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A case series of seven patients with recurrent median nerve neuropathy treated by the revision surgery of median nerve neurolysis and wrapping with radial artery perforator adipose flap

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Abstract

Adhesion neuropathy of the median nerve with persistent pain can be a challenging problem. Currently, coverage of the median nerve with a well-vascularized soft tissue is deemed necessary after secondary neurolysis. Herein, we reviewed the outcomes of seven patients with a persistent median nerve neuropathy after a primary open carpal tunnel release or a median nerve repair, treated with neurolysis and median nerve wrapping with radial artery perforator adipose flaps. During the revision surgery, after a careful and complete neurolysis of the scarred median nerve, the distally based radial artery perforator adipose flap without its fascia was raised and rotated to wrap the median nerve. The mean size of the perforator flap was 1146 mm^2, which was enough to wrap the median nerve in all patients. At 26 months post-surgery, both the visual analog scale score for pain with tingling and the patient-reported outcome measures improved. There was no recurrence of the median nerve adhesion neuropathy and no major complications were noted. Tinel's sign at the palmar wrist completely disappeared in four patients and was relieved in three patients. The median distal motor latency become recordable and closer to a normal compound motor action potential postoperatively in all patients. Secondary neurolysis and median nerve wrapping with a radial artery perforator adipose flap, which was modified to be softer and thinner than the radial artery perforator adipofascial flap, was a successful treatment for the recurrent median nerve neuropathy in terms of both pain relief and restoration of the hand function.

Keywords: perforator, radial artery, median nerve, carpal tunnel syndrome, adipofascial flap, neurolysis.

Introduction

Perforator flaps have become widely used for skin and soft tissue defects due to the advantage of not sacrificing major blood vessels.[1, 2] Recently, it has been reported that some kinds of perforator flaps can be applied not only for skin and soft tissue defects, but also for covering the peripheral nerves.[3-10] In the case of revision surgery for chronic compressive neuropathy and peripheral nerve repair, as the peripheral nerves often adhere to the surrounding tissue, neurolysis in an already scarred tissue bed can create additional adhesions, leading to a secondary nerve dysfunction or eventual symptom recurrence. Thus, in a revision surgery, covering the neurolysed peripheral nerves with a well-vascularized soft tissue, such as a muscle, adipofascial, or a perforator flap, is necessary for providing a healthy tissue bed owing to a cushion effect and preventing recurrent adhesion neuropathy.[11] In particular, persistent median nerve neuropathy, such as recurrent carpal tunnel syndrome or postoperative neuralgia after nerve suture can be a challenging problem, and there is little evidence-based guidance for the type of procedures to use during revision surgery.[12, 13] Previously, we have introduced a case of a radial artery perforator adipose flap used for coverage of the scarred median nerve during revision surgery after a median nerve suture in 2013.[5] In the present study, we reviewed the outcomes of seven patients with persistent median nerve neuropathy after primary carpal tunnel releases and median nerve repairs, treated with external neurolysis and nerve wrapping with radial artery perforator adipose flaps, at a mean follow-up of

more than two years.

Materials and methods

We treated seven patients (five males and two females) with a mean age of 64.4 (ranging 42 to 89) years between 2011 and 2018, who had persistent pain and tingling and residual median nerve dysfunction after an initial open carpal tunnel release (five patients) or repair of a sharp complete laceration of median nerve at just proximal of the wrist flexion crease (two patients). Five patients with four carpal tunnel syndrome and a median nerve laceration were primarily treated at another hospital and two patients with a carpal tunnel syndrome and a median nerve laceration in our institution. All patients had neuropathic pain and a positive Tinel's sign over the volar wrist despite the sufficient conservative treatment such as medication or steroid injection to the carpal tunnel; therefore, they were treated with revision surgery of neurolysis of the median nerve and nerve wrapping with radial artery perforator adipose flap. The mean time interval between the primary and revision surgeries was 30 (ranging five to 72) months. The Visual Analog Scale (VAS) score for pain with tingling, presence or absence of Tinel's sign at the wrist, wrist range of motion, and patient-reported outcomes measured by the Japanese Society for Surgery of the Hand version of the Quick Disability of the Arm, Shoulder, and Hand (Quick DASH) and Hand 20 were recorded just before the revision surgery.[14, 15] We have taken these post-operative measurements every month

until six months after the revision surgery and every three or six months continuously after that. We only described the measurement results at the last follow up. The median distal motor latency at abductor pollicis brevis was measured before and after the surgery. The mean of these measurements was compared qualitatively between pre- and post-surgery; however, due to the limited study size, no statistical analysis was performed. The mean follow-up period was 25.9 (ranging ten to 46) months. We measured the size of the radial artery perforator adipose flap intraoperatively. Postoperative complications were also investigated. We obtained an institutional review board approval for the medical chart review and all patients gave informed consent for their data to be presented in this article and to be submitted for publication.

