Pain Management Nursing 20 (2019) 170–173

Contents lists available at ScienceDirect

Pain Management Nursing

journal homepage: www.painmanagementnursing.org

Original Article

Arteriovenous Graft for Hemodialysis: Effect of Cryotherapy on Postoperative Pain and Edema

Li-Jun Yan, MD [*], Fei-Ran Zhang, MD [†], Chan-Shan Ma, RN [†], Yang Zheng, MD [†], Jun-Tian Chen, MD [†], Wei Li, MD [†]

[*] Department of Hemodialysis, The First Affiliated Hospital of Shantou University Medical College, Shantou City, Guangdong Province, China
[†] Department of General Surgery, The First Affiliated Hospital of Shantou University Medical College, Shantou City, Guangdong Province, China

ARTICLE INFO

Article history:
Received 30 August 2017
Received in revised form
14 February 2018
Accepted 13 July 2018

ABSTRACT

Background: Arteriovenous grafting offers an alternative for patients whose vessels are unsuitable for arteriovenous fistula. However, as a result of subcutaneous tunnel dissection, postoperative pain and edema of the operated limb present early after surgery. As a traditional therapeutic approach, cryotherapy has the ability to suppress postoperative pain and edema.
Aims: The purpose of the study was to investigate the feasibility of cryotherapy after arteriovenous graft surgery to decrease perioperative medication usage.
Design: This study was a randomized controlled trial.
Setting: A large integrated health care facility in South China.
Participants/Subjects: A total of 85 hemodialysis patients who received arteriovenous graft surgery from March 2011 to February 2017 were enrolled.
Methods: The participants were divided into an intervention group and a control group according to the postoperative management. Ice packs were applied covering the operative forearm for 120 minutes after wound closure in the intervention group. General information, pain score, analgesic consumption, wound inflammation, forearm edema, and participant satisfaction were compared between the two groups.
Results: Cryotherapy-treated patients required less analgesia (26.19% vs. 48.84%, $p < .05$), reported lower pain score from 30 minutes to 48 hours postoperative ($p < .05$), less wound inflammation (11.90% vs. 25.58%, $p < .05$), and higher participant satisfaction (8.92 ± 0.57 vs. 6.52 ± 0.63, $p < .05$), whereas the incidence of forearm edema was equivalent ($p > .05$). No adverse events were reported in either group.
Conclusions: Cryotherapy is a preferable intervention for patients after arteriovenous graft implantation as a result of its favorable cost, convenience, and fewer side effects.

Continuous dialysis, especially hemodialysis, is a life-supporting measure for patients with end-stage renal disease. An arteriovenous fistula is the predominant method for hemodialysis access. In patients with unhealthy vessels or an obstructed fistula, arteriovenous grafting is an alternative. Postoperatively, embolism and infection are treated, whereas early-stage (e.g., the first 48 hours after surgery) pain and edema are largely ignored. Because of renal failure, perioperative drug use should be avoided whenever possible in this patient population, which is increasingly sensitive to adverse drug reaction. Therefore it is important to find proper nursing measures to promote patient comfort using nonpharmacologic measures. As a traditional therapeutic approach, cryotherapy has been widely adopted in clinical nursing practice, with well-known efficacy in suppressing postoperative pain and edema (Barry, Wallace, & Lamb, 2003). However, no reports exist regarding the effect of cryotherapy on pain and edema following arteriovenous grafting. The rate and efficiency of cooling and the appropriate duration and temperature of cryotherapy are thus far unclear. A standard protocol for the practical use of cryotherapy is needed. This study was designed to characterize the impact of cryotherapy on pain, edema, and satisfaction of patients during the early stage after arteriovenous grafting for hemodialysis access.

