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Effect of a postoperative exercise program on arteriovenous fistula maturation: A randomized controlled trial

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Abstract

Exercises after arteriovenous fistula (AVF) creation may help to improve maturation; however, their usefulness has only been examined in indirect, non-comparative studies or small trials. Between June 2013 and November 2014, we included all ambulatory patients with stages 5-5D chronic kidney disease who were candidates for the creation of a native AVF in our center. After surgery, all patients were randomized to an exercise group or a control group with single-blind control. At 1 month postoperatively, clinical maturation (expert nurse inspection) and ultrasonographic maturation (flow >500 mL/min, venous diameter >5 mm and depth <6 mm) were assessed in all patients. A total of 72 patients were randomized, 3 were lost to follow-up, and 69 were finally analyzed. The mean age was 66.8 years (standard deviation 13.8), 70.0% were men, and 65.2% were in pre-dialysis. After surgery (42.0% had distal AVF), the patients were randomized (31 controls, 38 exercise group). At 1 month after surgery, global clinical and ultrasonographic maturation was assessed in 88.4% and 78.3% of AVF, respectively (kappa = 0.539). Non-significant differences in clinical or ultrasonographic maturation were seen between exercise and control group (94.7% vs. 80.6%, P = 0.069; 81.6% vs. 74.2%, P = 0.459). A stepwise logistic regression was performed to control previously analyzed asymmetrically distributed confounding factors (AVF localization), revealing that the exercise group showed greater clinical, but not ultrasonographic, maturation (odds ratio [OR] 5.861, 95% confidence interval: 1.006–34.146 and OR 2.403, 0.66–8.754). A postoperative controlled exercise program after AVF creation seems to increase 1-month clinical AVF maturation in distal accesses. Furthermore, exercise programs should be taken into account, especially in distal accesses.

Key words: Chronic kidney disease, arteriovenous fistula (AVF), maturation, exercise, clinical parameters, ultrasonographic parameters

INTRODUCTION

The native arteriovenous fistula (AVF) is the method of choice for achieving vascular access in chronic hemodialysis patients.[1–3] In comparison with the other types of vascular access, native AVF is related to a higher long-term

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patency rate and a significantly lower risk of infection, health-care cost, need for hospitalization, and mortality risk.[4,5] According to the last results of DOPPS study, the percentage of patients under hemodialysis with AVF varies around the world, with the highest rates of prevalent patients in Japan and France and the lowest percentage in Canada.[6]

Two major reasons for the greater use of central venous catheters may be the practice of delayed AVF creation and problems in the maturation process, which occurs in approximately 10%–33% of patients.[7] Therefore, it is crucial that native AVF be examined by an experienced clinician between 4 and 6 weeks after surgical creation.[8–10] Vascular access examination could also include an ultrasound of the AVF.[11]

Exercises in the pre- and postoperative period have been recommended by current vascular access guidelines (K/DOQI)[1] as helpful to improve vascular access maturation, increasing hyperemia and muscle mass, decreasing superficial fat, and enhancing vein prominence.[1,3,11] Currently, preoperative exercise can increase venous diameters and is significantly related to an increase in AVF maturation.[12–17] However, postoperative exercise programs (after AVF creation) have only shown increased flows and venous diameters in very short time periods; these changes have not been demonstrated to persist in time or to truly increase maturation.[15,17] Only one randomized controlled trial has analyzed the effect of exercise after AVF creation, but this trial had severe limitations (few patients, excessive early examinations [2 weeks], and very low maturation rates).[18]

The aim of this study was to determine whether a postoperative ambulatory controlled exercise program can increase AVF maturation at 1 month.

MATERIAL AND METHODS

A randomized controlled trial was designed and approved by the Ethics Committee and Investigation Committee of our institution (Hospital Clinic and University of Barcelona, Barcelona, Spain), prospectively registered before patient inclusion (January 2013, registration number 2013/8042); it was also retrospectively registered in the ISRCTN registry (ISRCTN15802482). This study followed all international good practice guidelines and those of our hospital.

