ORIGINAL ARTICLE ASIAN JOURNAL OF MEDICAL SCIENCES

Sensory recovery in medial plantar flaps for posterior heel defects as a guide to rehabilitation regime

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Submission: 07-03-2025 Revision: 02-05-2025 Publication: 01-06-2025

ABSTRACT

Background: For reconstruction of the foot, a medial plantar flap is used to provide a like-for-like replacement. The problem at present seems to be that there are no objective criteria to guide the rehabilitation regimes of these patients. The arbitrary rule that the patient may begin weight-bearing after 4 weeks of surgery may not be applicable to all patients as the etiology of the defect and time for recovery may differ. **Aims and Objectives:** The study was conducted with the primary objective of ascertaining the time needed for sensory recovery in the pedicled medial plantar flap. The secondary objective was to identify guidelines regarding weight-bearing on the flap during the recovery period. **Materials and Methods:** A prospective observational study was done, with the primary objective of recording the time in which sensory recovery occurs in sensate pedicled flaps. In 4 years, 14 patients who underwent medial plantar flap reconstruction were assessed. The sensory outcome of medial plantar flaps was assessed using 2-point discrimination (2PD) of the flap area compared with the heel of the normal leg. **Results:** Tactile sensation was found to recover within one month, but 100% recovery of pain and temperature sensation took about 6 months. A Mann–Whitney test to compare the 2PD scores of the flap to the normal heel showed them to be comparable at 6 months post-operative. **Conclusion:** Complete sensory recovery even in a sensate flap can take about 6 months and the patient needs to be counseled regarding using assisted weight-bearing and daily foot examination until that period is complete.

Key words: Sensory recovery; Medial plantar flap; Rehabilitation

Access this article online

Website: https://ajmsjournal.info/index.php/AJMS/index

DOI: 10.71152/ajms.v16i6.4503

E-ISSN: 2091-0576

P-ISSN: 2467-9100

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INTRODUCTION

Reconstruction of the posterior heel region is a difficult task as it is subject to a large shear force. This force is maximum during heel strike and midstance phases of walking and is felt primarily on the heel region.[1] When grafted tissue and insensate flaps, used to resurface this region, are subjected to this force they frequently breakdown. The medial plantar flap provides a durable cover as it brings like tissue to the region and provides a protective sensation into this area. The study of the pattern of sensory recovery in the flap becomes important as it should guide the rehabilitation regime of these patients. Allowing the patients to resume full weight-bearing before assessing for return of protective sensation may harm these flaps as well. At present, there has been no study that provides a basis to guide the rehabilitation regimes of these patients. If we can detect

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the pattern of sensory recovery, then it can be used to manage the workload of the foot.

Aims and objectives

The aim of our study was to evaluate sensory recovery in the pedicled medial plantar flap. The primary objective was to determine the time required for complete sensory recovery in the region of the flap tissue. Along with time an observation regarding pattern of recovery was also noted. This meant determination of which sensation, fine touch, tactile, pain and temperature recovered first. The secondary objective of our study was to determine guidelines for rehabilitation of patients based on the data from our primary objective so that the patient could safely begin weight bearing on the flap.

MATERIALS AND METHODS

A prospective cohort study was done from January 2020 to 2024 where patients having posterior heel defects covered by medial plantar flaps were included. We did not include patients who had large defects of the posterior heel needing free tissue transfer, those with injury to the posterior tibial artery, and patients with collapsed arch of the foot.

After discharge from the hospital, the patients were followed up in our Plastic surgery outpatient department where sensory examination of the foot was carried out by the resident posted in the ward.

The intervals of the visit were 1 month, 3 months, and 6 months post-operative. Besides light touch, pain, and temperature, 2-point discrimination (2PD) scores were noted at each visit. Full weight-bearing on the flap would only be allowed in those patients where pain and temperature sensation in the flap would be present. Until that time patient would be recommended assisted weight-bearing using a walking stick. Patients would be educated about the importance of daily foot examination and report on the presence of scratches, cracked skin, blisters, and calluses in the foot.

A student t-test was used to compare the 2PD scores with scores obtained from the opposite leg to evaluate the extent of recovery.

Surgical technique

The perforator line of the flap runs from the posterior heel to the medial sesamoid of the great toe.[2]

Flap dissection was started proximally by giving an incision just posterior to the medial malleolus. This helps to identify the posterior tibial vessels. Once identified the dissection proceeds distally till the margin of abductor halluces longus is reached. Now that the pedicle had been dissected, we switched the dissection to the distal end of the flap and began harvest from the distal to the proximal end. The incision was deep enough to include the plantar fascia in the flap. The medial plantar vessel with the nerve was found in the gap between the abductor halluces and the flexor digitorum brevis. The distal end of the artery was ligated and the artery is included in the flap. A gentle tug on the distal ligated end confirms that it is a branch of the posterior tibial artery as it had already been dissected proximally. The flap was raised with careful intrafascicular dissection of the medial plantar nerve, leaving the sensory branches to the flap intact and sparing the medial plantar nerve trunk (Figure 1). The proximal limit of dissection is the abductor halluces, which is then divided to free the pedicle. After the inset of the flap into the defect, the abductor halluces is repaired.