Address correspondence to Yang Zheng, MD, Department of General Surgery, The First Affiliated Hospital of Shantou University Medical College, No.57 Changping Road, Jinping District, Shantou City, 515041, Guangdong Province, China.
E-mail address: stenoname@163.com (Y. Zheng).

https://doi.org/10.1016/j.pmn.2018.07.002
1524-9042/

Materials and Methods

Materials

Patients receiving routine hemodialysis for end-stage renal disease in our hospital from March 2011 to February 2017 were enrolled. The center's ethics review board approved the study. Inclusion criteria were as follows: (1) Patients had to have previous unsuccessful bilateral arteriovenous fistula, (2) patients were unwilling to employ a permanent central catheter, and (3) preoperative echocardiogram indicated adequate blood supply running through vessels of the upper limb on the surgical side. Exclusion criteria were (1) swelling in the upper limb preoperatively and (2) the coexistence of peripheral vascular disease. A total of 85 patients were informed and provided written consent before being enrolled in the study. The intervention group, comprising 42 cases, and the control group, comprising 43 cases, were categorized according to a random number table. The intervention group was composed of 38 men and 4 women, with an average age of 60.1 ± 8.3 years. The control group was composed of 38 men and 5 women, with an average age of 62.3 ± 7.5 years. Operations were performed by three surgeons experienced in vascular surgery. Baseline characteristics between the two groups were comparable, with differences statistically insignificant (Table 1).

Surgical Process and Intervention

Both groups received 0.1 g phenobarbital (Luminal) 30 minutes before surgery and received ultrasonic-guided brachial plexus anesthesia. Anesthetic magnets were composed of a mixture of 10 mL 1% ropivacaine, 15 mL 2% lidocaine, and 25 mL 0.1% sodium chloride to a total amount of 50 mL. Both groups employed GORE-TEX polytetrafluoroethylene with a diameter of 4-6 mm as the vessel graft connecting the brachial artery and cephalic vein. The wounds of both groups were closed with absorbable suture and dressed with 3M Tegaderm for protection from water. Patients in both groups positioned the operative arm in an angle of 15-30° for 120 minutes after surgery. Both groups received routine postoperative management, whereas in the intervention group, ice packs were applied covering the operative forearm (ranging from the elbow to the wrist) and maintained in place for a continuous 120 minutes, with skin temperature in the region around the wound detected using a medical infrared thermometer every 10 minutes. Patients with a temperature deviation of less than 1°C (33.80°F) in three sequential temperature readings were considered to have a stable temperature, which indicated that temperature recording could be discontinued. Skin temperature was monitored every 10 minutes after the end of cryotherapy until it returned to the baseline level in three sequential recordings.

Table 1
Comparison of Baseline Characteristics between Groups

Characteristic	Intervention (n = 42)	Control (n = 43)	*p*
Gender			.97
Male (n)	38 (90.48%)	38 (88.37%)	
Female (n)	4 (9.52%)	5 (11.63%)	
Age (y)	60.11 ± 8.30	62.35 ± 7.52	.142
BMI	21.90 ± 2.99	22.16 ± 2.98	.715
Residence			.468
Urban (n)	26 (61.90%)	29 (67.44%)	
Rural (n)	16 (38.10%)	14 (32.56%)	
Duration of disease (mo)	78.42 ± 20.27	72.02 ± 24.11	.185
Have comorbidity (n)	16 (38.10%)	19 (44.19%)	.568
Surgeon			.746
Surgeon A (n)	7 (16.67%)	10 (23.26%)	
Surgeon B (n)	21 (50.00%)	20 (46.51%)	
Surgeon C (n)	14 (33.33%)	13 (30.23%)	
Duration of operation (min)	69.2 ± 6.8	71.7 ± 7.1	.145
Amount of anesthetic agent (mL)	44.1 ± 5.7	42.6 ± 5.3	.127

BMI = body mass index.