Between June 2013 and November 2014, all patients with chronic kidney diseases stages 5 (pre-dialysis) and 5D (hemodialysis) that were visited in our center and were candidates for the creation of native AVF in the upper extremity were invited to participate in this study. The inclusion criteria consisted of ambulatory status, the ability to understand and perform the exercise program, and attend the follow-up visit, acceptance to participate, and the provision of signed informed consent after receiving full information on the program. The exclusion criteria consisted of a previous dysfunctioning AVF in the same arm (AVF repairs), prosthetic accesses, known arterial or central venous diseases in the same arm, or patients living far from our hospital.

For all patients included in the study, preoperative demographic data and information related to AVF maturation were recorded (age, sex, previous medically treated diseases [hypertension, diabetes mellitus, dyslipidemia, ischemic heart disease, cerebrovascular disease, peripheral vascular disease], antiplatelet therapy, anticoagulant therapy, stage of renal disease). Preoperative ultrasound measurements (brachial artery diameter and flow, 3 cm proximal to brachial bifurcation, and venous diameter 3 cm proximal to the intended AVF anastomosis site) were also performed (as described below).

All surgical procedures were performed by the same two vascular surgeons with wide experience in the field of vascular access, after systematic physical and ultrasound examination, and following usual recommendations (vein diameter >2.5 mm after proximal tourniquet, radial arterial diameter >1.5 mm in distal AVF, and brachial diameter >2.5 mm in proximal AVF with normal Doppler curve). Local anesthesia was usually used, except for brachial-basilic AVF with superficialization, that were performed under regional blockade. AVF localization was recorded: proximal (brachial-cephalic, brachial-perforator, or brachial-basilic, with or without superficialization) or distal (radial-cephalic), all of them side-to-end anastomosis. Finally, an immediate postoperative ultrasound examination (after skin closure) was conducted, examining brachial artery flow and venous diameter, in the same localization as in the preoperative examination.

After AVF creation, the patients were randomized to an exercise or control group using an automatic randomization system based on Efron randomization (to ensure a similar distribution of patients in two groups in small trials, ratio 1:1). Patients in the exercise group were asked to follow a previously designed controlled exercise program (the exercises included a specific table with a flex band for 1 month after AVF creation), and the control group was asked not to perform specific exercises (usual lifestyle). Single-blind masking was performed (specialists dedicated to this study were blinded to the results of randomization in all phases of the study; only the nurse who is instructing the patients to follow the exercise

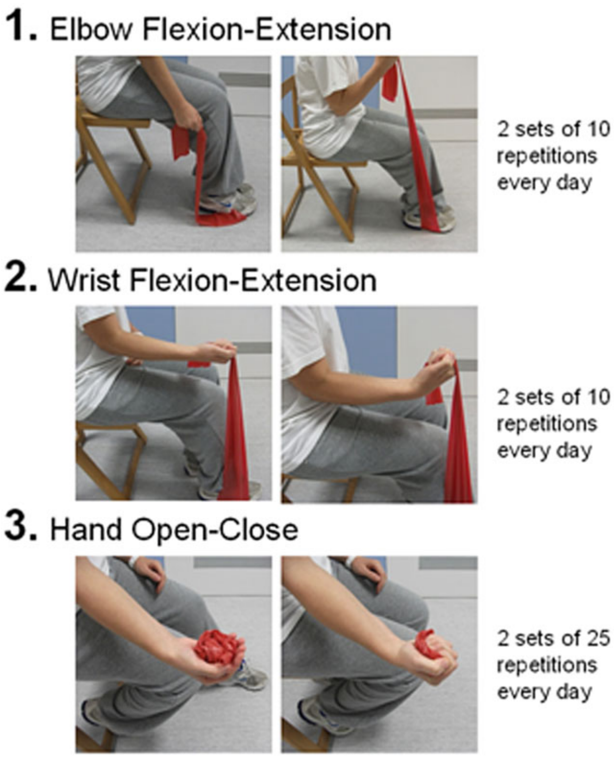

Figure 1 Ambulatory daily exercise program with flex band for 1 month after arteriovenous fistula creation.

program and the patients themselves knew the results of randomization).

