Quantification of Optimal Strength and Frequency of Grip Exercises in Patients After Autogenous Arteriovenous Endovascular Fistula

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Introduction. To observe the hemodynamic changes of the upper limb cephalic veins in patients with ESRD who were pre-treated with hemodialysis and required an arteriovenous internal fistula after grip exercise at different grip strengths and frequencies, and to explore the optimal grip exercise strength and frequency to promote blood circulation in the upper limb cephalic veins.

Methods. 200 patients aged ≥ 18 years who had undergone internal fistula surgery were selected and divided into 2 groups, 100 patients in each group were divided into groups A and B. Group A determined the appropriate grip strength; group B used an electronic grip strength device to perform grip strength exercise at 4 frequencies of 15, 20, 25, and 30 times/min under the appropriate grip strength determined in group A. The changes in cephalic venous hemodynamics at different frequencies were observed. The hemodynamic changes of the cephalic vein at different frequencies were observed.

Results. When the grip strength was 70 to 100% of the maximum grip strength, the cephalic venous blood flow velocity and vascular pressure increased significantly compared to the resting state ($P < .01$).

Conclusions. Grip strength exercise can promote blood circulation in the cephalic veins of the upper limb, with 70 to 100% of the maximum grip strength and 25 exercises/min being the best method. This conclusion can provide a reference basis for clinical guidance on functional exercise of the upper limb and promotion of blood circulation in the cephalic veins of the upper limb and maturation of AVF in patients after AVF surgery.

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INTRODUCTION

In recent years, end stage renal disease (ESRD) has become a global public health problem that threatens human health. About 93% of ESRD patients choose hemodialysis (HD) as their treatment.[1] Vascular access is the "lifeline" for HD patients,[2] and the autogenous arteriovenous fistula (AVF) is internationally recognized as the

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most effective way of providing access to the arteries. The AVF is a surgical vascular access to the radial artery-cephalic vein in the upper limb of patients with ESRD for HD. The most common clinical approach is an anastomosis of the radial artery and cephalic vein end-to-end in the distal forearm. To facilitate the patient's daily life, the AVF is preferred to be established in the non-dominant hand.[3] The AVF needs to be used after maturation, which usually occurs 4 to 8 weeks after surgery.[4] After the AVF is established, the cephalic vein becomes the main channel for the patient's body surface puncture to drain blood during HD, called the draining vein (DV). It has been confirmed that the DV diameter and DV blood flow are the main markers for determining the maturity of the AVF at the wrist.[5-7] With the widespread use of AVF in clinical practice, the problem of AVF maturation has gradually emerged as a major challenge in clinical use,[8] and the literature generally reports that the immaturity rate of AVF can range from 30 to 60%,[5,9,10] with insufficient blood flow being at the core of its immaturity. Numerous studies[11-16] have pointed out that instructing patients to perform fist clenching exercises or ball clenching exercises after AVF can lead to thickening of the patient's cephalic veins, increased blood flow and improved AVF maturation rates. However, fewer studies have been reported on specific exercise methods, such as the amount of strength and frequency of exercise. In this study, the changes in cephalic venous blood flow velocity, vascular pressure, vascular diameter and blood flow in patients with pre-established AVF were observed by color-doppler ultrasound (CDU) before and after exercise with an electronic grip on the non-dominant limb at different strengths and frequencies to investigate and quantify the optimal grip exercise pattern to promote cephalic venous blood circulation in the upper limb. The results of the study are reported below. The results of the observational study are reported below.

MATERIALS AND METHODS

Study Population

A convenience sampling method was used to select patients with ESRD who were admitted to our department from November 2023 to July 2024, who were pre-treated with hemodialysis and required an arteriovenous internal fistula, and all patients were willing to accept the pilot study and could actively cooperate. The trial was planned and conducted in accordance with the requirements of the hospital ethics committee and was approved by the hospital ethics committee. A total of 200 patients were included and divided into 2 groups A and B. Inclusion criteria: diagnosed uremia; age ≥ 18 years; unimpeded operative cooperation; all patients with AVF established on the non-dominant upper limb; informed consent and voluntary participation. Exclusion criteria: history of neurological or psychiatric diseases; history of upper limb trauma and surgery, hand dysfunction; history of severe cardiovascular and cerebrovascular diseases, etc. There were 100 cases in Group A, 48 males and 52 females, aged 18 to 65 years, mean age (51.36 ± 9.79); 100 cases in Group B, 53 males and 47 females, aged 18 to 63 years, mean age (49.85 ± 11.22); the differences were not statistically significant when comparing the general data of age and gender between the 2 groups ($P > .05$).

