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Effects of Handgrip Training and Intermittent Compression of Upper Arm Veins on Forearm Vessels in Patients With End-stage Renal Failure

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Abstract: The purpose of our study was to assess the influence of handgrip training and intermittent compression of the upper arm veins on forearm arteries and veins. Eighteen chronic hemodialysis patients performed daily handgrip training for 8 weeks using a rubber ring, together with daily intermittent compression of the upper arm veins by elastic band. The forearm circumference, maximal handgrip strength, and arterial and vein parameters, including endothelium-dependent vasodilatation, were measured at the beginning, and after 4 and 8 weeks (using ultrasound scanning). The maximal handgrip strength and forearm circumference increased significantly. The radial artery diameters were significantly higher after 8 weeks of training (1.89 mm ± 0.10 at the beginning, 1.95 ± 0.10 mm after 8 weeks, $P = 0.007$), and endothelium-dependent vasodilatation was also found to be increased after 4 and 8 weeks of both activities. The venous parameters before tourniquet placement increased significantly after 8 weeks (2.40 ± 0.16 mm at the beginning, 2.62 ± 0.17 mm after 8 weeks, $P = 0.014$), and the venous parameters after tourniquet placement increased significantly after 4 and 8 weeks (3.36 ± 0.17 mm at the beginning, 3.51 ± 0.18 mm after 4 weeks, $P = 0.009$), 3.68 ± 0.18 mm after 8 weeks, $P < 0.001$). The distensibility of veins was preserved. Our results showed that handgrip training and intermittent compression of the upper arm veins, performed daily, increase the diameter of forearm arteries and veins and improve endothelium-dependent vasodilatation. **Key Words:** Arteries, Handgrip training, Hemodialysis, Intermittent compression, Veins.

Adequate vascular access is one of the most important factors having a significant influence on morbidity and quality of life in patients with end-stage renal failure who are on hemodialysis. The native arteriovenous fistulas are considered to be the most appropriate because of the lower frequency of interventions and complications once they mature (1). The artery and vein status before construction of the native arteriovenous fistula is very important (2), because it is known that atherosclerotic and/or small-sized arteries and small-sized cephalic veins are mostly responsible for the primary failure of arteriovenous fistula construction (3). The number of elderly patients, patients with diabetes and those with peripheral vascular diseases continues to increase (4), which in turn increases the risk of native arteriovenous fistula failure.

It has been shown that local physical training in patients with end-stage renal disease may have a beneficial effect on forearm arteries and veins (5), and that intermittent compression of the upper arm veins alone improved the diameter of forearm veins (6). The purpose of our study was to assess the influence of both activities (i.e. handgrip training and intermittent compression of the upper arm veins, on the forearm arteries and veins).

PATIENTS AND METHODS

Patients

Eighteen patients (aged 15–65 years; mean age 40 ± 17 years; nine men, nine women) with end-stage renal disease were included in the study. To ensure proper supervision of the procedures, only patients on hemodialysis were included. The patients had previously been on hemodialysis for 1 month to 28.3 years, three times weekly, 4–5 h per

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session. A native arteriovenous fistula was used as vascular access in all patients. The causes of renal failure were: chronic glomerulonephritis (eight), diabetic nephropathy (four), chronic pyelonephritis (three) and analgetic nephropathy, hypertensive nephrosclerosis and polycystic renal disease in one patient each.

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

Handgrip training and intermittent compression of upper arm veins protocol

The patients were asked to perform handgrip training with the arm without vascular access, using a rubber ring (4.5 cm inner and 7 cm outer diameter; maximal compression force 50 N). They were asked to squeeze the rubber ring 20 times per min for altogether 30 min every day. They were additionally asked to perform intermittent compression of the upper arm veins by elastic band (Eschmarch) six times per day for 1.5 min. The patients were instructed that the pulse of the radial artery had to be palpable during compression. Both activities were performed for altogether 8 weeks. On dialysis days, both procedures were performed during the dialysis session and supervised by the dialysis staff.