The exercise program (Figure 1) was designed by our hospital physiotherapy team and included elbow and wrist flexion–extension and hand open–close. The patient instructions were as follows:

- *Elbow flexion–extension* (2 sets × 10 repetitions every day): In a seated position, hold one end of the resistance band with one foot and the other end with the hand of the AVF arm. Flex the forearm toward the body to reach the maximum available degree of flexion.
- *Wrist flexion–extension* (2 sets × 10 repetitions every day): Hold one end of the resistance band with one foot and the other end with the AVF arm. Perform palmar flexion of the wrist only toward the body to reach the maximum available degree of flexion.
- *Hand open–close* (2 sets × 25 repetitions every day): Curl up the resistance band and hold it in the hand. Flex the fingers toward the band in order to exert pressure on it. Release the tension slightly.

At the preoperative visit (both arms) and 1-month postoperative visit (AVF arm), grip strength (Hydraulic Hand Dynamometer Saehan®) was measured in the exercise and control groups. The handle of the handgrip was adjusted to the patient's hand size. In a seated position and with the elbow of the AVF arm at 90-degree flexion, the patient pressed the handgrip with the maximum force. The exercise was repeated three times in a row and the average of the measurements was calculated.

One month postoperatively, an experienced dialysis nurse and the medical coordinator of the vascular access unit assessed AVF maturity both clinically and ultrasonographically:

- *Clinical maturation* was defined, after physical examination, by a dedicated dialysis nurse, as an easily palpable vein, with a straight-superficial segment, length more than 10 cm, sufficient diameter, and good palpable thrill.[19]
- *Ultrasonographic maturation* was defined, after ultrasound examination, as a draining vein diameter ≥5 mm, skin–vein distance ≤6 mm, and brachial blood flow rate (BFR) ≥500 mL/min.[19–23] All examinations were performed by two different explorers, after determining good intra- and inter-observer variability in a previous sample of 20 cases of examination (interclass correlation coefficient for absolute agreement were very good: 0.949 [95% confidence interval {CI} 0.839–0.981] and 0.937 [95% CI 0.611–0.981], $P < 0.001$).

Ultrasound measurements

All ultrasound examinations were performed by two different operators using the same ultrasound device: SonoSite MicroMaxx Ultrasound System (Sonosite Inc., Bothell, WA, USA) and a HFL38/13-6 MHz 38-mm linear array transducer, with adjustment and steering of the pulsed wave Doppler angle to 60° to vessel direction and gate size to vessel diameter. Preoperative and immediate postoperative measurements were recorded in the operating room before and after surgery. These measurements were not considered in any surgical procedures or randomization decisions. The mean velocity (MV) was automatically calculated, and vessel diameter (intima-intima) was manually measured by B-mode, with transducer scan line perpendicular to the vessel wall, in a transverse plane. Flows (mL/min) were calculated using manufacturer-proposed parameters: cross-sectional area (0.785 × D2, in cm^2) × time-averaged mean velocity (cm/s) × conversion factor (0.06). Brachial artery flow was used as the best estimation of ultrasound examination of AVF flow in the immediate postoperative period and at 1 month.[24] All preoperative, immediate postoperative, and 1-month follow-up measurements were taken in the same place (3 cm proximal to brachial artery bifurcation, and vein measurements 3 cm proximal to arteriovenous anastomosis). Vascular access flow was estimated according to the flow of the brachial artery as the most reliable method. Vein flow rates were discounted as they are less reliable and several draining veins may exist, which often affects interpretation).[25,26]

