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Original Article

Effects of sensory nerve anterolateral femoral lateral flaps in the treatment of open fractures with soft tissue defects

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Abstract: Objective: The aim of this study was to investigate the clinical effects of sensory nerve-free anterolateral free flaps in the treatment of open fractures of the foot with soft tissue defects. Methods: A total of 100 cases with open fractures of the foot and soft tissue defects, from August 2015 to February 2017, were divided into two groups (n=50), according to the random number method. The observation group received sensory nerve free flap treatment. The control group underwent ordinary skin grafting, general skin grafting for the thigh. All patients were followed up for 6 months. This study compared the number of cases to restore protective sensory and overall feeling of the foot skin flap scores, statistics of two points of foot and foot dorsal discrimination, postoperative median nerve and peroneal nerve conduction velocities, quality of life scores (before and after) compared with complications during follow-up, and LEM assessment foot results. Results: One week after surgery, one month after surgery, three months after surgery, and six months after surgery, the number of protective sensations in the observation group was significantly higher than those in the control group ($P<0.05$). Overall sensory scores of the foot flap in the observation group were significantly better than scores of the control group ($P<0.05$). Differences in the foot and the dorsum of the observation group were significantly lower than those in the control group ($P<0.05$). Conduction velocities of the median nerve and peroneal nerve in the postoperative observation group were significantly faster than those in the control group ($P<0.05$). Quality of life in the postoperative observation group was significantly better than that in preoperative and postoperative control groups ($P<0.05$). Incidence of infection, ulcer or necrosis, thrombosis, and sensory loss in the observation group was significantly lower than in the control group ($P<0.05$). The excellent and good rate in the observation group was 90.0%, significantly higher than that in the control group 50.0% ($P<0.05$). Conclusion: For patients with foot skin defects, the use of sensory nerve with free lateral flap treatment can effectively improve foot sensory function, improve foot capacity, reduce complications, and improve patient quality of life.

Keywords: Sensory nerve, anterolateral free flap, open foot fracture, soft tissue defects

Introduction

With the progress of industrialization and the development of transportation, skin soft tissue defects caused by foot crushing injuries due to high energy have become more and more common [1]. Modern medical microsurgery technology has also evolved, making considerable progress in repair of skin defects. Technology has provided a variety of surgical approaches with advantages and disadvantages [2]. In the restorative treatment of foot skin defects, local flaps or pedicle flaps are commonly used. However, the optional length-width ratio of flaps is limited [3]. Thus, these flaps cannot be used to repair large wound surfaces. Their vessel pedicles are relatively short, usually with no sensory nerve endings, affecting their clinical promotion [4].

The anatomy site of vessel pedicles of sensory nerve anterolateral thigh free flaps is constant. Vessel pedicles are long with a large diameter. They are characterized by a rich blood supply, high survival rate after implementation of vascular anastomosis [5], a large optical area, good elasticity, no effects on appearance [6], few effects on sensory nerves at the donor site

after skin removal due to a large skin removal area and flaps containing lateral thigh cutaneous nerves [7], high success rate after transplantation, and conduciveness to the recovery of sensory function at the transplantation site. Therefore, this method has drawn widespread clinical attention [8]. The present study aimed to examine the treatment of patients with open foot fractures combined with soft tissue defects using sensory nerve anterolateral thigh free flaps.