Indices and Measurements

Surgeons were blinded to postoperative assessments to avoid bias. Assessments of pain, surgical site inflammation, and limb edema were performed by other staff and nurses. Several indexes were recorded. (1) Postoperative pain: According to visual analog scales (VAS), patients reported their pain by placing an X on a 10-cm line with 0 at one end and 10 at the other (0 representing no pain and 10 representing extreme pain). Distance was measured in centimeters from the beginning of the line to the center of the patient's X, using a ruler with 1-mm increments. The scales were obtained in both groups at 0 minutes (right at the end of surgery), 10 minutes, 20 minutes, 30 minutes, 2 hours, 6 hours, 12 hours, 24 hours, and 48 hours after surgery. (2) The dose of analgesic consumption: Participants were given 0.1 g tramadol intramuscularly whenever pain was intolerable, and the overall consumption was recorded. (3) Inflammatory response of the wounds: The wound was judged as inflamed according to the criteria of swelling and heat pain. Inflammation was assessed at 24 hours after surgery, when the staff was redressing the wounds. (4) Swelling of the operative forearm: The operative forearm was assessed by the staff from the elbow to the finger at 12 hours, 24 hours, and 48 hours after surgery. (5) Satisfaction of the patients: Patient satisfaction was assessed via questionnaire. Participants reported their overall satisfaction by placing an X on a 10-cm line, as described earlier (0 = extremely unsatisfied, 10 = extremely satisfied); the distance was measured in centimeters from the beginning of the line to the center of the patient's X, using a ruler with 1-mm increments.

Statistical Analysis

Data analysis was performed using SPSS Software Version 16.0. We described participant characteristics (age, gender) and outcome variables and calculated means, standard deviations, and proportions for all outcomes. Group differences were tested using two-sided t tests and χ^2 tests. A $p < .05$ was considered statistically significant.

Results

Surgical Outcomes

Surgeries were successfully completed in both groups, without excessive bleeding or accidental damage. Differences regarding the duration of surgery and the dose of anesthetic were statistically insignificant between groups (Table 1). Wounds in both groups healed favorably when the participants were followed up at 7 days after surgery, and no adverse events were reported or observed in either group.

Thermodynamic Curve of the Intervention Group

Skin temperature dropped to 15.82 ± 0.91°C (60.48 ± 33.64°F) in 20 minutes and leveled off at 12.39 ± 0.65°C (54.30 ± 33.17°F) at 30 minutes after cryotherapy. The temperature reached 12.19 ± 0.68°C (53.94 ± 33.22°F) when cryotherapy was over in 120 minutes. The curve started climbing up after removal of the ice packs, rose faster in the first 10 minutes and slower afterward, and reached 36.45 ± 0.57°C (97.61 ± 33.03°F) in about 80 minutes (Fig. 1).

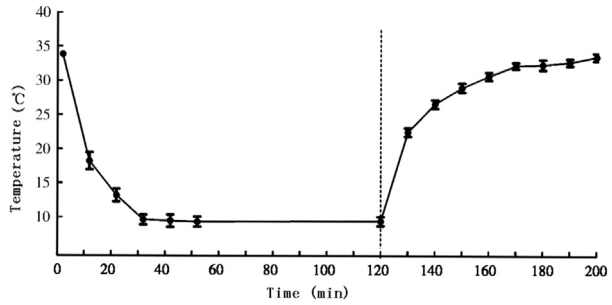

Figure 1. Thermodynamic curve of the intervention group.

Differences between Groups

The differences regarding pain rating scores were statistically insignificant between groups at 0 minutes postoperatively. The VAS scores were slightly lower in the intervention group at 10 and 20 minutes postoperatively, with differences compared with the control group being insignificant. VAS scores were lower in the intervention group from 30 minutes to 48 hours postoperatively, with significant differences compared with the control group (Table 2). Analgesic was prescribed postoperatively to 11 cases (26.19%) in the intervention group, which was significantly different compared with the 21 cases (48.84%) in the control group ($\chi^2 = 4.642$, $p = .031$). Five participants (11.90%) suffered from surgical site inflammation in the intervention group compared with 14 cases (32.56%) in the control group, with significant differences ($\chi^2 = 5.222$, $p = .022$). The incidence of edema in the operative forearm was similar in both groups, with insignificant differences ($p > .05$). Participant satisfaction was significantly higher in the intervention group compared with the control group ($p < .01$; Table 3).