Statistical analysis

Descriptive statistics and frequencies were obtained and comparisons were made using the SPSS version 15.0 statistical package (IBM statistic, New York, NY, USA). Statistically significant differences between randomization groups (control and exercise) were assessed using the Pearson χ^2 test or the Fisher exact test for categorical variables and the Student's *t*-test for continuous variables. The kappa coefficient was obtained to compare clinical and ultrasonographic maturation. Possible confounding factors were analyzed by following their asymmetrical distribution between the two groups (setting a $P \leq 0.20$), associated with the effect (clinical or ultrasonographic maturation) in the control group (with risk ratio [RR] < 0.67 or >1.5) and producing an odds ratio (OR) change >10% in the adjusted analysis. Thereafter, to analyze the real effect of the exercise program at 1 month on AVF maturation, a stepwise multivariate logistic regression analysis was performed by introducing the randomization group and confounding factors. All analyses were repeated to independently analyze clinical and ultrasonographic maturation. A value of $P < 0.05$ was usually considered to be statistically significant.

Sample size

Following previous studies describing a maturation rate of 20% without exercise and a rate of 52% with exercise (but with short follow-up), we had originally calculated that, with a 5% alpha error, 20% beta error, and an expected difference between groups of 32%, 82 patients (41 per group) would be needed to reach significant differences. We initially estimated that 1 year would be sufficient to reach this objective, but the study period was prolonged for 6 months because of a lack of patients.

RESULTS

During the study period, 416 AVF creations or repairs were performed and assessed for eligibility. Only 85 fulfilled inclusion criteria (mainly because including only autonomous patients living near our treating area), none declined to participate but 13 of them were excluded for other intraoperative reasons (prosthetic or unusual access, AVF could not be performed, or the patient finally declined to participate in the study). Seventy-two patients were finally randomized, allocating 39 to the exercise and 33 to the control group. All allocated cases received treatment, but one case in the exercise and two in the control group were lost on follow-up before 1-month visit; finally, 38 cases in the exercise group and 31 in the control group were analyzed (CONSORT flow diagram).

There were 29 distal AVF accesses (radial-cephalic) and 40 proximal accesses (29 brachial-cephalic, 7 brachial-basilic with superficialization, 2 brachial-basilic without superficialization, and 2 brachial-perforator). There were no statistically significant differences between the two randomization groups in preoperative or intraoperative variables (Table 1).

At 1 month after surgery, 3 AVF were thrombosed and assessed clinically and ultrasonographically as non-mature. Clinical and ultrasonographic maturation was noted in 88.4% and 78.3% of AVF, respectively (kappa between the two maturation assessments: 0.539; 95% CI: 0.283–0.795; Table 2). Non-significant differences in clinical or ultrasonographic maturation were seen between exercise and control group (94.7% vs. 80.6%, $P = 0.069$; and 81.6% vs. 74.2%, $P = 0.459$, Table 3). The only significant difference between the exercise and control groups in individual crude variables was the increase in grip strength (+1.65 kg [standard deviation {SD} 2.81] vs. −0.87 kg [SD 1.84], $P < 0.001$), but this increase did not show an independent significant relation with clinical or ultrasonographic maturation.

Possible confounding factors (age, sex, diabetes, current hemodialysis, previous antiplatelet therapy, preoperative venous diameter and arterial flow, localization of AVF) were analyzed by following their asymmetrical distribution between the two groups (setting a $P \leq 0.20$), associated with the effect (clinical or ultrasonographic maturation) in the control group (with RR < 0.67 or >1.5) and producing an OR change >10% in the adjusted analysis. AVF localization was detected as a confounding factor for both clinical and ultrasonographic maturation, leading to a greater effect of exercise in maturation of distal AVF (94.7% vs. 60.0% for clinical maturation and 68.4% vs. 50.0% for ultrasonographic maturation in the exercise and control groups, respectively, $P = 0.019$ and $P = 0.331$) than in proximal AVF (94.7% vs. 90.5% for clinical maturation and 94.7% vs. 85.7% for ultrasonographic maturation, $P = 0.609$ and $P = 0.342$).