Research Methods

Instrumentation and quality control

1) Instruments and equipment. VINNO Q5 portable ultrasound diagnostic instrument (model: VINNO Q5, equipped with 7L high frequency probe, manufactured by Feiyinuo Technology Co., Ltd.); CAMRY electronic grip strength device (model: EH101, Guangdong Xiangshan Weighing Instrument Group Co.)
2) Measuring personnel. The whole test was carried out by the same professional operator using the ultrasound diagnostic instrument.
3) Place, time and room temperature control. The whole study was conducted in the doctor's office of the hemodialysis center, and the uniform test time was from 14:00 to 18:00. The room temperature was air-conditioned and controlled, and the temperature was maintained at 25 ℃.

Measurement sites and methods.

1) Measurement site. All locations measured were cephalic veins, fixed in the distal 1/3 of the forearm of the upper limb.[17] The patient's

cephalic vein at this location was first located with the CDU and marked with a marker to facilitate measurement.

2) Measurement method. Using a VINNO Q5 portable ultrasound diagnostic instrument with a probe frequency of 7 L. The measurement method follows the recommendations of the guideline,[18] the patient is placed in a sitting position with the upper limb fully exposed and naturally extended, the probe is placed lightly on the skin and a cross-sectional view is made along the vascular path in B mode to measure and record the diameter of the vessel (select a vessel site that is flat, free of tumor-like dilatation, curvature and turbulence, and avoid branching). After the spectral curve has stabilized, freeze and take a screenshot of the spectral curve, measure and record the mean blood flow velocity (Vmean) and blood flow rate: Blood flow was calculated as Q = A(pr2) × V × 60s (Q represents blood flow in standard units of ml/min; A represents vessel area; V represents mean blood flow velocity in standard units of cm/s; s represents seconds),[19] and the amount of coupling agent was increased appropriately during the measurement, with the examiner holding the probe gently to avoid pressing on the vessel.

Grip strength exercise method. The study was divided into 2 processes, i.e. according to 2 groups A and B in sequence. Throughout the study, one researcher was fixed to explain the details of grip strength exercise essentials, grip strength and grip frequency in detail to ensure that the subjects understood them correctly and implemented them smoothly.

Group A) Determine the appropriate grip strength exercise. According to urn Changshui *et al*,[20] grip strength values measured in the seated position were greater and statistically significant, therefore the grip strength of the patients in this study was chosen to be measured in the seated position. According to the standard grip strength test posture,[21] the patient was placed in a seated position with both feet naturally on the ground, knees flexed at 90°, hips flexed, shoulders inward in a neutral position, elbows bent at 90° and forearms in a neutral position. The maximum grip strength (MGS) of the patient's non-dominant upper limb was first measured using an electronic grip strength device. The patient held the electronic grip strength device by its inner and outer grips with their maximum strength until the value on the display of the grip strength device did not jump, and the maximum value was determined by taking two consecutive tests with an interval of 60 seconds between tests.[22] During the measurement, the patient should not touch the body or clothing with the electronic grip and should not bend the arms, bend the waist or stir the feet. Calculate and record the values of 90, 80, 70, 60, 50, and 40% MGS based on the patient's MGS (during the conduct of the pre-experiment, it was found that the patient's grip strength was lower than the resting state in terms of cephalic venous vascular pressure and peak blood flow velocity at 10 to 30% MGS, in order to avoid excessive consumption of research time, manpower and material resources. (Therefore the 10 to 30% MGS strength experiment was removed). Patients were instructed to use an electronic grip strength device on the non-dominant upper limb at MGS; 90, 50, and 40% MGS; respectively, and to rest for at least 15 min after each grip,[23] to prevent interference with the hemodynamic measurements from two different grips before and after. Immediately after each grip, the patients were monitored by the measurement staff with a CDU for changes in cephalic vein vessel diameter, peak blood flow velocity and vessel pressure at the distal forearm marker of their upper limbs, and conclusions were drawn after statistical analysis.