Surgical technique

The operation was performed under loupe magnification with a tourniquet control under either general or brachial plexus anesthesia. An incision was made from the palm through the volar distal forearm using a zigzag incision, prolonged proximally along the axis of the radial artery. First, we carefully performed a complete external neurolysis of the scarred median nerve firmly adhering to the surrounding tissues. The median nerve must be identified proximally and followed distally past the carpal canal. The median nerve was released both from the superficial and deep surface leaving the nerve completely free with preserving the palmar cutaneous branch. Next, the distally based

radial artery perforator adipose flap, which did not include the fascia, was raised subcutaneously to wrap the neurolysed nerve by dividing the attachments of the adipose tissue from the skin in a radial direction.[5] As several radial artery perforators were reliably found within 2 cm proximal to the radial styloid, one or more major perforators supplying the adipose tissue were selected and the other proximal perforators were ligated to allow an adequate arc of adipose flap rotation.[16] Preoperative ultrasonic doppler examination can be useful to identify the radial artery perforators as a noninvasive test[17]. Intraoperatively, vascular dissection of the perforator itself is not necessary to avoid its damage. The superficial branch of the radial nerve should be carefully dissected away from the adipose flap. The blood supply to the adipose flap could be confirmed after releasing the tourniquet. Finally, the radial artery perforator adipose flap was turned approximately 180 degrees, wrapped around the neurolysed median nerve, and fixed with a few absorbable stitches to the surrounding soft tissue without tight tension. If the radial artery perforator adipose flap become bulky, the skin incision was closed with a V-Y plasty using the zigzag line at the wrist crease. Bulky dressing was applied postoperatively without administration of anticoagulants or prostaglandin agents. Early wrist range of motion exercise was started to minimize tethering and restore the adipose gliding surface of the neurolysed median nerve.

Results

The clinical data of the patients are summarized in Table 1. The mean size of the radial artery perforator adipose flap was 1146 mm^2 (ranging from 15 mm × 50 mm; 750 mm^2, to 25 mm × 75 mm; 1875 mm^2), which was enough to wrap the neurolysed median nerve, approximately 5cm, in all cases. The VAS score of pain with tingling was improved from the preoperative mean of 8.6 to the postoperative mean of 1.8, as the patients' symptoms started improving relatively early postoperative period about a few months after the revision surgery (Table 2). Tinel's sign at the palmar wrist was positive in all patients preoperatively, and it completely disappeared in four patients and was relieved in three patients post-surgery. The mean wrist range of motion in flexion and extension was increased from 120 degrees preoperatively to 139 degrees postoperatively. The mean scores of Quick DASH and Hand 20 were improved from 55.2 and 60 preoperatively to 21.4 and 28.7 postoperatively, respectively. The median distal motor latency was not recordable in five patients preoperatively, and it became close to a normal compound motor action potential postoperatively. The mean distal motor latency, excluding the cases of no response, was shortened from 11.0 ms preoperatively to 4.4 ms postoperatively. There was a slight pigmentation of the skin in one patient, but no major complications.

