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Effect of intermittent compression of upper arm veins on forearm vessels in patients with end-stage renal disease

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Abstract

Native arteriovenous fistula is the best vascular access for chronic hemodialysis. Primary and long-term success depends, in part, on the state of arteries and veins at the time of the operation. The aim of our study was to investigate the effects of intermittent compression of upper arm veins on forearm vessels in patients with terminal renal disease. The study group was composed of 16 chronic hemodialysis patients who performed daily intermittent compression of the upper arm without vascular access by elastic band (Eschmarch). Ten chronic hemodialysis patients were included in the control group, which performed no specific activity. Forearm measurements were obtained at the beginning of the study and 4 and 8 weeks later during the course of intermittent compression of the upper arm veins. The forearm circumference and maximal handgrip strength were measured. The artery measures, including endothelium-dependent vasodilatation and forearm vein variables, were obtained by ultrasonography measurements. The forearm circumference, maximal handgrip strength, and artery variables, including endothelium-dependent vasodilatation, remained unchanged. The basal venous diameters (2.29 ± 0.19 mm at the beginning, 2.46 ± 0.19 mm after 4 weeks, and 2.53 ± 0.18 mm after 8 weeks) were significantly increased in the study group. The distensibility of veins was preserved in the study group. There were no significant changes in the control group. Our study demonstrated that daily intermittent compression of the upper arm veins increases the forearm vein diameter and preserves the distensibility of veins in patients with end-stage renal failure.

Key words: Veins, vascular access, hemodialysis

INTRODUCTION

Proper vascular access is of crucial importance for patients with end-stage renal failure who are on hemodialysis. Native arteriovenous fistulas are generally considered preferable in comparison with other vascular accesses, because they are less often associated with complications such as infection, pseudoaneurysm, venous hypertension, and vascular steal than prosthetic grafts.[1,2] Native arteriovenous fistulas also have a better patency rate compared to grafts.[3] Small-sized cephalic veins and atherosclerotic and small-sized arteries are suggested as being responsible for the primary failure of arteriovenous fistula creation.[4] The clinical assessment and ultrasound evaluation of vessels before the construction of native arteriovenous fistulas are very useful.[5]

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Elderly persons and diabetics are more prone to primary arteriovenous fistula failure because of unsuitable vessels.[6] Patients with chronic diseases are also known to have many cannulations of the forearm veins, which become sclerotic and useless for later arteriovenous fistula creation. The avoidance of cannulations of the veins of both forearms proximal to the wrist is therefore suggested, and the dorsum of the hand should be used for intravenous lines in patients with chronic renal failure.[7,8] It was shown that local physical training in chronic renal patients may have a beneficial effect on the forearm arteries and veins.[9] In addition to local physical training, clinical practice also suggests that intermittent compression of the upper arm veins by tourniquet or an Eschmarch belt before arteriovenous fistula construction may have a beneficial influence on the forearm veins. To our knowledge, however, no studies have evaluated this practice.

The purpose of our study was to investigate the effect of daily intermittent compression of the upper arm veins on the forearm arteries and veins in patients with end-stage renal disease.

PATIENTS AND METHODS

Patients

The study group was composed of 16 patients who performed intermittent compression of the upper arm veins. Their ages ranged from 21 to 68 years. The patients had been on hemodialysis for periods ranging from 11 months to 16.6 years. Causes of renal disease in the study group were chronic glomerulonephritis in 7 patients; diabetic nephropathy in 2 patients; and analgesic nephropathy, polycystic kidney disease, dysplastic kidney, chronic pyelonephritis, amyloidosis, renal vein thrombosis, and hypertensive nephrosclerosis each in 1 patient.

Ten chronic hemodialysis patients were included in the control group of patients who did not perform any special activity. Their ages ranged from 21 to 70 years. The patients had been on hemodialysis for periods ranging from 4 months to 4.1 years. Causes of renal disease in the control group were diabetic nephropathy in 3 patients; chronic pyelonephritis and polycystic kidney disease each in 2 patients; and Henoch Schonlein vasculitis, obstructive nephropathy, and ischemic nephropathy each in 1 patient.