Group B) Selection of grip exercise frequency under the appropriate grip strength determined by group A. Patients were first rested in a seated position for 15 min, and an electronic grip device was used to grip 15 times/min, 20 times/min, 25 times/min, and 30 times/min at the appropriate strength determined by group A. Each frequency was gripped for 1 min, and rested for at least 15 min after each operation,[23] and then the other frequencies were performed. For the accuracy of the operation, the researcher used the recorded audio "Grip, Loose, Grip" to repeat the instruction. Immediately after each frequency of operation, the patient's venous blood flow velocity, vessel diameter and blood flow were measured by a diagnostic ultrasound device. The data was

statistically processed and conclusions were drawn (if the blood flow rate continued to increase, the selection of the grip frequency was continued at an increasing rate of 5 times/min without causing discomfort to the subject until the maximum blood flow rate was achieved, which was achieved at the current frequency in this trial).

Data collection and recording. The cephalic venous blood flow velocity, vessel diameter, vessel pressure and blood flow detected by the ultrasound professional at different grip strengths and grip exercise frequencies were carefully recorded by the same investigator during the experiment; data were double-entered and checked for consistency using Epidata 3.1. If data inconsistencies were found, the original data were promptly consulted for confirmation.

Statistical Methods

IBM SPSS Statistics 25.0 was used for statistical analysis of the data. Data were expressed as`x ± s. Statistical tests were all performed using a two-sided test, and differences were considered statistically significant if $P < .05$. Data results for measures obeying normal distribution were expressed as mean ± standard deviation, while median or interquartile spacing was chosen for those not obeying normal distribution. Changes in vessel diameter, blood flow, peak velocity and vessel pressure were first analyzed by one-way ANOVA, and if the overall difference was statistically significant, further two-way comparisons between groups were made, and the least significant difference (LSD) method was used for two-way comparisons of means in ANOVA.

RESULTS

Changes in Cephalic Venous Blood Flow Velocity, Vascular Diameter and Vascular Pressure at Different Grip Strengths in Group A

Analysis of variance (ANOVA) showed that the changes in cephalic vein diameter with decreasing grip strength after maximum grip strength were not statistically significant ($P > .05$) compared to the resting state pair. In contrast, the changes in venous blood flow velocity and vascular pressure were statistically significant ($P < .01$), with a gradual decrease in cephalic venous blood flow velocity and vascular pressure with decreasing grip strength; a two-by-two comparison revealed that the differences in cephalic venous vascular pressure and blood flow velocity compared to the resting state when grip strengths of 70, 80, 90, and 100% MGS were used statistically significant ($P < .05$), as detailed in Table 1.

Changes in Venous Blood Flow Velocity, Vessel Internal Diameter and Blood Flow in Group B With Different Grip Exercise Frequencies

As shown by ANOVA, the effects of different frequencies on cephalic vein diameter, blood flow velocity and blood flow were statistically significant ($P < .01$) compared with the resting state, and the two comparisons showed that: with the increase of grip exercise frequency, the change of blood vessel diameter was not obvious; the cephalic vein blood flow velocity and blood flow continued to increase under different grip exercise frequencies, and when the grip exercise frequency was 25 times/min, the blood flow velocity When the frequency of grip exercise was 25 times/min, the blood flow velocity

Table 1. Changes in Cephalic Venous Hemodynamics at Different Grip Force Levels

Grip strength	Vessel diameter (cm)	Peak blood flow rate (cm/s)	Vascular pressure (mmHg)
Resting condition	0.23 ± 0.03	11.38 ± 1.86	0.06 ± 0.01
MGS	0.29 ± 0.03	16.90 ± 2.19[a]	0.12 ± 0.02[a]
90% MGS	0.31 ± 0.03	15.27 ± 1.67[a]	0.11 ± 0.02[a]
80% MGS	0.27 ± 0.03	14.31 ± 1.64[a]	0.10 ± 0.02[a]
70% MGS	0.31 ± 0.03	12.83 ± 1.80[a]	0.07 ± 0.01[a]
60% MGS	0.27 ± 0.00	11.76 ± 1.67	0.06 ± 0.01
50% MGS	0.26 ± 0.03	11.29 ± 1.73	0.05 ± 0.02
40% MGS	0.23 ± 0.03	9.94 ± 1.57	0.05 ± 0.02
F	0.382	182.976	260.431
P	.857	< .01	< .01

Note. A indicates statistically significant blood flow velocity and vascular pressure after grip compared to resting state ($P < .05$); the rest of the groups were not statistically significant in a two-by-two comparison ($P > .05$).