A representative case (patient #2)

An 89-year-old woman, who had undergone an open carpal tunnel release at another

hospital five months prior to the visit, complained of persistent tingling and neuropathic pain in her right hand after the surgery and was referred to our hospital. The severe pain with tingling had a VAS score of 9.5 and Tinel's sign was positive on the palmar wrist. The compound muscle action potential of the abductor pollicis brevis muscle was non-recordable electrophysiologically. Secondary neurolysis and nerve wrapping with radial artery perforator adipose flap was performed. During the surgery, the median nerve was found to be constricted by the remnant of the transverse carpal ligament, and adhered severely to the surrounding scar tissue both in the proximal carpal tunnel and in the distal forearm fascia, and could not be easily mobilized from the surrounding scar tissue (Figure 1). External neurolysis of the scarred and congested median nerve was performed carefully, and then the denuded median nerve was wrapped with the distally-based, rotated radial artery perforator adipose flap of 20 mm × 40 mm in size. The patient was very satisfied with a relieved neuropathic pain with a VAS score of 2.0 and negative Tinel's sign at the wrist at 15 months after surgery. Quick DASH and Hand 20 scores were improved from 85 and 58.5 preoperatively to 25 and 35 postoperatively, respectively. The median distal motor latency was recordable 4.6 ms post-surgery. Postoperative magnetic resonance imaging, which was performed 15 months after the revision surgery, indicated that the radial artery perforator adipose flap remained viable as a cushion between the median nerve and the subcutis.

Discussion

Carpal tunnel release has become one of the most common hand surgery procedures.[13] However, failures and recurrence have been shown to occur in 3 to 19% in large series, necessitating revision surgery in up to 12% of the cases.[13, 18-22] Although possible reasons for the recurrent carpal tunnel syndrome have been hypothesized, such as an incomplete release of the transverse carpal ligament or the proximal antebrachial fascia, formation of epineural fibrosis and interstitial scar, and soft tissue adhesion to the nerve, its pathogenesis is still not clear.[13, 23, 24] Furthermore, some patients develop an excessive neuropathic pain beyond that normally experienced after a microsurgical repair of the peripheral nerves.[25] All nerve injuries heal with scar tissue formation between the nerve and the adjacent structures; yet, very few patients develop nerve scar tethering leading to a secondary nerve dysfunction or neuralgia.[11] In these cases of recurrent carpal tunnel syndrome and painful neuropathies after median nerve repair, revision surgery was often necessary to minimize the pain and preserve the residual nerve function. Neurolysis should be performed carefully to avoid devascularization of the nerve. We usually performed external neurolysis with separation of scar outside epineurium. If the epineural fibrosis or tethered epineurium was found, additional internal neurolysis with epineurotomy was performed and the constriction was released. Next, particular attention should be given to the removal of scar tissue and coverage or wrapping of the denuded nerve with vascularized tissue to prevent a new perineural scar

formation which may be more aggressive than the prior. The vascularized tissues promote nerve gliding, avoidance of scar-induced ischemia, and provide nutrition for the nerve.[11] Thus, we believe that median nerve wrapping with radial artery perforator adipose flap is indicated for the revision surgery as well, and not for the simple primary surgery alone, such as open carpal tunnel release or nerve suture.[5]

Previously, many kinds of procedures for median nerve wrapping have been reported to improve the outcomes of revision median nerve surgery. Several local flaps (hypothenar fat pad flap, tenosynovial flap), muscle flaps (abductor digiti minimi, pronator quadratus, palmaris brevis), regional flaps (reverse island radial artery fascial flap, posterior interosseous artery flap), and free flaps (anterolateral thigh flap, omental transfer, temporoparietal fascial flap) have been described.[12, 22, 26-35] However, these procedures have some disadvantages. The hypothenar fat pad flap has a limited volume and mobility to cover the large area of scarring over the median nerve, except for the carpal tunnel region.[26, 27] Muscle flaps involve more or less motor loss.[28-31] A reverse radial artery fascial flap or posterior interosseous artery flap provides a large covered area, but sacrifices the major arteries.[33] Free flaps require microsurgery under general anesthesia and have donor site morbidity and risk of flap necrosis.[34, 35]

To overcome these problems, more recently, the perforator-based adipofascial flaps have been applied for median nerve coverage.[4, 6-9, 22, 36] Mahmoud et al reported the benefit of using the perforator-based radial forearm fascial flap in eight patients with

