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ORIGINAL ARTICLE

Assessment of effects of upper extremity exercise with arm tourniquet on maturity of arteriovenous fistula in hemodialysis patients

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ABSTRACT

Objective: **This study was designed to investigate the effects of hand exercise using a tourniquet on arteriovenous fistula (AVF) maturity in patients with end stage renal disease.**

Methods: **Fifty patients were randomly allocated to 2 groups with 25 patients. After creating an AVF, in the control group, patients were asked to start doing simple hand exercise- opening and closing the fingers. In the second groups, patients underwent a structured isometric exercise program. The pre exercise and post exercise ultrasound examination were performed in the first 24 hours and 2 weeks after the operation respectively. Patients were also clinically evaluated at the end of the study.**

Results: **Post exercise ultrasound showed significant difference in the draining vein diameter, vein wall thickness, vein area and blood flow rate (BFR) (p-value: 0.009, 0.04, 0.02 and 0.02 respectively). The number of patients who had clinically mature AVFs in the case group was significantly more than the control group (13 vs. 5; p-value: 0.008).**

Conclusion: **We conclude that hand exercise using arm tourniquet affects most sonographic parameters which are associated with AVF maturity, and could be beneficial for acceleration of AVF clinical maturation.**

Key words: Arm tourniquet, AV fistula, Dialysis, Doppler evaluation, Isometric exercise, Ultrasonography

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INTRODUCTION

Since the introduction of hemodialysis (HD), vascular access has been the Achilles heel for this kind of renal replacement therapy (1). Dialysis Outcomes Quality Initiative (DOQI) guidelines consider arteriovenous fistula (AVF) as the recommended method of vascular access for HD (2-3).

After surgical creation of an AVF as the vascular access for HD, it typically needs time to reach the appropriate diameter and blood flow, or become "mature". AVF maturity can be assessed both clinically and ultrasonographically (4). In order to have sufficient time for maturation, it is important to construct the AVF early when renal failure is diagnosed. Depending on the maturity progression, current guidelines advise delaying initial cannulation for one to six months after AVF construction (5). However, many fistulas (28% to 53%) fail to mature adequately, and are not usable for dialysis (6-9). It is an important issue, especially in patients who require HD to be commenced early, and do not have enough time for AVF maturation.

Given the need to have a safe and stable vascular access for HD and the complications associated with using other AVF alternatives, it would be vital to find ways which can accelerate AVF maturation.

Selective obliteration of major venous side branches, resting enough until resolution of AVF swelling and doing hand-arm exercise are supposed to enhance AVF maturation (10). Forearm exercise, such as squeezing of a tennis ball either prior (11) or after (12) AVF creation has been suggested as helpful to acceleration of AVF maturation (11-12); however, the number of such studies is small, and they are not compared with control groups. Given the above, this study was designed to compare simple exercise to the supervised structured isometric exercise with tourniquet programme on the maturation of brachiocephalic fistulas.