Table 2. Changes in Cephalic Venous Hemodynamics with Different Grip Exercise Frequencies

Frequency	Vessel diameter (cm)	Peak blood flow rate (cm/s)	Blood Flow (mL/min)
Resting condition	0.22 ± 0.03	9.91 ± 1.17	15.87 ± 8.06
15 times/min	0.23 ± 0.03[a]	11.41 ± 1.17[a]	24.30 ± 11.39[a]
20 times/min	0.25 ± 0.03[ab]	12.31 ± 1.12[ab]	29.75 ± 12.88[ab]
25 times/min	0.26 ± 0.03[abc]	13.21 ± 1.10[abc]	39.46 ± 14.92[abc]
30 times/min	0.25 ± 0.03[abd]	12.51 ± 1.15[abd]	27.80 ± 12.00[abd]
F	27.369	122.330	49.968
P	< .001	< .001	< .001

Note. A represents $P < .05$ compared to resting state, B represents $P < .05$ compared to 15 beats/min, C represents $P < .05$ compared to 20 beats/min; and D represents $P < .05$ compared to 25 beats/min.

reached the maximum (13.21 ± 1.10) cm/s and the blood flow reached the maximum (39.46 ± 14.92) mL/min, see Table 2 for details.

DISCUSSION

Functional upper limb exercise using 70 to 100% of maximum grip strength has the best effect on the cephalic vasculature.

In recent years, researchers at home and abroad have continued to explore methods to promote AVF maturation. Functional exercise, physiotherapy, pharmacological intervention, and surgical treatment have all produced good results; shortening the maturation time and extending the life of the AVF. Among them, functional exercise is the most commonly used method, which is safe, convenient and economical. The most commonly used exercise modality in functional exercise clinically is grip exercise.[24] It has been shown that grip exercise not only dilates and fills the AVF vessels, improves blood flow during dialysis and promotes the maturation of the internal fistula, but also reduces complications such as AVF stenosis and thrombosis, thus prolonging the life of the AVF.[25] The mechanism of grip exercise to promote AVF maturation is through rapid repetition of "grip-release" fist to squeeze muscle groups, stimulate musculoskeletal contraction, enhance muscle strength, promote venous and lymphatic return to the upper limb, and increase the internal diameter of AVF vessels and blood flow to improve AVF blood flow Kinetics. When a patient makes a fist, the muscles of the dorsal interosseous muscles of the palm, the short flexors of the little finger, the thumb retractors, the short flexors of the thumb and the deep flexors of the forearm, the long flexors of the thumb and the superficial flexors of the fingers contract sharply, generating pulsatile pressure on the veins and causing rapid flow of venous blood towards the heart, thus increasing the tangential and pulling forces on the endothelial cells of the blood vessels and causing a biochemical effect on the endothelial cells to release diastolic factors such as carbon monoxide and prostacyclin. The combined effect of these factors leads to vasodilation, which increases the internal diameter, cross-sectional area, mean blood flow velocity and blood flow, and promotes AVF maturation. Repeated grip strength exercise accelerates the rapid flow of venous blood to the heart, promotes blood and lymphatic circulation in the affected limb, helps to reduce blood viscosity, and reduces AVF thrombosis.[26,27] Therefore, grip strength exercises for patients are particularly important in promoting AVF.

In this study, we found that the differences in the degree of improvement in venous hemodynamics when patients performed 70% MGS to MGS grip strength were all significant when compared to the resting state. However, the majority of ESRD patients suffer from poor circulation, weakness and frailty, making it difficult for them to use their maximum strength for grip exercise, resulting in reduced compliance. From a humane point of view, it was considered "whether the patient could use the least amount of exercise to improve the quality of the AVF cephalic vessels and minimize the patient's burden". The patient can exercise with 70% MGS, which not only saves 30% of the grip force, but also improves the hemodynamic profile of the cephalic vessels in an equally effective way, resulting in improved AVF vascular quality, such as increased cephalic blood flow velocity, increased vascular pressure and better AVF maturation.