All flaps were islanded, and the secondary defect required skin grafting (Figure 2). Post-operative follow-up was for 6 months and sensory assessment in the flap area was done.

All procedures performed were in accordance with the ethical standards of the institutional and/or National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Figure 1: Flap dissection with medial plantar nerve

Figure 2: Final post op appearance

RESULTS

We followed up with 14 patients of which 11 patients were males and 3 were females for a period of 1 year after surgery.

The mean age of the study group was 41 years with a range of 31–58 years.

Of the various etiologies, we found that 28% (4/14) developed an ulcer following a secondary infection of trivial trauma to the foot. These patients had a history of a non-healing wound ranging from 1 month to 3 months.

Other causes included squamous cell carcinoma (SCC) of the foot (22%), infected diabetic foot (28%), trauma (14%), and pressure ulcer over the heel (8%) (Table 1).

The mean area of the flap in our study group was 71 cm^2 (range 48–117). The average operating time was 150 min (range 132–190 min) from flap harvest to inset.

Sensory recovery

Tactile sensation was the first to recover in the flaps within 1 month (9/14).

Pain and temperature sensation was next to recovery and was found in 10/14 patients by 3 months (Table 2). At this point, 2PD scores of the normal side and the flap were compared using the Mann–Whitney test. The scores on the flap side were found to be significantly higher as compared to the normal side (P<0.05) (Table 3).

By 6 months we found pain and temperature sensation recovery in all flaps. On comparison of 2PD scores at this point, we found no statistical difference between the scores on the normal side and on the flap site (Mann–Whitney test shows P<0.05) (Table 4). On further subgroup analysis of our patients, we found that in cases of diabetes mellitus, the 2PD scores of the flap were significantly higher than the flap site scores of non-diabetic patients(Mann Whitney test shows P<0.05) even though pain and temperature sensation was present at the flap site.

In our cohort of patients, weight-bearing without daily flap examination was allowed only when pain and temperature sensation had recovered (at 3 months post-operative). We kept the patient on strict bed rest for 14 days as we waited for graft recovery.

Between 14 days and 1 month, the patient is allowed to use only assisted weight-bearing for mobilization so that could attend to his daily activities. After 1 month the patient was allowed normal weight-bearing on the flap with a compulsory examination of the flap area at night.

DISCUSSION

The rehabilitation of patients undergoing medial plantar flap is mostly based on the dictum of allowing skin graft to heal and subsequently allowing assisted weight-bearing at 1 month.[3] Gradually patients are allowed full weight-bearing with off-loading of the heel around 2 months.[4] In our study

Table 1: Demographic details and patient presentation information

S. No.	Age (in years)	Sex	Etiology	Time from onset to presentation (weeks)	Culture report
1	34	M	SCC	20	N/A
2	45	M	SCC	24	N/A
3	47	F	SCC	23	N/A
4	52	M	Infective	8	*Pseudomonas*
5	36	F	Infective	9	*Pseudomonas*
6	31	M	Infective	5	*Pseudomonas*
7	23	F	Infective	15	*Klebsiella*
8	51	M	Infective+DM	16	*Escherichia coli*
9	46	M	Infective+DM	20	*Pseudomonas*
10	54	M	Infective+DM	17	*Pseudomonas*
11	39	M	Infective+DM	16	*Klebsiella*
12	58	M	Trauma	1	*Staphylococcus epidermidis*
13	28	M	Trauma	1	*Staphylococcus aureus*
14	43	M	Spinal trauma (S2,3,4)	20	*Escherichia coli*

DM: Diabetes mellitus, SCC: Squamous cell carcinoma

Table 2: Sensory recovery pattern over 6 months

Time in months	Patients with tactile recovery	Patients with temperature recovery	Patients with pain sensation recovery
1	9	2	2
3	14	12	12
6	14	14	14

Table 3: Comparison of 2 PD scores at 3 months

Etiology	2 PD flap (In mm)	2 PD on contralateral normal foot (In mm)
SCC	36	28
SCC	38	30
SCC	32	24
Infective	42	33
Infective	42	30
Infective	37	29
Infective	46	37
Diabetes	63	52
Diabetes	55	40
Diabetes	48	39
Diabetes	43	32
Trauma	36	28
Trauma	42	35

SCC: Squamous cell carcinoma, 2PD: 2 point discrimination

Table 4: 2 point discrimination at post-operative follow up of 6 months

S. No.	2PD flap (In mm)	2PD normal (In mm)	Size of flap (in centimeters)
1	32	28	11×10
2	36	30	13×9
3	28	24	10×8
4	37	33	8×8
5	36	30	10×8
6	33	29	9×6
7	42	37	8×7
8	55	52	8×6
9	44	40	9×7
10	42	39	8×6
11	36	32	8×6
12	26	28	10×8
13	38	35	10×8

Figure 3: Injury to grafted area while off loading heel

we found that full pain and temperature sensation does not return even at 3 months even in a sensate flap. Therefore, our patients were counseled and trained regarding daily flap examination once every day until 3 months post-op. Allowing mobilization with offloading poses a greater danger to the grafted instep region as well. This can usually present as breakdown of the grafted area (Figure 3). This was detected as our patients were counseled to remain vigilant as a complete recovery of protective sensation would not occur by the 3rd-month post-operative.