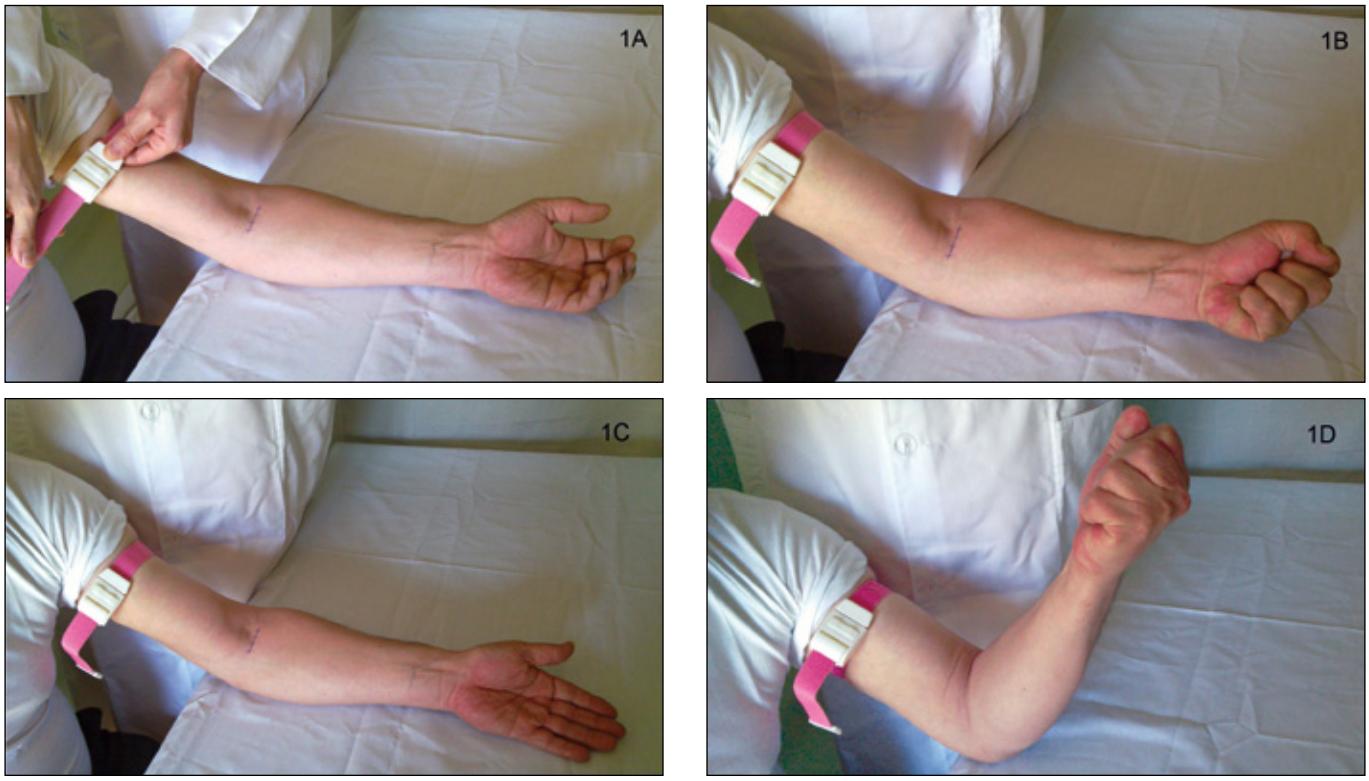

Fig. 1 - *Upper extremity exercise for the days 2 and 3:*
1A: Fasten the tourniquet to the marked point, 15 cm above the operation site. 1B: Clench the fist to contract the forearm muscles for 5 seconds. 1C: Open the fist, rest for 30 seconds, and repeat the previous steps 5 times. 1D: Flex the elbow to contract the arm muscles for 5 seconds. Then, extend the elbow to the normal position; rest for 30 seconds, and repeat the previous steps 5 times. Open the tourniquet, and tap the arm several times.

MATERIAL AND METHODS

Patients

A total of 55 ESRD patients referred for AVF construction entered this investigation after assessment of the arteriovenous system and determination of inflow and outflow sufficiency according to the criteria. All subjects read and signed the informed consent after a fully informative session.

A brachiocephalic AVF, with a side to end anastomosis, was created by a single vascular surgeon.

Exclusion criteria were age less than 14 years, having brachiobasilic AVF or distal AVF, central venous stenosis determined after taking history, physical examination and venography if indicated, atherosclerotic vascular diseases, arterial diameter less than 2 mm and being thin or obese (body mass index [BMI] <21 kg/m^2 and >25 kg/m^2 respectively [13]). Patients unable to exercise correctly and patients who require distal fistula were also excluded from the study.

Study design and interventions

According to the patients' file number, patients were randomly allocated into two groups (25 in the control group and 30 in the case group), and all patients underwent training on routine care of an AVF.

AVF was created in the non-dominant side. The first day after the operation, all patients were advised to rest and elevate the operated arm.

Two days after the operation, patients from the first group were asked to start a simple hand exercise - opening and closing the fingers.

In the second group, patients underwent a structured isometric exercise programme, designed by a sports medicine specialist, which commenced two days after the operation. The exercise programme was administered both on-site and at home. Training sessions were being held three days a week. At the end of each training session, patients were asked to repeat the exercise under physician's supervision. Patients were then advised to undergo the exercise programme four times a day (morning, noon, afternoon and night) at home. A pamphlet was given to the patients in which exercise instructions were explained in detail (Figs 1-4).