Table 1 Description of sample data and distribution (number and percentages, or means and standard deviations) between the two randomized groups

Variable	Randomized group Control (n = 31)		Exercise (n = 38)		P
Preoperative variables					
Sex (male)	25	(80.6%)	23	(60.5%)	0.071
Age (years; mean and SD)	66.4	(13.3)	67.2	(14.4)	0.808
Hypertension	29	(93.5%)	37	(97.4%)	0.439
Diabetes mellitus	14	(45.2%)	13	(34.2%)	0.354
Dyslipidemia	11	(35.5%)	15	(39.5%)	0.734
Ischemic heart disease	7	(22.6%)	5	(13.2%)	0.410
Cerebrovascular disease	2	(6.5%)	1	(2.6%)	0.439
Peripheral vascular disease	6	(19.4%)	2	(5.3%)	0.069
Antiplatelet therapy	12	(38.7%)	9	(23.7%)	0.177
Anticoagulant therapy	4	(12.9%)	2	(5.3%)	0.263
Stage of renal disease (hemodialysis)	19	(61.3%)	26	(68.4%)	0.536
Handgrip (kg; mean and SD)	22.99	(8.45)	22.95	(9.8)	0.986
Preoperative ultrasound examination					
Venous diameter (mm; mean and SD)	3.15	(0.42)	3.37	(0.86)	0.217
Brachial arterial flow (mL/min; mean and SD)	127.9	(94.8)	106.8	(84.1)	0.366
Intraoperative variables					
AVF localization (proximal)	21	(67.7%)	19	(50.0%)	0.138
AVF side (left)	17	(54.8%)	28	(73.7%)	0.102
Immediate postoperative variables					
Venous diameter (mm; mean and SD)	4.06	(0.85)	4.00	(1.09)	0.828
Brachial arterial flow (mL/min; mean and SD)	841.6	(551.9)	797.3	(514.3)	0.748

AVF localization: proximal (brachial-cephalic, brachial-basilic) or distal (wrist radial-cephalic or forearm radial-cephalic). Preoperative ultrasound examination of the arm used for the AVF. Venous diameter of the vein used in the creation of the AVF. Brachial artery flow is an estimation of AVF flow in the immediate and 1-month postoperative period. AVF = arteriovenous fistula; SD = standard deviation.

Thus, AVF localization was taken into account for future analysis: a stepwise logistic regression with randomization group and AVF localization was performed to analyze the real effect of exercise on AVF maturation (adjusted by the confounding factor: AVF localization), showing that the exercise program was independently related to significantly greater clinical maturation, but only a non-significant tendency toward better ultrasonographic maturation (OR 5.861, 95% CI: 1.006–34.146 and OR 2.403, 0.66–8.754; Table 4).

DISCUSSION

The main aim of this randomized controlled trial was to assess the usefulness of an exercise program on native AVF maturation in patients with chronic kidney disease stages

Table 2 Comparison of clinical and ultrasonographic maturation

		Ultrasonographic maturation No	Mature	Total
Clinical maturation	No	7	1	8 (11.6%)
	Mature	8	53	61 (88.4%)
Total		15 (21.7%)	54 (78.3%)	69

The kappa coefficient was good (0.539, 95% confidence interval: 0.283–0.795).

Table 3 Description of 1-month follow-up visit variables, their increase between the immediate postoperative results and 1-month results, and distribution between the two randomized groups (mean values and crude comparisons)

	Randomization group		
Variable	Control (n = 31)	Exercise (n = 38)	P
Venous diameter (mm)	6.46	6.33	0.732
Increase in venous diameter (mm)	2.48	2.08	0.300
Venous depth (mm)	2.49	2.43	0.850
AVF flow (brachial arterial flow)	1328.1	1324.9	0.985
Increase in AVF flow	431.3	388.7	0.742
Handgrip (kg)	21.60	24.68	0.182
Increase in handgrip (kg)	−0.87	+1.65	<0.001
Clinical maturation	80.6%	94.7%	0.069
Ultrasonographic maturation	74.2%	81.6%	0.459

AVF = arteriovenous fistula.