The two groups were comparable by age (52.3 ± 16.0 years in study group vs. 48.7 ± 17.9 years in control group), weight (73.5 ± 14.9 kg in study group vs. 64.9 ± 15.6 kg in control group), smoking habits (two smokers in the study group and one smoker in the control group), number of patients with diabetes mellitus, and prescribed drugs potentially interfering with vascular tone. The groups were not matched by time on dialysis (mean, 6.4 ± 4.8 years in the study group vs. 1.5 ± 1.3 years in the control group; $p < 0.05$). The patients participated in the study voluntarily. The study was approved by the ethics committee, and written informed consent was obtained from all patients after they had been duly informed of the nature of the study.

Methods

Protocol of intermittent compression of the upper arm in the active group of patients

The intermittent compression of the upper arm veins without vascular access was performed by elastic band (Eschmarch). The patients were instructed that the pulse of the radial artery had to be palpable and were advised, on nondialysis days, to perform this activity six times a day for 1.5 min. On dialysis days, the same procedure was performed during the dialysis session to ensure the supervision of the dialysis staff.

Measurements

Forearm measurements were obtained at the beginning of the study and 4 and 8 weeks later during the course of intermittent compression of the upper arm veins. The forearm circumference, maximal handgrip strength, brachial artery variables (diameter before and after hyperemic test), radial artery variables (diameter, velocity), and forearm vein variables (basal venous diameter, venous diameter after placement of the tourniquet, and distensibility, which was calculated from these two diameters) were measured. The measuring locations of forearm veins were marked at the beginning of the study using water-resistant, harmless paint to ensure that all further measurements were made at exactly the same location.

Forearm circumference. The forearm circumference was measured at a 25% distance from the olecranon process to the wrist of the forearm where the intermittent compression of veins was performed.

Maximal handgrip strength. The maximal handgrip strength was measured using a hand dynamometer (Model AD 141; Aesculap, Tuttlingen, Germany). The pressure on the dynamometer scale is expressed in millimeters. The mean strength of two consecutive handgrips, each lasting approximately 3 s, was calculated.

Arteries. All measurements were performed by means of two-dimensional (B-mode) ultrasound and duplex Doppler scanning (Model 128 XP/10 computed sonography system, Acuson, Mountain View, CA, USA). A two-dimensional linear electronic probe (Acuson L7) at 7.0 MHz, a pulse-wave Doppler at 5.0 MHz, and a color Doppler at 5.0 MHz were used. The arterial flow velocity was measured by a pulsed Doppler signal at an up to 60° angle to the vessel, and the time-averaged flow velocity was calculated. Patients were advised to rest for 10 min at room temperature before measurements of the radial arteries in the wrist and cubital veins were performed on patients in a supine position. The radial arterial diameters and flow velocity were measured three times, and their mean values were calculated. The basal brachial artery diameters were measured three times, and their mean values were calculated. In this case, as well, the modified protocol proposed by Celermajer *et al.*[10] was used to estimate the endothelium-dependent vasodilatation of the brachial artery. The pneumatic tourniquet was placed proximally to the place where the brachial artery diameter was measured and inflated to a pressure of 250 mmHg for 4 min. The brachial diameter was measured 60 s after tourniquet deflation. The increase of brachial diameter was expressed as a percentage of the baseline value.

Veins. The same ultrasound and Doppler was used to measure vein variables. The vein diameter was measured three times at three previously marked locations on the forearm before and 1 min after placement of the pneumatic tourniquet around the upper arm (inflated to a pressure of 100 mmHg). The distensibility of veins was expressed as the percentage mean increase in tourniquet measurements.[9] To minimize the impact of a patient's hydration status on venous diameter, all measurements were always performed at the same time in relation to the hemodialysis session.

Statistics

The results are expressed as mean values ± SD for descriptive data and as mean values ± SE for comparative data. Repeated-measures analysis of variance (r-ANOVA) was used to compare data at baseline and after 4 and 8 weeks of intermittent compression of the upper arm veins. If the r-ANOVA was significant ($p < 0.05$), paired t tests were performed with Bonferroni adjustment for three-way comparison. The results of measurements were analyzed using computer software (SPSS package for Windows, Version 10.1, SPSS Institute, Chicago, IL).

RESULTS

The forearm circumference

The forearm circumference remained unchanged in the study group (25.69 ± 0.73 cm at the beginning, 25.50 ± 0.74 cm after 4 weeks, and 25.68 ± 0.75 cm after 8 weeks) and in the control group of patients (25.03 ± 1.21 cm at the beginning, 24.99 ± 1.22 cm after 4 weeks, and 25.00 ± 1.23 cm after 8 weeks).

