed their prompt treatment. In the same way, UDE makes it possible to control the absence of leak when inflating the balloon, which avoids the risk of over-dilatation, potentially noxious for the venous wall.

Clinical success

Fourteen angioplasties were carried out in patients not yet on dialysis. Among the 58 remaining procedures, five did not allow to use the AVF thereafter, which corresponds to a clinical success of 91.4%.

Ultrasound parameters

After exclusion of the occluded accesses, the average flow of the fistulas was 536.7 ± 283.7 mL/min ([100-1600 mL/min], median 500 mL/min) before angioplasty and 930.6 ± 348.3 mL/min ([300-2000 mL/min], median 850 mL/min) after angioplasty. For prosthetic AVFs, the flow increased on average by 466.7 ± 115.4 mL/min (median 400 mL/min). For mature

native AVFs, the post procedure flow went up by 395 ± 375 mL/min on average ([- 450-1550 mL/min], median 400 mL/min). Lastly, for the non-mature native AVFs, the flow was increased by 314.6 ± 205.6 mL/min on average ([0-700 mL/min], median 275 mL/min).

Follow-up

The AVFs that were treated several times were analyzed only once, starting from the first angioplasty. Thus, fifty-two fistulas were analyzed, with two patients treated by balloon dilatation on another AVF after the abandonment of the first one. The average duration of follow-up was 13.4 ± 12.9 months ([1-45 month], median 8 months). Five patients received a kidney transplant. The fistula was abandoned in seven other cases, and 12 patients died. The cumulative rates of primary, assisted primary and secondary patency were 43.5%, 68.8%, and 81.5% at one year, and 31.7%, 63.9%, and 76.8% at two years, respectively (Fig. 3).

DISCUSSION

Functioning AVFs often develop stenoses, generally on the venous outflow tract, which require angioplasty to maintain the optimal patency required to initiate and continue hemodialysis. Angioplasty is usually carried out classically under fluoroscopy with injection of a iodinated contrast product, which exposes to an allergic risk and a renal toxicity.^{2,3} The same procedure performed under ultrasound guidance avoids iodine, which is particularly interesting in chronic renal failure patients who are not yet on dialysis, but also after the beginning of hemodialysis to preserve the kidneys. UDE makes it possible to optimize the site of puncture, offers a significant gain of examination time,⁴ and detects some stenoses that are not visible on a fistulogram.⁵

The procedures performed in this study led to a technical success of 100%, through a careful selection of the patients. We excluded central venous stenoses, the long stenoses and extremely calcified arterial lesions. Several studies proved the feasibility of this technique,

with technical success rates varying from 93 to 100%, and some physicians use it in their office outside the hospital environment.⁶⁻¹⁰ We made the choice to use this technique only for rather short stenoses, with balloons measuring less than six cm in length. We think that longer lesions are less accessible to UG dilatation, just as occlusions, even if some authors reported the treatment of longer stenoses.⁸ We observed three hematomas and one rupture of the dilated outflow vein, which did not affect the patency. These complications occurred exclusively on non-mature AVFs, thus pointing the fragility of recently arterialized veins. The complications which we met are classically described in the literature. Arterial spasms have also been reported, but we did not observe this complication.⁸⁻¹¹

Our results are incomplete because of the retrospective character of the study, which did not allow collecting enough data, in particular the arterial resistivity index and the peak systolic velocity, which are often lacking in the pre- or postoperative examination, or for the patients followed outside our center. We observed satisfactory patency rates, in agreement with the data of the literature, but the interpretation of the results remains limited by the small population size of our study.^{2,12,13} We did not seek factors influencing the patency of the fistulas, in particular because of the lack of collected data, but this analysis should be addressed in our next research. Several stenoses had to be dilated several times. These iterative percutaneous angioplasties extend the lifespan of the access, avoid the need for open surgery or the creation of a new AVF and preserve the venous capital. If necessary, the creation of a more proximal access can create ischemic phenomena, in particular in older and diabetic patients, and must be avoided in case of central venous stenosis or occlusion.¹⁴

Eight stents were implanted in these procedures, without the use of fluoroscopy. We had no problems with the deployment of the stents but the gesture proved more delicate to carry out, because the stent is hidden when it is contained in its sheath.