Discussion

As a traditional therapeutic method, cryotherapy has been used from the time of Hippocrates (Kullenberg, Ylipää, Söderlund, & Resch, 2006). It reduces nerve sensitivity to relieve pain by reducing the conduction velocity of the nerve impulse signal, thereby paralyzing peripheral nerves (John Hochberg, 2001). Moreover, the signal for cold runs faster than the signal for pain in nerve fibers, and therefore the cold is felt more intensely than the pain, which indirectly elevates the pain threshold (Knobloch et al., 2006). Many researchers have reported the clinical use of reducing temperature for analgesia (Adie, Kwan, Naylor, Harris, & Mittal, 2012; Kol, Erdogan, Karslı, & Erbil, 2013; Murgier & Cassard, 2014). In this study, in patients treated with cryotherapy the skin temperature was reduced to 12.39 ± 0.65°C (54.30 ± 33.17°F) after cooling with ice for 30 minutes and reached an average stable temperature of 12.19 ± 0.68°C (53.94 ± 33.22°F) after 120 minutes. VAS scores were lower in the intervention group than in the control group from 30 minutes to 48 hours postoperatively. Cryotherapy-treated patients benefit from reduced analgesic dosage. Moreover, the skin returns to normal temperature within 80 minutes after the end of cryotherapy, whereas analgesia lasts for 48 hours postoperatively.

Aseptic inflammatory responses emerge in the early stage of soft tissue damage. Cryotherapy has been found to cause vessel contraction and reduction of capillary infiltration, which relieves inflammation through reduction of inflammatory factors such as substance P, histamine, 5-hydroxytryptamine, and bradykinin (Schaser et al., 2006). Therefore cryotherapy should be able to block inflammation during the early stage postoperatively. We found that the wounds in both groups healed, but with a lower incidence of wound inflammation in the intervention group, supporting our expectation. More detailed mechanisms will be discovered through further design and investigation.

According to Akgun et al. (2004), a body temperature of 10-15°C (50-59°F) minimizes cellular metabolism and a skin temperature of less than 13.6°C (56.5°F) should produce analgesia, indicating that control of local tissue temperature within a reasonable range will ensure the optimal benefit of cryotherapy. Nerves can tolerate hypothermia down to 10°C (50°F), above which irreversible damage to the nervous structure and function will be avoided (Løseth, Bågenholm, Torbergsen, & Stålberg, 2013). In our research the cryotherapy patients were exposed to constant temperatures between 10-13.6°C (50-56.5°F) for at least 90 minutes. Persistent monitoring indicated that the hypothermia was maintained >10°C (50°F), which guaranteed efficiency and safety. Regarding the duration of cryotherapy, in our study the pain tended to be relieved in the initial stages of cryotherapy. After 30 minutes, differences in pain scores became statistically significant between the two groups. Therefore cryotherapy lasting at least 30 minutes was required, which was consistent with a prior study (Thorlacius, Vollmar, Westermann, Torkvist, & Menger, 1998).

Cryotherapy has been found to relieve edema of surgical wounds (Rana et al., 2013). In our study, differences in edema in the operative forearm were insignificant between the two groups. Although cryotherapy could relieve inflammatory exudation after surgery, a postoperative arteriovenous shunt has more impact on limb edema because of increased venous pressure (Varun et al., 2016). Participant satisfaction is also higher in the intervention group. Although one could hypothesize that greater satisfaction could be associated with less pain and ultimately better outcomes, the higher level of satisfaction may be attributable to greater contact with the staff, who conducted the skin checks and VAS recordings.

Limitations of the Study

Our study has several potential limitations. First, because patients could not be blinded to group allocation, subjective measures such as level of pain and level of satisfaction are subject to potential bias. Second, it is important to acknowledge that these findings may not be generalizable to pain management beyond the 48-hour postoperative period.

Implications to Clinical Nursing

With superiority of adequate diameter, excellent compatibility, sufficient blood flow, and convenient access, arteriovenous grafting

Table 2
Comparison of Visual Analog Scale Score between Groups

Time after Operation	0 min	10 min	20 min	30 min	120 min	6 hr	12 hr	24 hr	48 hr
Intervention	1.28 ± 0.40	1.33 ± 0.64	1.29 ± 0.58	1.23 ± 0.36	1.16 ± 0.42	1.31 ± 0.75	1.98 ± 0.76	1.40 ± 0.52	1.06 ± 0.38
Control	1.25 ± 0.43	1.36 ± 0.53	1.32 ± 0.50	1.54 ± 0.41	1.82 ± 0.46	2.92 ± 0.59	2.53 ± 0.98	1.94 ± 0.48	1.86 ± 0.35
p	.225	.874	.781	.016	<.001	<.001	<.001	<.001	<.001