recurrent carpal tunnel syndrome.[8] Zahra et al. successfully treated 15 patients with recurrent or persistent carpal tunnel syndrome by vascularization of the median nerve using a tubed adipofascial radial artery perforator flap.[6] Moreover, the ulnar artery perforator adipofascial flap has also been used for vascularized coverage of the median nerve.[7, 9, 22] Adani et al reported the outcomes of eight patients with painful median nerve neuromas treated with external neurolysis and covered with radial or ulnar artery perforator adipofascial flaps.[3] Irifune et al also presented two patients with recurrent adhesion neuropathy with allodynia after wrist lacerations treated successfully with radial and ulnar artery perforator adipofascial flaps.[4] The radial artery perforator adipose flap used in the present study was modified to be softer and thinner than the radial artery perforator adipofascial flap due to freeing of the fascia, which may otherwise cause median nerve compression.[5] The radial artery perforator adipose flap procedure is easier than the ulnar artery perforator adipose flap because radial artery perforators are reliably present and do not require dissection.[36] Saint-Cyr et al showed that at least two perforators were raised from the radial artery within 2 cm proximal to the styloid in 100 percent of 26 human cadaveric forearms.[16] As in our previous study, we used color Doppler ultrasonography for preoperative planning and reliably elevating the radial artery perforator adipose flap.[17] We agree with Adani et al. opinion that the radial artery perforator adipofascial flap allows a longer, wider, and thicker flap to be raised reliably than does the ulnar artery perforator adipofascial flap, although the final decision

depends on the local conditions.[36]

The clinical results of the present study, such as neuropathic pain VAS score, were equivalent to those of the previous reports about revision median nerve surgery with similar flap coverage.[12, 13] Moreover, in the present study, improvement of the postoperative patient-reported outcome measures was noted for the first time in addition to the objective evaluation, including median nerve distal motor latency. In a meta-analysis of 14 studies using flap coverage during revision carpal tunnel release, 86% of patients improved in pain, numbness and tingling who were substantially higher than the 74% of patients treated with neurolysis alone.[11, 12] Conversely, Pace et al reported an unmatched retrospective cohort study of patients who underwent flap interposition or decompression alone during revision carpal tunnel release.[37] They did not detect a significant difference in the outcomes, but the major problem was that they did not include a power analysis. Carmona et al introduced that the combined treatment of anti-adhesion gel around the median nerve with the Canaletto implant, which recreated a gliding space for the volar surface of the median nerve, after performing secondary neurolysis, led to satisfactory post-operative outcomes for recurrent carpal tunnel syndrome.[38] Thus, alternatively to the perforator adipose flap, various coverage or wrapping materials may be developed in the future.[39]

The radial artery perforator adipose flap has the advantage of less bulkiness without the fascia, ease and safe of elevation without dissection of the perforators, reliability of

perforators, enough volume with high mobility to cover the median nerve from the distal part of the forearm to the palm, and neither functional motor or sensory loss.[5] We concluded that the median nerve wrapping with radial artery perforator adipose flap after neurolysis was effective treatment for the recurrent median nerve neuropathy. The present study has some limitations. The first is that it was a retrospective study with a small number of cases without a control group and short-term follow-up period. Although wrapping the median nerve with a radial artery perforator adipose flap could prevent the nerve from adhering to the surrounding soft tissues and presumably exhibit a cushion effect on the nerve, an additional detailed mechanism through which the pain and symptom may be alleviated is unclear. The microenvironment and perfusion of the median nerve might be improved, as the local inflammatory cells, interleukins and substance P was suppressed by the nerve wrapping with radial artery perforator adipose flap. A long-term prospective multicenter study including a control group is needed to ascertain the potential superiority of the median nerve coverage with radial artery perforator adipose flap.

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None.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article

Ethical approval

We obtained an institutional review board approval for the medical chart review and all patients gave informed consent for their data to be presented in this article and to be submitted for publication.

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Table 1. Patients' characteristics.

Patient	Age (years)	Sex (F/M)	Affected side (R/L)	Primary surgery	Period between primary and revision surgery (months)	Follow-up period (months)	Size of RAPAF (mm*mm, mm^2)
1	42	M	R	Nerve repair	11	28	30*40, 1200
2	89	F	R	OCTR	5	15	20*40, 800
3	50	M	L	Nerve repair	8	21	30*30, 900
4	62	M	L	OCTR	72	46	15*50, 750
5	50	M	R	OCTR	35	36	20*90, 1800
6	69	M	R	OCTR	30	25	10*70, 700
7	89	F	L	OCTR	50	10	25*75, 1875
Average	64.4	-	-	-	30.1	25.8	1146

RAPAF, radial artery perforator adipose flap; OCTR, open carpal tunnel release.