The exercise commenced with gentle movements of the upper extremity, and gradually increased in intensity with more contraction of the arm and forearm muscles. The isometric exercise included squeezing of a tennis ball, exercise with a dumbbell (0.5 or 1 kg) and flex-band

Fig. 2 - *Upper extremity exercise for days 4 and 5:*
2A: After fastening the tourniquet, squeeze the ball in the hand for 5 seconds. Then, open the hand; rest for 30 seconds, and repeat the previous steps 5 times. 2B: Extend the upper extremities; put the palms of the hands together to contract the arm muscles for 5 seconds; rest for 30 seconds, and repeat the previous steps 5 times. 2C: Try to lift a heavy table with both hands to contract the arm muscles for 5 seconds. Rest for 30 seconds, and repeat the previous steps 5 times. Open the tourniquet, and tap the arm several times.

exercise after fastening a tourniquet 15 cm proximal to the AVF. We increased tourniquet pressure gradually for each patient, and a mark was made on the tourniquet when the thrill was absent, and the bruit was present.

Assessment

AVF maturity was assessed both clinically and ultrasonographically. The pre-exercise and post-exercise ultra-

Fig. 3 - *Upper extremity exercise for days 6 to 10:*
Days 6 and 7: After fastening the tourniquet, repeat steps 2A and 2B. Then, flex the elbow while holding a 0.5 kg dumbbell. Repeat this exercise 5 times. Open the tourniquet, and tap the arm several times. Days 8 to 10: Repeat the aforementioned exercise, but using 1 kg dumbbell.

Fig. 4 - *Upper extremity exercise for days 11 to 13:*
After fastening the tourniquet, repeat steps 2A and 3 with 1 kg dumbbell. Then, 4A: Fix the flex-band; then, flex the elbow while pulling the flex-band; holds for 5 seconds. 4B: Extend the elbow, and rest for 30 seconds. Repeat this exercise 5 times. Open the tourniquet, and tap the arm several times.

sound examination were performed in the first 24 hours and two weeks after the operation respectively. The same assessment was performed in the control group.

A single radiologist who was not aware of patient group assessed all patients for draining vein diameter, vein wall thickness, skin-vein distance, vein area and blood flow rate (BFR) 2 cm from the anastomosis site. Draining vein diameter ≥6 mm, skin-vein distance ≤ 6mm and BFR ≥ 600 mL/min were considered as AVF ultrasonographic maturation criteria (14). Only patients who fulfilled all three criteria were considered to have an ultrasonographically mature AVF. Mature AVF is easily palpable clinically. It has a straight-superficial vein, with a length more than 10 cm. In addition, it has sufficient diameter and palpable thrill (15).

Clinical assessment of AVF maturation was performed at the end of the study (two weeks after the operation) by a single expert dialysis nurse who was not aware of patient group. AVFs were considered mature if they were easily palpable, relatively straight with >10 cm length of the superficial vein and had a uniform thrill on palpation (15).

Statistical analysis

Data were analyzed by statistical package for the social sciences 16 software (SPSS Inc., Chicago, IL, USA). Chi-square, independent sample *t* test and paired *t* test were used when appropriate. P values less than 0.05 were considered statistically significant.

TABLE I - BASELINE CHARACTERISTICS

		Case group (N:25)	Control group (N:25)	P-value
Age (year)		51.12±13.41	51.28±19.54	0.97
Sex	Men	21(84%)	19(76%)	0.36
	Women	4(16%)	6(14%)	

Age is presented as mean±SD, and sex distribution is presented as N (%)

RESULTS

Five patients in the case group did not correctly follow the exercise programme and were excluded from the final analysis. Therefore, data obtained from 50 patients were analyzed.

Baseline data

There was no statistically significant difference between the two groups in the mean age and sex distribution (Tab. I).

Ultrasonographic assessment:

Patients were assessed pre and post-exercise ultrasonographically. Although no statistically significant difference was found between the two groups in the pre-exercise ultrasonographic characteristics, post-exercise ultrasound revealed a statistically significant difference in draining vein diameter, vein wall thickness, vein area and BFR (Tab. II). All of the post-exercise ultrasonographic parameters were statistically significantly different from pre-exercise parameters in each group (P values for all parameters were <0.0001). AVF maturation status was then assessed based on the aforementioned ultrasonographic criteria. The numbers of patients with mature AVF in the case and control groups were 22 and 17, respectively, which was not statistically different (P value: 0.14).