Table 3
Comparison of Outcomes between Groups

	Intervention (n = 42)	Control (n = 43)	*p*
Tramadol use (n)	11 (26.19%)	21 (48.84%)	.031
Wound inflammation (n)	5 (11.90%)	14 (25.58%)	.022
Forearm edema (n)			
12 hours postoperatively	11 (26.19%)	14 (32.56%)	.519
24 hours postoperatively	5 (11.90%)	8 (18.60%)	.391
48 hours postoperatively	2 (4.76%)	6 (13.95%)	.147
Patient satisfaction (cm)	8.92 ± 0.57	6.52 ± 0.63	.002

offers a suitable alternative for patients whose vessels are unsuitable for an arteriovenous fistula (Lok et al., 2013). However, as a result of subcutaneous tunnel dissection, postoperative pain and edema of the operated limb appears early after surgery (Gage, Ahluwalia, & Lawson, 2011; Ren et al., 2012). Management of postoperative pain and edema helps relieve stress, promote recovery, improve satisfaction, and reduce hospital stay (Bech et al., 2015). As a result of renal failure, side effects of perioperative medication are more likely to appear. Therefore it is important to find appropriate nursing measures to promote patients' comfort and minimize their pain by using nonpharmacologic measures. Cryotherapy was studied and found to be effective in pain relief. In recent practice the type and technique of cryotherapy was not standardized in different clinical centers. It would be advantageous to promote the study procedures as a standard protocol for the practical use of cryotherapy. Further nursing education addressing nonpharmacologic techniques for pain relief should be promoted in motivating such intervention, which will bring great benefit to patients with renal failure.

Conclusions

Because of its favorable cost, convenience, and few side effects, cryotherapy could be recommended as the principal analgesic technique for patients after arteriovenous graft implantation. Potential toxicity and adverse effects are concerns for currently used analgesic drugs or techniques. Opiates (e.g., morphine, tramadol, fentanyl, and pethidine [meperidine]) may provoke respiratory depression, nausea, vomiting, and bowel paralysis. Nonsteroidal anti-inflammatory drugs can aggravate peptic ulcers and increase the risk of thrombosis (Barthélémy et al., 2013). Although effective, patient-controlled intravenous analgesia may have inhibitory effects on cardiopulmonary function. In patients with end-stage renal disease who have various comorbidities, dose-dependent adverse effects of narcotic are more likely to happen as a result of drug or metabolism accumulation. Optimal analgesia for this population should display advantages in aspects of duration, specificity, convenience, and safety (Vixner et al., 2014). Therefore further investigation addressing alternation techniques for pain relief is needed for the end-stage renal disease population.

References

Adie, S., Kwan, A., Naylor, J. M., Harris, I. A., & Mittal, R. (2012). Cryotherapy following total knee replacement. *Cochrane Database of Systematic Reviews, 9*, CD007911.

Akgun, K., Korpinar, M. A., Kalkan, M. T., Akarirmak, U., Tuzun, S., & Tuzun, F. (2004). Temperature changes in superficial and deep tissue layers with respect to time of cold gel pack application in dogs. *Yonsei Medical Journal, 45*, 711–718.

Barry, S., Wallace, L., & Lamb, S. (2003). Cryotherapy after total knee replacement: a survey of current practice. *Physiotherapy Research International, 8*, 111–120.

Barthélémy, O., Limbourg, T., Collet, J. P., Beygui, F., Silvain, J., Bellemain-Appaix, A., Cayla, G., Chastre, T., Baumgartner, I., Röther, J., Zeymer, U., Bhatt, D. L., Steg, G., & Montalescot, G. (2013). Impact of non-steroidal anti-inflammatory drugs (NSAIDs) on cardiovascular outcomes in patients with stable atherothrombosis or multiple risk factors. *International Journal of Cardiology, 163*(3), 266–271.