Table 2. Results preoperatively and postoperatively.

	Preoperative Clinical Evaluation						Postoperative Clinical Evaluation					
Patient	Pain VAS (0-10)	Tinel's sign	Range of wrist motion (degrees)	Quick-DASH (0-100)	Hand 20 (0-100)	Distal motor latency (ms)	Pain VAS (0-10)	Tinel's sign	Range of wrist motion (degrees)	Quick-DASH (0-100)	Hand 20 (0-100)	Distal motor latency (ms)
1	9.5	Presence	140	56.8	90.5	Absence	3	Improved	180	34.1	64	3.62
2	9.5	Presence	120	85	58.5	Absence	2	Absent	145	25	35	4.6
3	10	Presence	130	42.5	50	Absence	3.5	Improved	150	25	34.5	4.26
4	5.8	Presence	150	11.4	14	9.7	1.2	Absent	150	0	2	3.6
5	10	Presence	80	50	79.5	12.3	0.1	Absent	115	11.4	15.5	3.8
6	8	Presence	120	79.5	75	Absence	0.7	Absent	125	31.8	27	4.85
7	7.5	Presence	100	61.4	52.5	Absence	1.9	Improved	105	22.7	23	5.8
Average	8.6	-	120	55.2	60	11.0	1.8	-	139	21.4	28.7	4.4

Figure legends

Figure 1.

A. The scarred median nerve (black triangles) around the carpal tunnel.

B. Elevation of the distally-based radial artery perforator adipose flap (asterisk) and neurolysed median nerve (black triangles).

C. The adipose tissue (asterisk) pedicled with the radial artery perforator (black arrow).

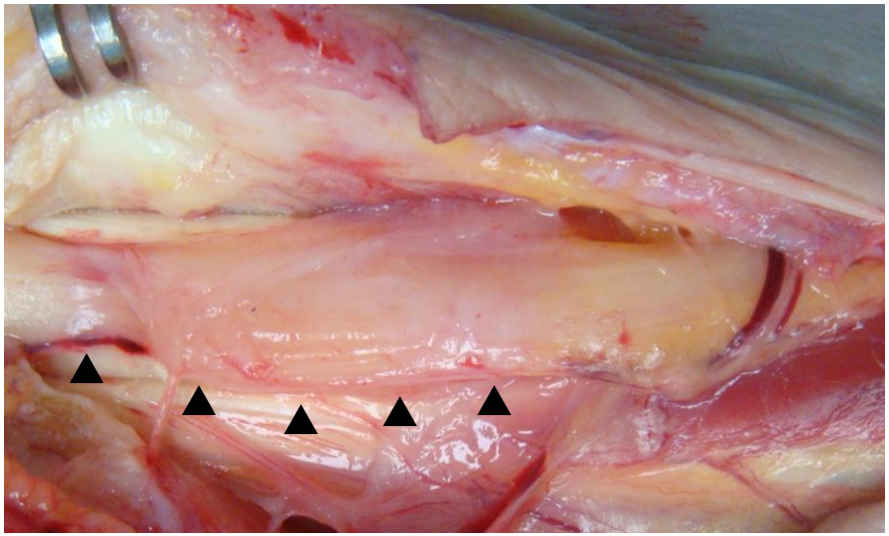
D. Coverage of the neurolysed median nerve with the radial artery perforator adipose flap.

E. Postoperative appearance of the patient's right hand and palmar abduction of her thumb.

Postoperative magnetic resonance imaging of the carpal tunnel. The radial artery perforator adipose flap (asterisk) was observed between the median nerve (white arrow) and the volar skin in the axial T2-weighted image.