TABLE II - COMPARISON OF PRE AND POST-EXERCISE ULTRASONOGRAPHIC CHARACTERISTICS BETWEEN TWO GROUPS

Parameter	Assessment time	Case	Control	P-value
Draining vein diameter (mm)	Pre-exercise	5.36±1.02	5.10±1.17	0.39
	Post-exercise	7.68±1.23	6.73±1.21	0.009
Vein wall thickness (mm)	Pre-exercise	0.28±0.05	0.31±0.07	0.10
	Post-exercise	0.53±0.10	0.47±0.10	0.04
Skin-vein distance (mm)	Pre-exercise	4.54±1.22	4.24±1.39	0.42
	Post-exercise	2.59±0.77	2.44±0.89	0.52
Vein area (mm)	Pre-exercise	0.24±0.09	0.21±0.09	0.28
	Post-exercise	0.47±0.13	0.39±0.12	0.02
BFR (mL/min)	Pre-exercise	439.80±181.81	411.44±187.01	0.58
	Post-exercise	870.32±246	727.92±167.09	0.02

All results are presented as mean±SD. Pre-exercise study was performed in the first 24 hours after the procedure. Post-exercise study was performed two weeks after the procedure. BFR, blood flow rate

Clinical assessment

According to the clinical assessment, the number of patients who had clinically mature AVF was significantly more than the control group (13 vs. 5; P value: 0.008).

DISCUSSION

Renal replacement therapy is vital for ESRD patients. Therefore, it is necessary to provide a durable, safe and stable vascular access for HD as soon as possible. Based on the evidence, the best choice for this purpose in these patients is AVF which needs time to become mature and usable (2-3). It would be beneficial if a measure can accelerate the maturation, and shorten the interval between AVF creation and utilization.

Despite no definitive evidence, some guidelines suggest hand exercise before and after AVF construction (11,16) because of its effects on vein diameter.

This clinical trial investigated the effects of hand exercise using arm tourniquet on AVF maturation. Unlike the few previous studies which have only assessed one parameter, not a set of criteria, we assessed different aspects of AVF maturity separately as well as the overall maturation.

Two different sets of criteria, clinical and ultrasonographic, were used in this study to assess AVF maturity.

Based on the Turmel-Rodrigues et al. study, ultrasound measurements at two to four months after the operation are considered highly predictive of AVF maturation (4). According to the ultrasonographic assessment, exercise using arm tourniquet was found to be effective on four important AVF maturity components including draining vein diameter, vein wall thickness, BFR and vein area; however, the number of patients who had ultrasonographically mature AVF was not significantly different between the two groups.

Similar to our findings about draining vein diameter, Leaf et al. (11) concluded that isometric hand exercise is an effective way to enhance AVF maturation, and decrease morbidity associated with vascular access. Similarly, the study by Oder et al. (12) found that hand exercise increases vein diameter by 9.3%, and therefore recommended hand exercise for better maturation. In addition, Khavanin Zadeh et al. (3) demonstrated that higher vein diameter leads to enhanced AVF maturation.

On the other hand, Rodriguez Moran et al. (17) found no increase in fistula blood flow, and therefore discouraged hand exercise in uremic patients. Instead of long-term effects, they verified the short-term effects of hand exercise on blood flow rate, so the difference could be because of different study design.

Apart from the aforementioned effects of exercise on AVF maturity, it is supposed that hand exercise increases muscle mass, which may enhance vein prominence, and decreases superficial fat (18). The latter effect was not proven in our study and we did not find a statistically significant difference between the two groups in skin-vein distance probably because of short duration of exercise.

According to the clinical assessment, only two out of four parameters were significantly different between the two groups (firmness and engorgement), but there was a significantly higher number of patients who had clinically mature AVF in the case group. This implies the efficacy of exercise using arm tourniquet on clinical aspects of the maturation process.

Regarding ultrasonographic criteria, hand exercise using arm tourniquet improved most parameters; however, overall maturation was not affected. This contrast may be because of cut off points considered as maturation criteria, but it does not disprove the efficacy of hand exercise using arm tourniquet in AVF maturation.

In summary, we conclude that hand exercise using arm tourniquet affects most sonographic parameters associated with AVF maturity, and could be beneficial for acceleration of AVF clinical maturation.

However, we strongly recommend further investigation in order to identify a more accurate clinical scoring system and ultrasonographic cut off points which can assess AVF overall maturation more reliably.

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Informed consent: All subjects read and signed the inform consent after fully informative session.

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