Measurements

The following parameters were measured at the beginning of the study, and 4 and 8 weeks later during the course of both activities (handgrip training and intermittent compression of the upper arm).

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.

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 average 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, using a 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 were used. The arterial flow velocity was measured by a pulsed Doppler signal at up to a 60-degree angle to the vessel. The patients were advised to rest for 10 min at room temperature before undergoing measurements of the radial arteries in the wrist and forearm veins while in supine position. The radial arterial diameters, flow velocity and the basal brachial artery diameters were measured three times and their mean values calculated. The modified protocol proposed by Celermajer et al. (7) 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 mm Hg 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 the vein parameters. 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 mm Hg). The distensibility of veins was expressed as a percent increase of the vein diameter after inflation (5,6). In order to minimize the impact of a patient's hydration status on the vein diameter, all measurements were always performed at the same time in relation to the hemodialysis procedure.

Statistics

The results are expressed as mean values ± SD for descriptive data and as mean values ± SE for comparative data. A repeated-measures analysis of variance (r-ANOVA) was used to compare data at baseline and after 4 and 8 weeks of both activities. 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 the SPSS package for Windows (version 10.1) (SPSS Inc., Chicago, IL, USA).

RESULTS

Forearm circumference

The mean forearm circumference slightly but significantly increased from 24.89 ± 0.74 cm before both activities to 25.28 ± 0.73 cm after 4 weeks ($P = 0.024$), and to 25.22 ± 0.71 cm after 8 weeks ($P = 0.017$) of both activities.

TABLE 1. *Effect of handgrip training and intermittent compression of the upper arm on forearm arteries*

Variable	At the beginning	After 4 weeks	After 8 weeks	r-ANOVA *P*-values
Diameter arteria radialis (mm)	1.89 ± 0.10	1.90 ± 0.09 NS ($P = 1.000$)	1.95 ± 0.10 $P = 0.007$	$P = 0.005$ –
arteria radialis flow velocity (cm/s)v	14.8 ± 0.6	15.6 ± 0.6 NS ($P = 0.371$)	15.1 ± 0.6 NS ($P = 1.000$)	NS ($P = 0.304$)
arteria radialis blood flow (mL/min)	26.3 ± 3.5	28.4 ± 3.6 NS ($P = 0.254$)	28.3 ± 3.2 NS ($P = 0.562$)	NS ($P = 0.228$)

NS, not significant; r-ANOVA, repeated-measures analysis of variance.

Maximal handgrip strength

The maximal handgrip strength increased significantly from 24.7 ± 1.7 mm before both activities to 28.3 ± 1.9 mm after 4 weeks ($P = 0.001$), and to 29.1 ± 1.7 mm after 8 weeks ($P < 0.001$) of both activities.

Effects of handgrip training and intermittent compression of the upper arm on forearm arteries

The effects of both activities on the radial arteries are presented in Table 1. The radial artery diameters remained unchanged for the first 4 weeks, but were significantly increased after 8 weeks ($P = 0.007$) of both activities. However, the flow velocity and blood flow remained almost unchanged.

The brachial artery diameters remained unchanged during both activities (3.87 ± 0.17 mm at the beginning, 3.86 ± 0.16 mm after 4 weeks, 3.82 ± 0.17 mm after 8 weeks). Endothelium-dependent vasodilatation increased significantly after 4 ($P < 0.001$) and after 8 weeks ($P < 0.001$) of both activities (7.2 ± 0.7% at the beginning, 10.8 ± 0.7% after 4 weeks, 12.3 ± 0.6% after 8 weeks).