Data and methods

General data

A total of 100 patients with foot open fractures combined with soft tissue defects, enrolled and treated from August 2015 to February 2017, were selected. All patients were confirmed cases receiving clinical manifestations, physical examinations, and imaging examinations. Patients with wound infections, diabetes mellitus, general immune system diseases, liver and kidney dysfunction, severe heart and lung dysfunction, systemic infections, mental illness, and fractures in other parts or other motor system diseases were excluded. The study was approved by the Ethics Committee and written informed consent was obtained by each patient and/or guardian. According to the random number method, the patients were divided into the observation group (n=50) and control group (n=50). In the observation group, there were 39 males and 11 females, aged 18~50 years old, with an average age of (42.1±1.2) years old. Injured sites included pelma injury (n=15), dorsum pedis injury (n=15), and whole foot injury (n=30). Causes of injury included car accident injury (n=35), machine crushing injury (n=10), injury caused by a heavy crashing object (n=4), and other causes (n=1). The time from patients being injured to receiving surgery was 4~17 hours, with the mean time of (7.1±0.3) hours. In the control group, there were 38 males and 12 females, aged 18~50 years old, with an average age of (42.0±1.2) years old. Injured sites included pelma injury (n=16), dorsum pedis injury (n=14), and whole foot injury (n=30). Causes of injury included car accident injury (n=34), machine crushing injury (n=11), injury caused by a heavy crashing object (n=4), and other causes (n=1). The time from patients being injured to receiving surgery was 4~18 hours, with the mean time of (7.0±0.3) hours. There were no statistically significant differences in general information between these two groups, such as gender, age, injured sites, causes of injury and the time from patients being injured to receiving surgery (P>0.05).

Methods

Patients in the observation group were treated with sensory nerve anterolateral thigh free flaps. First, a flap of suitable size was designed according to the skin defect area of the foot. Under the condition of lifted straight legs, A line was drawn in the space between the rectus femoris and vastus lateralis at the mid-thigh, then C line was drawn along the anterior superior iliac spine to the outer edge of the sacrum. The intersection point of the vertical line and A line was set as A point. Combined with an ultrasound Doppler flowmeter, the intersection point of inguinal ligament midpoint and A point was determined as B point. In addition, the flap design was performed with A-B intersection point as the axial position in the process of selection and rotation of flaps to the greatest extent. It was ensured that 2/3 of the flaps were located at the lateral thigh below A point and A point was located at the mid-site of the flaps. During the operation, the leading edge of the flap proximal end was excised before the flaps were excised and the space between the rectus femoris and vastus lateralis was selected as the entrance. Lateral thigh cutaneous nerves were searched along the space. These were upward freed at an appropriate length after determination, then divided and labeled for standby application. Furthermore, the descending branches of femoral circumflex main arteries in the superficial region of the vastus internus were selected, then the flap separation was conducted at the distal end. Flaps were opened through the laminectomy surface and cut with part of the fascia latae for standby application. This was followed by the inward separation under the deep fascia. According to the condition of vessels in the grafted area, the length of vascular pedicles at the donor site was selected. Patients with wound healing difficulties at the donor site were treated with a free skin graft. When the free flaps were completed, pedicles were not divided for the time being. In contrast, after flaps were covered with gauze containing warm normal saline and vascular anatomy and exposure were in good condition in the grafted area, pedicle division was conducted. Patients in the

control group were treated with ordinary skin grafts, in which the inner thigh skin was generally taken.

Observation indexes

All patients were followed up for 6 months in the form of outpatient service. The number of cases recovering protective sensation and overall sensory scores of foot flaps were compared between the two groups at different time points. Two-point discriminations of the pelma and dorsum pedis were counted, as well as median nerve and peroneal nerve conduction velocities after the operation. Quality of life, before and after the operation, complications during follow-up, and lower extremity measure (LEM) results of foot function were compared between the two groups.