The functional upper limb exercise using 70 to 100% of maximum grip strength produced a significant boost to cephalic venous blood flow velocity and blood pressure.

A comparison with resting cephalic vein hemodynamics revealed that the use of various grip strengths did not have a statistically significant effect on the change in vein diameter ($P > .05$), and that there was a significant change in blood flow velocity and vascular pressure ($P < .05$). The results showed that when the strength of the grip exercise was reduced, there was a significant reduction in both cephalic venous blood flow velocity and vascular pressure. After statistical analysis, it was found that there was a statistically significant difference ($P < .05$) when grip strength was performed using 70% MGS to MGS compared to the resting state. The reasons for this were explored as follows: 1) Patients have the greatest effect of muscle compression on blood vessels at maximum grip strength. Therefore, the sudden pressure on the venous vessels can cause the blood in the veins to be pumped out rapidly, which results in a rapid increase in blood flow velocity and an increase in venous vascular pressure; 2) when the patients' grip strength gradually decreases, the squeezing effect of their muscles on the cephalic veins will gradually decrease, and the squeezing of the muscles cannot meet the pressure required for the vessels to empty the blood flow, thus, the blood flow velocity and intravascular pressure of the cephalic veins will decrease; and 3) The change in cephalic vein diameter at various sizes of grip force is not statistically significant, probably due to the thin and weak elasticity of the vein wall, which is easily compressed by the CDU probe during CDU examination and cannot measure the diameter of the venous vessels well and accurately. According to the results of this study: the use of 70 to 100% maximal grip exercise in ESRD patients had a positive promotion effect on the upper limb cephalic veins and did not cause any discomfort to the patients.

Grip strength exercises are most effective at a grip strength of 70% MGS to MGS and at a frequency of 25 times/min.

It has been demonstrated that regular continuous grip and release exercises of the hand have a greater effect on vasodilation and increased blood flow,[28] however excessive grip and release exercises of the hand can lead to fatigue of the arm muscles and trigger soreness. This soreness can be relieved by rhythmic grip and fist release and short rest periods between fist releases. Although grip exercises can improve blood flow in the upper limb by increasing circulation, there is no literature that specifies how hard and how often grip exercises can be performed to maximize hemodynamics in the upper limb while minimizing the strain on the patient when performing the exercise. It has been suggested that the force of sustained muscle contraction induced by grip force of a certain duration can exert a better effect on evacuating vascular blood over time than rhythmic contraction of the same force; however, rhythmic grip force has a longer duration and longer effect on muscle contraction than sustained grip force, and has a stronger effect on evacuating vascular blood over time than sustained grip force of the same force.[29] COOK M *et al*.[30] found in their experiments that the muscle contraction produced by grip force caused changes in vascular blood flow in the arm, with a very rapid blood flow response within 1 to 2 seconds of muscle contraction, peaking within 2 to 5 seconds of contraction. Furthermore, there is a clear correlation between the change in peak velocity of vascular blood flow in the arm caused by muscle contraction during handgrip and muscle contraction force, implying a direct stimulus-response relationship between grip force magnitude and vascular hemodynamics. It has been reported in the literature[31] that under steady-state conditions, the duration of sustained contraction of human skeletal muscle affects the associated skeletal muscle blood flow during exercise during grip strength exercise.

The results of the present study showed that at appropriate grip strength, blood flow velocity and blood flow were significantly increased ($P < .05$) after subjects performed grip exercise at different frequencies (15, 20, 25, and 30 times/min) compared to the resting state, indicating that grip exercise can have a good effect on cephalic venous blood circulation, which is consistent with the results of previous studies.[32] The results of this study showed that blood flow velocity and blood

flow in the upper limb veins was greatest at a grip exercise frequency of 25 beats/min ($P < .01$) and decreased at a grip exercise frequency of 30 beats/min compared to 25 beats/min. Therefore, this study suggests that patients should choose a frequency of 25 repetitions/min for grip exercise, which has the best effect on upper limb cephalic hemodynamics. In response to the study, cephalic venous blood flow velocity and blood flow did not increase consistently with increasing frequency of grip exercise. This may be due to the following factors: 1) If the frequency of grip exercise is too fast per unit time, the muscle contraction caused by grip force does not have enough time to compress the blood vessels so that the blood is completely pumped out of the upper limb veins, resulting in no significant increase in the velocity and flow of blood. 2) If the frequency of grip exercise is too slow, making the single grip and release time too long will cause the patient's hands to be easily fatigued during the exercise process, resulting in the strength of the grip exercise not achieving the effect of muscle contraction and not getting the desired exercise effect.