Effects of handgrip training and intermittent compression of the upper arm on forearm veins

The effects of both activities are presented in Table 2. The average vein diameters before placement of the tourniquet remained unchanged after 4 weeks, but were significantly increased after 8 weeks ($P = 0.014$) of both activities. The average vein diameters were significantly higher after 4 ($P = 0.009$) and after 8 weeks ($P < 0.001$) of both activities. The distensibility of veins remained unchanged after 4 and 8 weeks of handgrip training and intermittent compression of the upper arm.

DISCUSSION

Not only for the experienced surgeon (8), but also the status of arteries and veins is important for accurate arteriovenous fistula construction (3). Recently, we performed two studies. In the first, we studied the impact of handgrip training on forearm arteries and veins in 14 patients with end-stage renal disease who were on hemodialysis. Significant changes in maximal handgrip strength, diameter of forearm arteries and veins, and in endothelium-dependent vasodilatation were found after 8 weeks of training, while the increase in forearm circumference was not large enough to be statistically significant (5). In the second study, another group of 16 patients with end-stage renal disease who were on hemodialysis, performed intermittent compression of the upper arm veins for 8 weeks. As expected, no increase in forearm circumference and maximal handgrip strength was noted. A significant increase in the diameter of forearm veins was detected, while no changes in arteries, including endothelium-dependant vasodilatation, were found (6). The enlargement of forearm veins after 8 weeks of intermittent compression of the upper arm veins was believed to be the result of the intermittent increase of forearm vein pressure, which led to venous distension.

TABLE 2. *Effect of handgrip training and intermittent compression of the upper arm on forearm veins*

Variable	At the beginning	After 4 weeks	After 8 weeks	r-ANOVA *P*-value
Average vein diameter before compression (mm)	2.40 ± 0.16	2.50 ± 0.17 NS ($P = 0.349$)	2.62 ± 0.17 $P = 0.014$	$P = 0.002$ –
Average vein diameter after compression (mm)	3.36 ± 0.17	3.51 ± 0.18 $P = 0.009$	3.68 ± 0.18 $P < 0.001$	$P < 0.001$ –
Distensibility of veins (%)	43.3 ± 4.2	43.4 ± 4.0 NS ($P = 1.000$)	42.6 ± 3.6 NS ($P = 1.000$)	NS ($P = 0.933$) –

NS, not significant; r-ANOVA, repeated-measures analysis of variance.

The purpose of the present study was to assess whether both activities together had any further benefit over handgrip training or intermittent compression of the upper arm veins alone. Both activities were performed in the very same way as in the two studies mentioned above (5,6). The forearm circumference and maximal handgrip strength increased significantly, which is in concordance with the results of our previous study of handgrip training (5), and is therefore believed to be the result of handgrip training alone. Furthermore, in both cases, the increase in artery diameter and endothelium-dependent vasodilatation were found to be statistically significant. We believe this to be also due to handgrip training alone, since a similar observation was noted in the first study of handgrip training (5), but not in the second-intermittent compression (6). The only parameter that increased significantly in all three studies was the vein diameter. It is therefore impossible to estimate to which extent this may be attributed to either handgrip training or intermittent compression of the upper arm. Given that the increase in vein diameter is not larger than in previous studies, where each procedure was studied separately (5,6), it seems that a combination of the two methods has no additional benefit over each procedure being performed alone. The distensibility remained unchanged as in the previous two studies. It should be noted, however, that sonography is a highly operator-dependent method that can result in technical errors, especially when measuring vessels with a very small diameter. This also appears to be a shortcoming of this and similar studies (5–7).

According to our experience, handgrip training is the preferred activity because it is simple to perform and significantly improves both the forearm arteries and veins in patients with end-stage renal disease. There is the impression that both activities performed together did not bring additional benefit to veins, although a direct comparison was not made. Whether these activities improve the success rate of arteriovenous fistula function or even improve steal syndrome in some patients remains to be clarified in further studies.

In conclusion, our results showed that handgrip training and intermittent compression of the upper arm veins, performed daily, increases the diameter of forearm arteries and veins and improve endothelium-dependent vasodilatation.

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