Maximal handgrip strength

Maximal handgrip strength also remained unchanged in the study group of patients (23.4 ± 2.9 mm at the beginning, 23.9 ± 2.9 mm after 4 weeks, and 24.3 ± 2.8 mm after 8 weeks) and in the controls (21.66 ± 4.35 mm at the beginning, 20.98 ± 4.317 mm after 4 weeks, and 21.07 ± 4.23 mm after 8 weeks).

Arteries

No increase in the brachial artery diameters was found 4 and 8 weeks after the beginning of the study in the study group (4.17 ± 0.22 mm at the beginning, 4.15 ± 0.21 mm after 4 weeks, 4.18 ± 0.21 mm after 8 weeks) and in the control group of patients (3.80 ± 1.81 mm at the beginning, 3.80 ± 1.79 mm after 4 weeks, 3.79 ± 1.82 mm after 8 weeks). In addition, the endothelium-dependent vasodilatation in the study group (5.6 ± 0.5% at the beginning, 6.0 ± 0.6% after 4 weeks, 5.8 ± 0.5% after 8 weeks) and in the control group (5.4 ± 0.71% at the beginning, 5.3 ± 0.82% after 4 weeks, 4.9 ± 0.75% after 8 weeks) also remained unchanged.

The radial artery diameters in the study group (2.04 ± 0.11 mm at the beginning, 2.02 ± 0.10 mm after 4 weeks, and 2.04 ± 0.1 mm after 8 weeks) and in the control group (2.01 ± 0.11 mm at the beginning, 2.00 ± 0.11 mm after 4 weeks, and 1.99 ± 0.10 mm after 8 weeks), as well as the radial artery mean time-averaged velocity in the study group (15.1 ± 0.7 cm/s at the beginning, 15.3 ± 0.8 cm/s after 4 weeks, and 14.4 ± 0.8 cm/s after 8 weeks) and in the control group of patients (15.1 ± 0.6 cm/s at the beginning, 15.3 ± 0.8 cm/s after 4 weeks, and 14.9 ± 0.3 cm/s after 8 weeks), were found to be practically unchanged in both groups of patients.

Veins

The diameters of forearm veins before and after tourniquet placement and the distensibility of veins in the study and control groups of patients are presented in Table 1. The mean basal vein diameters (before placement of tourniquet) in the study group were found to be significantly increased after 4 ($p < 0.001$) and 8 weeks ($p < 0.001$) of intermittent compression of the upper arm veins. There was also a tendency toward the further increase of basal venous diameters in the second month of compression, but this was not significant. The mean vein diameters after placement of the tourniquet were also significantly increased after 4 ($p < 0.001$) and 8 weeks ($p < 0.001$) and also during the second month of daily compressions ($p = 0.029$) in the study group of patients.

The mean vein diameters in the control group remained unchanged. The distensibility of veins expressed as a percentage of increase of diameter after inflation also remained unchanged in both groups of patients.

The body weight did not change significantly at the beginning of the study (study group, 73.5 ± 3.9 kg; control group, 64.8 ± 4.9 kg), after 4 weeks (study group, 73.7 ± 3.9 kg; control group, 64.8 ± 5.0 kg), and after 8 weeks (study group, 73.6 ± 3.9 kg; control group, 65.0 ± 5.0 kg) in both groups.

DISCUSSION

One of the most vital factors highly influencing the quality of life and morbidity in patients with end-stage renal failure on hemodialysis is adequate vascular access. The native arteriovenous fistula, constructed from endogenous arteries and veins, still remains the preferred form of vascular access. Not only a skilled operator but also suitable veins and arteries are believed to be essential for adequate native arteriovenous fistula construction. It was shown that less early arteriovenous fistula failures occurred when the diameter of arteries and veins before fistula construction was greater than 1.6 mm.[4] There was also a significantly higher rate of successful fistula maturation in patients whose preoperative minimal cephalic vein size was greater than 2.0 mm.[11] Any activity that improves vessel status before arteriovenous fistula construction could be beneficial. It has been already shown that physical training may have beneficial effects

Table 1 The diameters of forearm veins before and after tourniquet placement and distensibility of veins in the study and control groups of patients