Evaluation criteria

Flap sensory partitions included pain and warm sensations, tactility, and two-point discrimination. First, flaps were divided into 8 regions: F1 was mainly located in the proximal end of flaps, F8 in the distal end, F2~F4 parallelly below F1, and F5~F7 in corresponding positions of F2~F4, respectively, above F8. The larger the value was, the better the displayed sensation of flaps was. Determination methods: Pain was measured by a 4# needle. Tactility was measured with cotton swabs. Cold water at 0°C was regarded as rhigosis and warm water at 40°C as thalposis. Discrimination was determined using two points of a two-foot compass. Overall sensory scores were divided into 6 grades. Grade 0: no sensation in flap areas; Grade 1: deep pain recovery in flap areas; Grade 2: slight recovery of pain and tactility in flap areas; Grade 3: complete recovery of superficial pain and tactility in flap areas with no hyperesthesia but a certain degree of two-point discrimination; Grade 4: sensation was completely recovered, but the two-point discrimination was more than 8 cm; Grade 5: sensation was completely recovered, but the two-point discrimination was less than 8 cm. Moreover, median nerve and peroneal nerve conduction velocities were measured using a NeuroExam M-800A electromyography instrument (Shanghai Siou Medical Instrument Co., Ltd.) at 24°C. Relevant nerve conduction velocities were recorded. Foot function was assessed using LEM. Results were regarded as excellent if the walking ability of patients returned to a normal state, and patients could do normal housework. Results were regarded as good if patients had certain difficulties in climbing stairs but no difficulty in walking on flat ground, toe flexion and dorsal stretch could be inflexibly achieved, but patients could not bear heavy housework. Results were regarded as normal if patients could not climb stairs but could walk on flat ground with certain difficulties and had certain ankle dyskinesia, toe flexion, and dorsal stretch could not be achieved. Results were regarded as poor if great dyskinesia appeared after treatment and patients could not climb stairs, walk on flat ground, and move ankle joints. Dxcellent and good rate of LEM score (%)=(excellent cases+good cases)/total cases±100%.

Statistical processes

Statistical Product and Service Solution (SPSS) 13.0 was used for statistical processes. Measurement data are expressed as mean ± standard deviation (SD). Student's *t*-test was used for comparison of means between the two groups and Chi-squared test was used to compare percentages between the two groups. $P<0.05$ indicates that differences are statistically significant.

Results

Comparison of the number of cases recovering protective sensation at different time points between the two groups

At 1 week, 1 month, 3 months, and 6 months after the operation, the number of cases recovering protective sensation in the observation group was 15, 25, 35, and 49, respectively, while those in the control group were 3, 12, 19, and 23, respectively. The number of cases recovering protective sensation in the observation group at different time points was significantly larger than those in the control group (χ^2=8.198, 7.250, 10.306 and 31.002, $P<0.05$) (**Figure 1**).

Comparison of overall sensory scores of foot flaps at different time points after treatment

At 1 week, 1 month, 3 months, and 6 months after the operation, overall sensory scores of foot flaps in the observation group were (2.1±0.2) points, (3.5±0.3) points, (4.1±0.2) points, and (4.3±0.2) points, respectively, while those in the control group were (1.5±0.1) points, (2.6±0.2) points, (3.5±0.2) points, and (3.7±0.3) points, respectively. Overall sensory

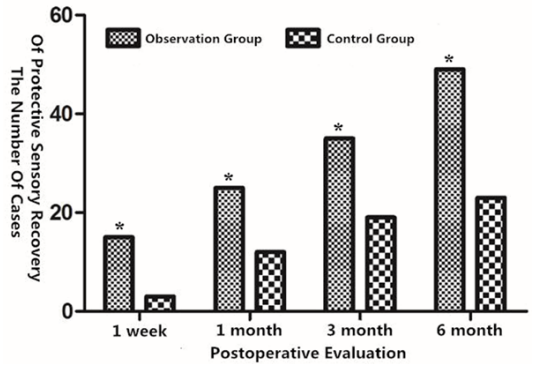

Figure 1. Comparison of the number of cases recovering protective sensation at different time points between the two groups. At 1 week, 1 month, 3 months, and 6 months after the operation, the number of cases recovering protective sensations in the observation group was significantly larger than in the control group (*P<0.05).