Therefore, this study recommends that the optimal grip strength to be used when clinically instructing patients to perform upper limb functional exercises after AVF is 70% of the patient's own maximum grip strength at a frequency of 25 times/min.

Limitations of the Study

By analyzing the effects of using different sizes of grip strength and frequency on the hemodynamics of the upper limb cephalic veins in patients with ESRD who have undergone pre-AVF surgery, this study remedies the current gap in the study of grip strength size and grip frequency of grip exercise in patients after AVF surgery, and achieves individualization of grip exercise in patients after AVF surgery. However, there are two limitations of this study: 1) This study used a before-and-after control method to quantify the optimal strength and frequency of grip exercise in patients who had undergone AVF surgery, and it has not yet been applied to clinical validation of the implementation of the quantified optimal strength and frequency of grip exercise, and it is recommended that a controlled trial be designed in subsequent studies to further analyze the effectiveness of this quantified grip exercise method in promoting AVF maturation. 2) This study took into account the effect on the maturation of the AVF.

CONCLUSION

In this study, considering that the quantification of strength and frequency in post-AVF patients may lead to bleeding from the surgical incision, the application of the quantification of optimal strength and frequency of grip exercise in patients who have undergone AVF surgery has certain shortcomings in the application of grip exercise in post-AVF patients, and may be considered in the future to find a suitable method for grip exercise in post-AVF patients when conditions permit. In the future, we may consider finding methods to quantify grip strength exercises in post-AVF patients, so that quantified grip strength exercises can better promote AVF maturation.

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REFERENCES

1. HE Mao-xin, YANG Yu-jie, YU Shao-bin. Study on the correlation between exercise capacity and quality of life in maintenance hemodialysis patients. Chinese Hemodialysis. 2020;19(4):238-41.
2. Bashar K, Conlon PJ, Kheirelseid EA, et al. Arteriovenous fistula in dialysis patients: Factors implicated in early and late AVF maturation failure. Surgeon. 2016;14(5):294-300.
3. Liu WH. Comparison of the effects of functional arteriovenous endo-lateral anastomosis and traditional cephalic vein radial artery anastomosis endovascular fistula in uremic hemodialysis. Journal of Southwest Medical University. 2021;44(1):63-6.
4. Qizhuang J, Yuzhu W, Chaoyang Y, et al. Expert consensus on vascular access for hemodialysis in China (2nd ed.). China Blood Purification. 2019;18(6):365-81.