5 and 5D. The results obtained suggest that an ambulatory postoperative controlled exercise program with a flex band after AVF creation increases 1-month clinical AVF maturation.

After AVF creation, a rapid increase in laminar blood flow significantly increases nitric oxide (NO) and prostacyclin levels, inducing vasodilatation, inhibition of smooth muscle cell migration and proliferation, thrombosis, and platelet aggregation. The NO also combines with free radical oxygen form peroxynitrite, which stimulates metalloproteinase-2 (MMP-2) and MMP-9, destroying elastin fibers within the vessels and inducing a more permanent remodeling process.[29–31] This process, which includes vein dilation and an increase in artery and vein flow, is known as maturation, which should allow puncture of AVF 1 month after creation.[1]

Table 4 Logistic regression analyzing the effect of randomization group (exercise) and confounding factors (AVF localization) on the expected effect (clinical and ultrasonographic maturation)

			OR 95% CI	
Clinical maturation	P	OR	Lower	Upper
Exercise group	0.049	5.861	1.006	34.146
AVF localization (proximal)	0.109	3.776	0.744	19.158
Constant	0.303	1.907		
			OR 95% CI	
Ultrasonographic maturation	P	OR	Lower	Upper
Exercise group	0.184	2.403	0.660	8.754
AVF localization (proximal)	0.005	6.820	1.762	26.404
Constant	0.909	0.938		

AVF = arteriovenous fistula; CI = confidence interval; OR = odds ratio.

Early thrombosis and AVF maturation failure occur in 10%–37% of patients.[7] Numerous studies have analyzed clinical predictors of native AVF maturation failure. In general, the data suggest that age more than 65 years old, female sex, obesity, diabetes, lower arm AVF, extensive vascular disease, heart disease, and surgeon-specific factors constitute the most important clinical predictors of delay or failure in the vascular access maturation process.[28,32–35] In addition, small vessels (arteries <1.6 mm and veins <2–2.5 mm in diameter)[27,36] and lower BFR[37] are also related to lower permeability of native AVF. During surgery, intraoperative clinical (detection of thrill and murmur) and ultrasound measurements (mainly end-diastolic artery velocity after AVF creation, which can slightly improve isolated clinical findings) are also useful to predict AVF patency.[24]

Assessment of maturation is crucial at 4–6 weeks after AVF creation for early diagnosis of immature AVF and prompt referral for radiological or surgical treatments; excellent results are obtained using endovascular treatments to dilate stenotic lesions (the main cause of non-maturating AVF), or open surgical repairs (proximal AVF reanastomosis in anastomotic stenosis, ligature of collaterals, superficializations).[38–41] This approach could decrease the number of patients who start hemodialysis with central venous catheters.

Current vascular access guidelines suggest that preoperative exercises may be helpful to improve vascular access maturation.[1–3] A simple incremental resistance exercise training program could significantly increase the size of the cephalic vein commonly used in the creation of native AVF,[14] and these exercises have been significantly related to an increase in AVF maturation.[12–17,42]

However, exercise programs in the postoperative period have only been demonstrated to increase flows and venous diameters in very short time periods, but not to persist in time or to truly increase maturation.[15,17] Only one randomized controlled trial[18] has analyzed the effect of exercise after AVF creation in 50 AVF. That trial concluded that exercise was related to clinical but not ultrasonographic maturation (52% in the exercise group vs. 20% in control group, $P = 0.008$ and 88% vs. 68%, $P = 0.14$, respectively). However, that study had serious limitations: it was based on a non-ambulatory exercises program (performed during hemodialysis sessions only), it was designed with few patients (only 25 per group), there were no descriptions of thrombosis or losses to follow-up (a 0% thrombosis rate is extremely rare), and follow-up examinations were carried out too early (at 2 weeks, before the usual 1-month maturation period), which led to very low maturation rates (52% and 20%). In our study, we achieved higher and more reliable maturation rates (94.7% and 80.6% in the exercise and control groups).