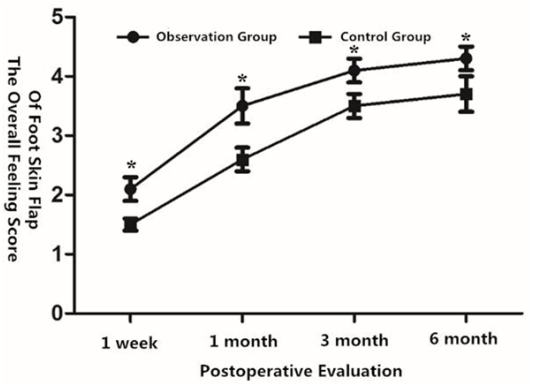

Figure 2. Comparison of overall sensory scores of foot flaps at different time points after treatment. At 1 week, 1 month, 3 months, and 6 months after the operation, overall sensory scores of foot flaps in the observation group were significantly higher than those in the control group (t=18.974, 17.650, 15.000 and 11.767, *P<0.05).

scores of foot flaps at different time points in the observation group were significantly higher than those in the control group (t=18.974, 17.650, 15.000 and 11.767, P<0.05) (**Figure 2**).

Comparison of two-point discriminations of the pelma and dorsum pedis between the two groups

Two-point discriminations of the pelma and dorsum pedis in the observation group were significantly lower than those in the control group (P<0.05) (**Table 1**).

Table 1. Comparison of two-point discriminations of the pelma and dorsum pedis between the two groups (mm, $\bar{x}\pm s$)

	Pelma	Dorsum pedis
Observation group	8.6±0.3	8.1±0.2
Control group	11.8±0.4	12.1±0.5
t	45.255	52.523
P	<0.001	<0.001

Table 2. Comparison of median nerve and peroneal nerve conduction velocities at 6 months after the operation between the two groups (m/s, $\bar{x}\pm s$)

	Median nerve	Peroneal nerve
Observation group	53.5±3.0	49.6±2.8
Control group	41.3±2.1	36.3±1.8
t	23.558	28.253
p	<0.001	<0.001

Comparison of median nerve and peroneal nerve conduction velocities at 6 months after the operation between the two groups

Median nerve and peroneal nerve conduction velocities after the operation in the observation group were significantly higher than those in the control group (P<0.05) (**Table 2**).

Comparison of quality of life between the two groups before and after the operation

There were no statistically significant differences in quality of life between the two groups before the operation (P>0.05). Quality of life in the observation group after the operation was significantly better than that in the control group before and after operation (P<0.05) (**Table 3**).

Comparison of incidence rates of complications between the two groups

Incidence rates of infection, ulcer or necrosis, thrombosis, and anesthesia in the observation group were significantly lower than those in the control group (P<0.05) (**Table 4**).

Comparison of LEM results of foot function between the two groups

The excellent and good rate in the observation group reached 90.0%, significantly higher than

Table 3. Comparison of quality of life between the two groups before and after the operation (point, $\bar{x}\pm s$)

	Before operation	After operation	*t*	*P*
Observation group	36.7±2.3	85.5±4.5	68.280	<0.001
Control group	36.8±2.3	70.2±3.0	62.476	<0.001
t	0.217	20.004	-	-
P	0.828	<0.001	-	-

Table 4. Comparison of incidence rates of complications between the two groups (n)

	Infection	Ulcer or necrosis	Thrombosis	Anesthesia
Observation group	1	1	1	1
Control group	10	9	10	15
χ^2	6.537	5.444	6.537	12.574
P	0.011	0.020	0.011	<0.001

Table 5. Comparison of LEM results of foot function between the two groups (n)

	Excellent	Good	Normal	Poor	Excellent and good rate
Observation group	35	10	3	2	90.0%
Control group	13	12	15	10	50.0%
χ^2					19.048
P					<0.001

that in the control group (50.0%, $P<0.05$) (**Table 5**).