We chose to carry out these procedures in the operating theatre to decrease the risk of septic contamination. The ultrasound unit occupies less room than a C-arm with an easier handling. Intraoperative ultrasound control makes it possible to immediately analyze the anatomical and hemodynamic results of angioplasty (measurement of the flow and of the peak systolic velocity), which reduces the number of balloon inflations and can detect residual stenoses that are really less visible in fluoroscopy. The size of the balloon should ideally be selected according to the diameter of the vessel which is perfectly measured by echography. Complications are easily detectable, the puncture site can be immediately checked after the withdrawal of the material, and a leak can be optimally compressed under ultrasound control. However, this examination requires an experienced operator.

CONCLUSION

Ultrasound guided angioplasty of arteriovenous fistulas is feasible and effective but present some limits. The procedure is more delicate when the implantation of a stent is required, but it still entirely possible. No study to date compared ultrasound guidance with conventional angiography, but this technique could bring significant benefits, without fully replacing the fistulogram, in particular in the presence of central venous stenoses, very tortuous or aneurysmal vessels, heavily calcified arteries, or long occlusive lesions. A controlled study comparing ultrasound-guided angioplasty with the conventional angiographic technique would clarify the interest of this technique.

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Legend of figures

Fig. 1. Installation of the patient.

Fig. 2. Ultrasound imaging of each stage of the operation. **A.** Stenosis on the outflow vein of an AVF. **B.** Visualization of the introducer. **C.** Visualization of the guidewire in the introducer. **D.** Stenotic imprint during balloon inflation. **E.** Removal of the stenosis by angioplasty. **F.** Deflation of the balloon. **G.** End result showing the disappearance of the stenosis and a homogeneous regular flow.

Fig. 3. Cumulative patency rates (Kaplan Meier). **A.** Cumulative primary patency rate. **B.** Cumulative assisted primary rate. **C.** Cumulative secondary patency rate.

Arteres MS

L12-3

36Hz

2,5cm

2D

HGén

Gn 40

55

3/3/2

Couleur

4,0 MHz

Gn 44

3/8/4

Filtr Moy.

P

+ Long. 0,143 cm

+160

cm/s

-160

2

2,5cm

P
R
4,4 0,8

Arteres MS
L12-3
55Hz
2,5cm

2D
HGén
Gn 40
55
3/3/2

P

Arteres MS

L12-3

55Hz

2,0cm

2D

HGén

Gn 40

55

3/3/2

TSA Optim
L12-3
104Hz
2cm

2D
F 2
Gn 63
232dB/C4
F/3/3

Arteres MS

L12-3

55Hz

2,0cm

2D

HGén

Gn 40

55

3 / 3 / 2

Artériel
L12-3
25Hz
3cm

2D

HGén
Gn 40
55
3/3/2

Couleur

4,0 MHz
Gn 51
3/8/4
Filtr Moy.

	12 months	24 months
N of patients at risk (total n of patients = 52)	40	28
Patency rate (%)	43.5 ± 9.4	31.7 ± 9.9

	12 months	24 months
N of patients at risk (total n of patients = 52)	42	30
Patency rate (%)	68.8 ± 8	63.9 ± 8.8

	12 months	24 months
N of patients at risk (total n of patients = 52)	42	30
Patency rate (%)	81.5 ± 6.8	76.8 ± 7.9

Table I. Sites of angioplasty in native AVFs

Site of angioplasty	Native AVFs	
	Mature AVFs	Defect in maturation
Juxta-anastomotic	10	11
Post-anastomotic	2	0
Outflow vein	53	19
Artery	2	1

Site of angioplasty	Prosthetic AVF
Graft/vein anastomosis	5
Intragraft	1
Outflow vein	2
Artery	2

Table II. Sites of the angioplasties in prosthetic AVFs