Figure 1

A



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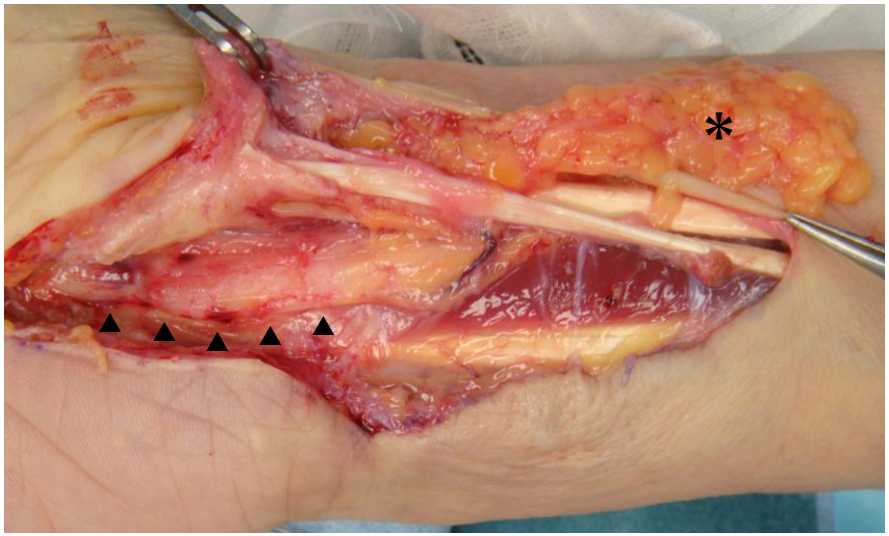

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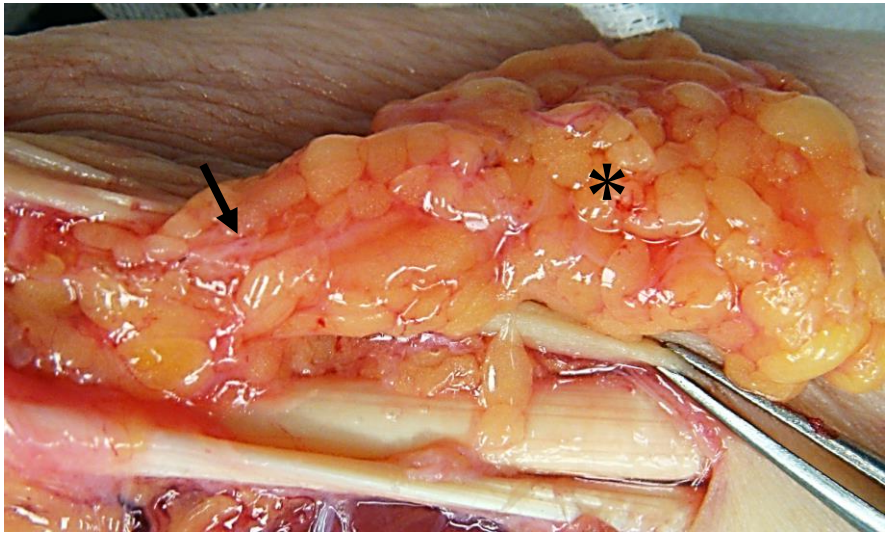

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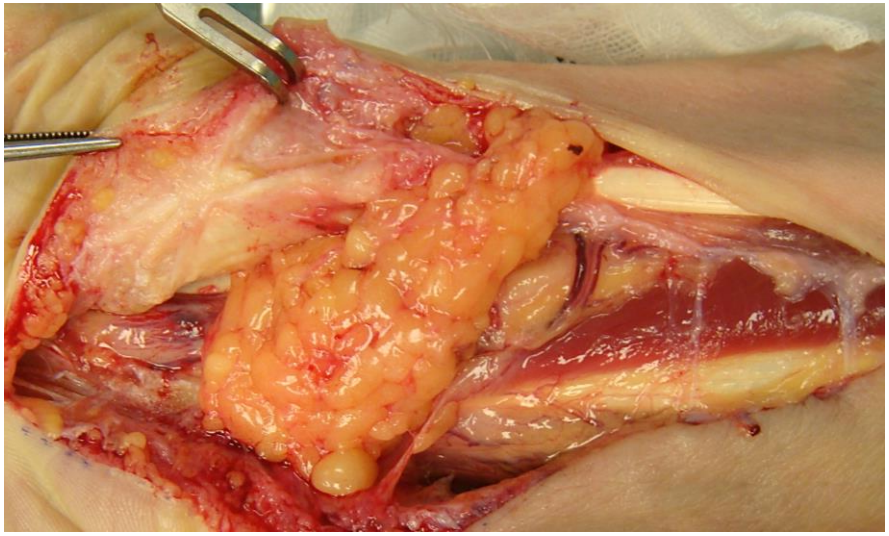

Figure 1

E

F