Discussion

Foot skin defects, especially heel skin defects, have a hard and pliable texture and a subcutaneous fat pad due to relatively thick cuticles, in which abundant vascular nerves are distributed. They are wear-resistant, pressure-resistant, and sensitive [9]. Clinically, foot surgery, especially skin soft tissue avulsion caused by heel injuries, is relatively common. In view of the above characteristics and the special anatomical structure, repair effects of the conventional flap graft need improvement [10]. Treatment is often conducted based on specific injury conditions and specific required vascular nerve repair materials, under the guidance of the principle "take simplicity as the priority". During treatment, vascular pedicle flaps are required. At the same time, the recovery of foot sensory function in patients should be noted, thus the nerve graft needs to be performed at the same time period [11]. Although graft survival rates of the previously used pedicle flaps and free flaps are high, they are more suitable for patients with minor flap contusions. Foot neurological function cannot be effectively restored after treatment [12], resulting in bloated repair parts after the operation. This affects motor function with unsatisfactory sensory recovery. Hence, ulcers often occur in the grafted area [13].

The study objects were patients with foot open fractures combined with soft tissue defects. Patients in the observation group were treated with sensory nerve anterolateral thigh free flaps, in contrast to the normal thigh medial graft treatment. At 1 week, 1 month, 3 months, and 6 months after the operation, the number of cases recovering protective sensation in the observation group was significantly larger than the control group. Overall sensory scores of foot flaps in the former were higher than those in the latter, indicating that sensory nerve anterolateral thigh free flaps can effectively restore foot sensory function in patients with foot skin defects, improving their nerve recovery abilities. In addition, comparison of two-point discriminations of the pelma and dorsum pedis between the two groups showed that two-point discriminations of the pelma and dorsum pedis in the observation group were significantly lower than those in the control group. This further indicated that, for patients with foot skin defects, sensory nerve anterolateral thigh free flaps have positive significance in improving tactility and other fine sensations in injured areas. At the same time, comparison of the median nerve and peroneal nerve conduction velocities after the operation between the two groups revealed that median nerve and peroneal nerve conduction velocities in the observation group were higher than those in the control group at 6 months after operation. Results indicate that treating patients with foot skin defects with sensory nerve anterolateral thigh free flaps is more con-

ducive to the preservation and recovery of nerve conduction velocities of the lower extremities. Finally, comparison of the quality of life, complications during treatment, and LEM results of foot function between the two groups indicated that quality of life in the observation group after the operation was significantly better than that in the control group before and after operation. Incidence rates of infections, ulcers or necrosis, thrombosis, and sensation loss in the former were lower than those in the control group. Moreover, overall LEM results in the former were significantly better than those in the latter. Present results suggest that treating patients with foot skin defects with sensory nerve anterolateral thigh free flaps can significantly improve foot function and quality of life, due to ideal operation results with fewer complications.

Treatment of foot skin defects with sensory nerve anterolateral thigh free flaps is in line with the treatment causes of the trauma microsurgery with the principles of "the same species aid each other" and "take simplicity as the priority" [14]. This treatment method recovered foot skin sensations of patients to the maximum degree, reducing occurrence of pressure foot ulcers. Used flaps have deep fascia, vascular fascicles [15], and a very small amount of subcutaneous fat. Thus, mobility problems caused by postoperative bloated feet after grafting were effectively avoided [16]. At the same time, only part of the deep fascia and a small amount of skin needed to be cut off at the donor site, to maintain the main blood supply vessels. Therefore, the trauma was minimal and scars were scarcely formed after the operation [17]. Moreover, the position of vascular pedicles of the selected anterolateral thigh free flaps in the observation group was relatively constant [18]. It was easy to successfully draw materials and the diameter of vascular pedicles in flaps was larger, significantly improving the success rate of anastomosis after grafting [19]. In addition, there were many anastomosing branches. When the flaps were cut, they did not affect skin sensations at the donor site [20].

In summary, treating patients with foot skin defects with sensory nerve anterolateral thigh free flaps can effectively enhance foot sensory function, improve foot motor ability, and reduce complications, thereby improving patient quality of life.

Disclosure of conflict of interest

None.

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