Previous studies have shown that clinical examination had a sensitivity of 96% for predicting successful dialysis, but a specificity of only 21%, and vein diameter above 5 mm was slightly better than arterial velocity in predicting maturity (sensitivity: 83% vs. 67%, specificity: 68% vs. 65%). The authors concluded that 1 month after surgery, a new AVF with a thrill or a vein diameter >5 mm is mature.[43] Nevertheless, we used the following commonly employed criteria to define maturity: after ultrasound examination, a draining vein diameter ≥5 mm, skin–vein distance ≤6 mm, and BFR ≥500 mL/min.[19–21] Therefore in some patients with a good vein diameter (>5 mm) with thrill and a BFR between 400 and 500 mL/min, AVF use for hemodialysis can be considered. In our study, we observed that ultrasonographic examinations are more restrictive than clinical examinations (78.3% vs. 88.4%), and only one AVF deemed mature by ultrasound examination was considered immature by clinical examination (an AVF of the control group with a distal access).

Despite non-significant differences in the crude analysis, asymmetrical distribution of important variables was found in both groups ($P < 0.20$: sex, antiplatelet therapy, AVF localization, side). Analysis of confounding factors and subsequent stepwise logistic regression was performed to control these possible confounding factors. Localization of AVF was detected as a confounding factor in the relationship between the exercise program and clinical maturation (OR 5.861, 95% CI: 1.006–34.146). Exercise was significantly more useful in distal than in proximal AVF. In spite of all the limitations in this study, exercise should at least be taken into account after vascular access creation, especially in patients with distal native AVF.

We have not observed a higher crude increase in mean values of vein diameters or brachial artery flows after exercise compared with control group, because mean values are just a central tendency measure. Probably, more patients with small veins and low flow arteries in the exercise group achieved bigger enough veins and higher enough flows to finally be considered mature, compared with the control group. Therefore, exercise does not seem to increase vein diameter and AVF flow in all patients, but mainly in those with small veins and low flow arteries (again, as previously described, it seems to be more useful in distal than proximal AVF).

Analyzing the behavior of those AVF deemed as non-mature, we have noticed that seven were classified as clinically and ultrasonographically non-mature (six never achieved maturation, but one finally matured and was used after repeated venous PTA), eight were classified as ultrasonographically non-mature but clinically mature (two never matured, but six achieved late maturation without secondary procedures: four were successfully used for hemodialysis, and two matured but still in predialysis), and one as clinically non-mature but ultrasonographically mature (needed secondary procedures but maturation was never achieved). Hence, clinical maturation seems to be far more precise than ultrasonographic maturation in predicting real AVF maturation, and it reinforces the results of our study, where exercise may increase 1-month clinical (but not ultrasonographic) maturation.

The major limitations of our study were its single-center design and the limited number of patients. In addition, compliance to the exercise program could not be assessed in the exercise group (the increase in hand-grip strength at 1 month in the exercise group, compared with the control group, indirectly showed that there was a general compliance with the postoperative exercise program, increasing hand strength, but real home compliance and its degree could not be assessed because of the ambulatory study design). For these reasons, further studies with larger samples are required to confirm our results and evaluate the effect of ambulatory exercises on AVF maturity.

This trial was performed only with our institution founding (*Hospital Clinic* and *Fundació Clínic per la Recerca Biomèdica*, Barcelona, Spain), with no other grant support.

In conclusion, this study suggests that, in adult patients with chronic renal disease, a postoperative controlled exercise program after AVF creation may increase 1-month clinical maturation, especially in distal accesses. In spite of the absence of significant differences in ultrasound maturation, these results advocate that exercise programs should be taken into account to improve clinical maturation in distal AVF.

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