5. Yan YH, Hou GC, Wang H, Sun XUL, Yin N, Feng GZ, et al. The value of ultrasonography in assessing the maturation process of autologous arteriovenous endovascular fistula. China Blood Purification. 2018;17(11):761-65.
6. Zhang F, Li Y, et al. Influence of cephalic vein dilation on arteriovenous fistula maturation in patients with small cephalic veins. Medicine (Baltimore). 2020;99(1):e18576.
7. Hentschel DM. Determinants of Arteriovenous Fistula Maturation. Clin J Am Soc Nephrol, 2018;13(9):1307-8.
8. Venkatnarayanan R, Dogra PM, Bavdekar R, et al. Primary failure of autogenous arteriovenous fistula:Critical analysis. Journal of Nephrology. 2020;30(6):382-90.
9. Wilmink T, Hollingworth L, Powers S, et al. Natural history of common autologous arteriovenous fistulae:consequences for planning of dialysis. Eur J Vasc Endovasc Surg. 2016;51(1):134-40.
10. Masengu A, Maxwell AP, et al. Investigating clinical predictors of arteriovenous fistula functional patency in a European cohort. Clin Kidney J. 2016;9(1):142-7.
11. Yin Y, Zheng X, Liu S-Y, Bao J. Effect of different grip styles on the vascular condition of forearm preoperative intravenous fistula. Nursing Research. 2018;32(01):99-102.
12. Yanhong G, Zhongmei L, Yamei Z, Yihong C, Xiaojun H. Study on the effect of adjustable and quantifiable arteriovenous internal fistula movers on the maturation time and quality of internal fistula vessels. Nursing Research. 2019;33(13):2302-5.
13. Caixia S, Shujun A, Xiaojie H. Study on the effect of hand resistance exercise on maturation of arteriovenous internal fistula and long-term use time frame. Nurse's Journal of Continuing Education. 2018;33(19):1774-6.
14. Liu K, Zhou Y, Xie W, et al. Handgrip exercise reduces peripherally inserted central catheter-related venous thrombosis in patients with solid cancers:A randomized controlled trial. Int J Nurs Stud. 2018;86:99-106.
15. Tapia GI, Esteve SV, Ibanez S, et al. Elderly patients, isometric exercise, and native vascular access maturation: An unsolved question. Hemodial Int,2020.
16. Kumar A, Suryani SL, Guo HL, et al. Effect of isometric handgrip exercise on the size of cephalic veins in patients with stage 3 and 4 chronic kidney disease: A randomized controlled trial. J Vasc Access. 2020;21(3):372-8.
17. Lirong Q, Dongmei C, Shouying Z, Yanli L, Jing Z. Effect of functional exercise with herbal fumigation on the maturation of autogenous arteriovenous internal fistula. Chinese Medicine Herald. 2016;22(17):91-3.
18. American Institute of Ultrasound in Medicine. AIUM practice guideline for the performance of a vascular ultrasound examination for postoperative assessment of dialysis access. J Ultrasound Med. 2014;33(7):1321-32.
19. Zamboli P, Fiorini F, et al. Color Doppler ultrasound and arteriovenous fistulas for hemodialysis. J Ultrasound. 2014;17(4): 253-63.
20. Changshui W, Huiru H, Na W, et al. Retest reliability and measurement error of a grip strength device in elderly men. Chinese Rehabilitation Theory and Practice. 2010;16(1):3-5.
21. Fess E, Moran C. Clinical Assessment Recommendations. Philadelphia: American Society of Hand Therapists Monograph.1981.
22. Helen CR, Hayley JD, Helen JM, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age and Ageing. 2011;40(4):423–9.
23. Min Z, Xiuxin F, Ming'e L, Chunhui Z, Xihuan Z, Xiaoqin L. Effect of grip strength device grip exercise method on upper limb venous hemodynamics. Chinese Journal of Nursing. 2014;49(11):1325-9.
24. Yawen M, Jingya H, Chunyan S, Lifang Z, Xia F. Current status of evaluation and intervention of autologous arteriovenous fistula function in maintenance hemodialysis patients. Nursing Research. 2020;34(01):119-22.
25. Liping C. Application of functional exercise combined with far infrared therapy in the maturation of arteriovenous endovascular fistula. Nursing Practice and Research. 2016;13(19):101-3.
26. Cildag BM, Koseoglu KOF. Discriminative role of brachial artery Doppler parameters in correlation with hemodialysis arteriovenous fistula. Clujul Med. 2017;90(4):407-10.
27. Viecelli AK, Lok CE. Hemodialysis vascular access in the elderly: getting it right. Kidney Int. 2019;95(1):38-49.
28. Inder JD, Carlson DJ, Dieberg G, et al. Isometric exercise training for blood pressure management: a systematic review and meta-analysis to optimize benefit. Hypertens Res. 2016;39:88-94.
29. Wenqi M. Study on the effect of red light therapy combined with limb functional exercise on the maturation effect of autologous arteriovenous internal fistula. Huzhou Normal University. 2021.
30. Cook M, Smart NA, et al. Predicting blood flow responses to rhythmic handgrip exercise from one second isometric contractions. Physiol Res. 2016;65(4):581-9.
31. Jennifer CR, Anne RC. Brett SK, et al. Muscle contraction duration and fibre recruitment influence blood flow and VO2 independent of contractile work during steady-state exercise in humans. Exp Physiol. 2012;97(6):750-61.
32. Zhang M. Quantifying the effect of upper limb exercise pattern on hemodynamics on the side of PICC placement. Binzhou Medical College. 2015.

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