Group	At the beginning	After 4 weeks	After 8 weeks	r-ANOVA p value
Study group				
Mean vein diameter before compression (mm)	2.29 ± 0.19	2.46 ± 0.19	2.53 ± 0.18	< 0.001
		$p_{0-4} < 0.001$	$p_{0-8} < 0.001$ p_{4-8} = NS (0.077)	
Mean vein diameter after compression (mm)	2.95 ± 0.17	3.16 ± 0.17	3.22 ± 0.17	< 0.001
		$p_{0-4} < 0.001$ $p_{4-8} < 0.029$	$p_{0-8} < 0.001$	
Distensibility of veins (%)	33.2 ± 4.5 NS (1.000)	32.0 ± 4.0 NS (0.502)	29.8 ± 3.4	NS (0.396)
Control group				
Mean vein diameter before compression (mm)	2.45 ± 0.16	2.43 ± 0.15	2.44 ± 0.16	NS (0.478)
	NS (p = 1.000)	NS (p = 1.000)		
Mean vein diameter after compression (mm)	3.03 ± 0.26	3.02 ± 0.25	3.00 ± 0.25	NS (0.092)
	NS (p = 1.000)	NS (p = 0.199)		
Distensibility of veins (%)	23.54 ± 5.63 NS (p = 1.000)	24.52 ± 5.87 NS (p = 1.000)	23.44 ± 5.70	NS (0.349)

NS = not significant; p_{0-4} = p value comparing variable at the beginning of the study with Week 4 variable; p_{4-8} = p value comparing Week 4 variable with Week 8 variable; p_{0-8} = p value comparing variable at the beginning of the study with Week 8 variable. r-ANOVA = repeated-measures analysis of variance.

on arteries and veins in patients with chronic renal failure[9] or on veins alone.[12] The patients on hemodialysis with end-stage renal failure and with an already constructed arteriovenous fistula on the other arm were included in the study to assure compliance and better supervision during the study. Our measurements were performed by ultrasonography, which does not appear to be absolutely accurate when measuring vessels with a very small diameter. This seems to be a shortcoming of this and other studies.[10,12]

We believe that the fact that the study and control groups differ in terms of time spent on dialysis (6.4 years vs. 1.5 years) does not compromise the results. No direct comparisons between the study and control groups were made, because the purpose of the study was to see whether intermittent compression of the upper arm veins has a beneficial effect on vessel variables. The basic values in the study group served as a control to which the data obtained after 8 weeks of intermittent compression were compared. The control group was integrated in the study to ensure that changes detected in the study group can be attributed to intermittent compression rather than erroneous measurements.

The results of our study showed that intermittent upper arm compression of veins has no influence on forearm circumference, maximal handgrip strength, brachial and radial artery diameters, radial artery flow velocity, and on endothelium-dependent vasodilatation. Such results were somehow expected, because both groups of patients did not perform any physical training. Conversely, intermittent compression of the upper arm veins significantly improved the diameter of forearm veins before and after tourniquet placement in the study group, whereas no changes in forearm vein diameter were observed in the control group. Despite the increased native venous diameter, the distensibility of forearm veins remained unchanged. The modest but significant enlargement of forearm vein diameter after intermittent compression of the upper arm veins for 8 weeks is probably the result of the intermittent increase of forearm venous pressure, which led to venous distension and preserved distensibility. A similar situation that could lead to increased intravenous pressure occurs during pregnancy, when increased intraabdominal pressure or direct pressure on the iliac veins by the gravid uterus is known to result in increased pressure on the distal venous system. The study performed by Rabhi *et al.*[13] demonstrates that the increase in lower limb venous pressure seen during pregnancy leads to venous overdistension. The mean diameters of saphenous veins increased significantly, whereas vein distensibility decreased. We believe that the preserved distensibility of veins in our study was the result of intermittent daily compression of veins, which did not last as long as the compression of gravid uterus on veins in pregnancy. Compression during gravidity is continuous and lasts longer. The intermittently increased forearm venous pressure induced by the compression of upper arm veins in our study is high enough to lead to the increase of forearm venous diameter without jeopardizing venous distensibility, which is also important for effective arteriovenous fistula construction.

Our study demonstrated that intermittent daily compression of the upper arm veins increases forearm venous diameter with preserved distensibility in patients with end-stage renal failure. This activity could be beneficial for renal patients with suboptimal venous diameters before the creation of native arteriovenous fistula.

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