Bech, M., Moorhen, J., Cho, M., Lavergne, M. R., Stothers, K., & Hoens, A. M. (2015). Device or ice: The effect of consistent cooling using a device compared with intermittent cooling using an ice bag after total knee arthroplasty. *Physiotherapy Canada, 67*(1), 48–55.

Gage, S. M., Ahluwalia, H. S., & Lawson, J. H. (2011). Salvaging vascular access and treatment of severe limb edema: case reports on the novel use of the hemodialysis reliable outflow vascular access device. *Annals of Vascular Surgery, 25*, 1–5.

John Hochberg, M. (2001). A randomized prospective study to assess the efficacy of two cold-therapy treatments following carpal tunnel release. *Journal of Hand Therapy, 14*, 208.

Knobloch, K., Kraemer, R., Lichtenberg, A., Jagodzinski, M., Gosling, T., Richter, M., & Krettek, C. (2006). Microcirculation of the ankle after cryo/cuff application in healthy volunteers. *International Journal of Sports Medicine, 27*, 250–255.

Kol, E., Erdogan, A., Karslı, B., & Erbil, N. (2013). Evaluation of the outcomes of ice application for the control of pain associated with chest tube irritation. *Pain Management Nursing, 14*(1), 29–35.

Kullenberg, B., Ylipää, S., Söderlund, K., & Resch, S. (2006). Postoperative cryotherapy after total knee arthroplasty: A prospective study of 86 patients. *Journal of Arthroplasty, 21*(8), 1175–1179.

Lok, C. E., Sontrop, J. M., Tomlinson, G., Rajan, D., Cattral, M., Oreopoulos, G., Harris, J., & Moist, L. (2013). Cumulative patency of contemporary fistulas versus grafts (2000–2010). *Clinical Journal of the American Society of Nephrology, 8*(5), 810–818.

Løseth, S., Bågenholm, A., Torbergsen, T., & Stålberg, E. (2013). Peripheral neuropathy caused by severe hypothermia. *Clinical Neurophysiology, 124*(5), 1019–1024.

Murgier, J., & Cassard, X. (2014). Cryotherapy with dynamic intermittent compression for analgesia after anterior cruciate ligament reconstruction. preliminary study. *Orthopaedics & Traumatology Surgery & Research, 100*(3), 309–312.

Rana, M., Gellrich, N. C., Von, S. C., Weiskopf, C., Gerressen, M., Ghassemi, A., & Modabber, A. (2013). 3D evaluation of postoperative swelling in treatment of bilateral mandibular fractures using 2 different cooling therapy methods: A randomized observer blind prospective study. *Journal of Cranio-Maxillo-Facial Surgery, 41*(1), e17.

Ren, J., Han, X., Liu, H., Chen, X., Ma, N., & Tan, Q. (2012). Ultrasonographic assessment of polytetrafluoroethylene upper extremity arteriovenous hemodialysis access: A retrospective analysis of 31 cases. *Therapeutic Apheresis & Dialysis, 16*, 548–553.

Schaser, K. D., Stover, J. F., Melcher, I., Lauffer, A., Haas, N. P., Bail, H. J., Stöckle, U., Puhl, G., & Mittlmeier, T. W. (2006). Local cooling restores microcirculatory hemodynamics after closed soft-tissue trauma in rats. *Journal of Trauma, 61*, 642–649.

Thorlacius, H., Vollmar, B., Westermann, S., Torkvist, L., & Menger, M. D. (1998). Effects of local cooling on microvascular hemodynamics and leukocyte adhesion in the striated muscle of hamsters. *Journal of Trauma, 45*(4), 715–719.

Varun, M., Aneesh, S., Rakesh, K., Hira, L., Tarun, J., Sanjoy, S., Nitesh, P., Sohrab, A., & Manoj, K. (2016). Management of venous hypertension following arteriovenous fistula creation for hemodialysis access. *Indian Journal of Urology, 32*(2), 141–148.

Vixner, L., Schytt, E., Stener-Victorin, E., Waldenström, U., Pettersson, H., & Mårtensson, L. B. (2014). Acupuncture with manual and electrical stimulation for labour pain: a longitudinal randomised controlled trial. *BMC Complementary and Alternative Medicine, 14*, 1–11.