Another reason for fewer complications despite the decrease in sensation is the septa attaching to the plantar fascia which minimizes the shear damage in these flaps. This is the probable reason why very few recurrences have been reported even when patients begin to ambulate early. In our series instead of offloading the heel we encourage the patient to walk on the flap as that is the primary goal of the surgery but continue to examine the flap area every day until 3 months post-surgery.

We used 2PD as a tool for sensory evaluation as it provides a method of quantitatively testing loss of nerve function.[5] In diabetic patients, in our study, the 2PD of the flap region was significantly higher than the flaps in non-diabetic patients of our study group (Mann–Whitney test shows $P<0.05$). When the 2PD of flaps in the diabetic subgroup when compared to the contralateral foot the results did not differ (Mann–Whitney test shows $P>0.05$). This means that even though the loss of sensation was more common in diabetic patients, the sensation was comparable to the contralateral foot, which did not develop ulcers. Our results were similar to studies by Trevatt et al., and Wan et al., which also did not find any difference in the sensory recovery of the flap area and the sensation of the contralateral heel of the foot.[6,7]

The reason for a superior sensory recovery in the sensate flaps seems to be because of a central route of reinnervation.[8] According to this theory the nerve fibers in these flaps regenerate from the center of the flap along the direction of the severed nerve fibers. This contrasts with the peripheral route of reinnervation where gradually nerve fibers from the surrounding tissue first enter the periphery of the flap.[9] The sensory recovery in the peripheral route is always inferior to the recovery that occurs by the central route. Yu et al., found that in abdominal flaps done for finger reconstruction, the recovery occurred first in tactile sensation and then in pain and temperature.[10] Therefore, the pattern of recovery seems to be similar both in sensate and non–sensate flaps but the extent of recovery differs. Quantitatively this can be estimated through 2PD, which was nearly equal to the contralateral side in sensate flaps in our study.

The extent of recovery in the central pathway was reliable to the extent that in one of our patients of pressure sore the 2PD values were superior to the contralateral side. On further analysis, we found that this was due to injury of the spinal cord roots S1 and S2. The region of the medial plantar flap is supplied by the lumbar nerve roots, even though both nerve roots travel through the tibial nerve.

Therefore, to make the observations comparable in this case comparison was done with the 2PD recorded from the contralateral forefoot instead of the heel.

Another factor that could affect the recovery of sensations in the flap is exposure to chemotherapy and radiotherapy. In our series, 28% of the patients had SCC of the foot but none of these patients required any adjuvant treatment. In the case of neoadjuvant therapy, the neuropathy may even be worst as preclinical studies have shown that it is the interaction between cancer and chemotherapy that tends to worsen chronic sensory neuropathy.[11] This study conducted on rats found that systemic interactions between cancer and chemotherapy also determined the extent of deficits in sensory encoding and ion channel protein one potential contributor to sensory neuron dysfunction. Further studies where a comparison of sensory recovery in neoadjuvant and adjuvant groups could help confirm this hypothesis.

Radiotherapy also can affect sensory recovery adversely with radiation-induced fibrosis, direct axonal damage, and ischemic changes to the capillary bed.[12] This may further delay the recovery and prolong the time of assisted weight-bearing.

Limitations of the study

The study was limited to 14 cases and a larger cohort of patients would be useful for studying the pattern of sensory recovery. It would provide a more robust data to determine pattern of recovery in conditions which could bias the sensory recovery pattern such as diabetes. Our study also did not include any patients on radiotherapy o chemotherapy, and it would be useful to observe how these conditions affect sensory recovery of the flap.

CONCLUSION

Our study shows that complete sensory recovery takes about 6 months even in a sensate flap and the patient needs to be counseled regarding using assisted weight-bearing and daily foot examination until that period is complete. The recovery of tactile sensation is earliest followed by temperature and then pain. We do not think off-loading of the foot should be done as the flap area is from the foot itself and can bear the shear forces that occur on the posterior aspect of the foot.

ACKNOWLEDGMENT

None.

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Authors' Contribution:
DM- Definition of intellectual content, literature survey, prepared first draft of manuscript, implementation of study protocol, data collection, data analysis, manuscript preparation and submission of article; **MPM**- Concept, design, clinical protocol, manuscript preparation, editing, and manuscript revision; **SKC**- Design of study, statistical analysis and interpretation, **AK**- Literature survey, manuscript preparation and review, **DC**- Coordination and Manuscript revision.

Work attributed to:
Institute of Post Graduate Medical Education and Research, Kolkata, India, Medical College, Kolkata, India and All India Institute of Medical Sciences-Rishikesh, India.

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Source of Support: Nil, **Conflicts of Interest:** None declared.