Earthquake generated proximal tibial nerve compression treated by surgery

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Abstract

Purpose This article reports on nine cases of proximal tibial nerve compression by the soleal tendinous arch caused by unsuitable treatment of acute compartment syndrome (ACS). Also, we report the clinical results of neurolysis and analyse the cause of this special type of neurological compression.

Methods There were nine extremities in nine patients included in the study. All patients were among the victims of the Wenchuan earthquake in 2008. All patients had a previous lower extremity ACS. Pain level, numbness in the sole, muscle strength of the flexor hallucis longus and Tinel's sign were evaluated pre- and post-operatively. Each proximal tibial nerve compression was subjected to neurolysis with division of the soleal tendinous arch.

Results At a mean follow-up of 22 months, eight patients (87 %) with weakness of the flexor hallucis longus showed improvement in flexor strength and seven patients (78 %) exhibited improved sensory function in the sole. All patients experienced pain relief. Subjective pain was reduced from an average score of 2.7 to 0.7 based on a visual analogue scale. Physical examination for Tinel's sign revealed all patients experienced relief of radiating pain, but two patients still retained a positive Tinel's sign (mild) over the soleal tendinous arch. In summary, four patients were highly satisfied, four were satisfied and one was neither satisfied nor dissatisfied with functional recovery after neurolysis.

Conclusions Unsuitable treatment of lower extremity ACS can lead to tibial nerve compression beneath the soleal tendinous arch. Neurolysis may improve pain and sensory and motor function.

Keywords Compartment syndrome ·

Tibial nerve compression · Neurolysis · Soleal tendinous arch ·
Earthquake · Fasciotomy · Crush injury

Introduction

A closed crush injury of an extremity is common in an earthquake casualty and can lead to acute compartment syndrome (ACS) [1]. If the condition is not recognised or fasciotomy is delayed, ACS can result in muscle necrosis and nerve damage with subsequent contractures, muscle weakness and sensory changes [2–4]. Although the complications of ACS have been extensively described, no study has focused on proximal tibial nerve compression by the soleal tendinous arch caused by lower extremity ACS (Fig. 1).

Proximal tibial nerve compression is less frequently encountered in clinical practice [5, 6]. Mastaglia et al. [7] in 1981 were the first to describe tibial nerve compression by the soleal tendinous arch. However, there have been few subsequent reports on this condition [8, 9]. In addition to primary compression, secondary compression of the proximal tibial nerve can be caused by trauma, surgery, nerve tumours and Baker's cysts in the popliteal fossa [10]. Also infrequently, the entrapment can affect the popliteal artery and cause intermittent claudication, which have been established as popliteal artery entrapment syndrome (PAES) [11–13]. Unlike the tibial nerve entrapment that we discuss in this study, PAES was found among young adults and athletes, caused by an anomalous course of the popliteal artery or other anatomical abnormality, which can be diagnosed by ultrasonography and magnetic resonance arteriography.

In this report, we review the findings in nine patients with the tibial nerve compression beneath the soleal tendinous arch. Also, we report the clinical results of neurolysis and analyse the cause of this special type of neurological compression.

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Fig. 1 The tibial nerve travels from the popliteal fossa to the deep posterior compartment by passing over the popliteus and beneath the tendinous arch of the soleus muscle

Patients and methods

There were nine extremities in nine patients included in the study. All patients were among the victims of the earthquake that occurred in Wenchuan, Sichuan Province, in China at 14:28:04 on 12 May 2008. There were seven men and two women. Patient ages ranged from 20 to 45 years with a mean of 31 years. All patients had a

previous lower extremity ACS caused by a closed crush injury. Conservative treatment was performed in three cases and fasciotomy was performed in six cases. The mean time from the initial injury to neurolysis was 4.3 months (range three to six months).

Clinical criteria for ACS include passive stretch pain, pallor, pulselessness and sensory or motor dysfunction. The indication for fasciotomy was the presence of these symptoms of ACS. Of the cases receiving conservative treatment, mannitol was added to the fluid regimen to lower the raised compartment pressure. At five to seven days after intravenous infusion of mannitol, the symptoms of lower extremity ACS gradually abated. Of the cases undergoing fasciotomy, operations were all performed in the operating suite under sterile conditions with the patient under general anaesthesia. Three cases associated with tibial shaft fracture were treated with an external fixator in one stage. Wounds were left open after fasciotomies and were allowed to close by secondary intention if possible. The mean interval from extrication to fasciotomy was 5.3 hours (range four to eight hours).

All nine extremities underwent examinations by ultrasound, electromyography (EMG) and magnetic resonance imaging (MRI) (Fig. 2). One of the nine patients had “peripheral neuropathy” and no further diagnosis. Four patients’ ultrasound results showed mild tibial nerve thickening and the other five had negative results. MRI of all patients showed no specific compression on the very site of the soleal tendinous

Fig. 2 Four patients’ ultrasound results showed mild tibial nerve thickening and the other five had negative results. MRI of all patients showed no specific compression on the very site of the soleal tendinous arch to the proximal tibial nerves

arch to the proximal tibial nerves. Therefore, the diagnosis of tibial nerve entrapment was based on clinical history and physical examination.

The patients in this series were required to meet all of the following criteria: (1) victims who previously had a lower extremity ACS after the earthquake, (2) persistent numbness and/or pain in the sole of the foot, (3) flexor hallucis longus weakness, (4) positive Tinel's sign when palpating the tibial nerve beneath the soleal tendinous arch and (5) at least three months of aforementioned symptoms that could not be alleviated after any conservative treatments (Table 1).

Exclusion criteria were: (1) patients who had degenerative disease of the lumbosacral spine, such as lumbar spinal disc herniation or lumbar spinal stenosis, (2) tarsal tunnel syndrome, (3) chronic exertional compartment syndrome and (4) peripheral neuropathy.

Operative technique

The operation was performed under general anaesthesia with tourniquet control and surgical microscope. We made an S-shaped skin incision on the popliteal fossa. The small saphenous vein was identified and protected. Thereafter, the fascia was divided, and the tibial nerve was identified. Care was taken to not injure the popliteal vein. The nerve was then dissected distally to the distal border of the popliteal fossa. After that, the gastrocnemius was dissected bluntly between the medial and lateral heads until the soleal tendinous arch was divided (Fig. 3). The nerve was then dissected completely free from all attachments. Usually, there was a great deal of scar tissue in the proximal portion of the deep posterior compartment, and a more extensive release of the posterior fascia was performed until the nerve was complete released. With the aid of the surgical

microscope, epineurial neurolysis was performed at the site of the visual narrowing in the tibial nerve as it travelled beneath the tendinous arch of the soleus (Fig. 4). Finally, a noncompressive dressing was applied after the wound was closed. At 72 hours post-operatively, walking was encouraged to prevent post-operative adhesions.

Evaluation of outcomes

Muscle strength and sensory function were assessed according to the Louisiana State University Health Sciences Center (LSUHSC) Nerve Grading System [14]. Muscle strength was assessed only to the flexor hallucis longus [9]. The pain of the injured extremities was evaluated subjectively by the patient using the visual analogue scale (VAS), which ranged from 0 to 10 (0 = no pain and 10 = worst pain). Tinel's sign was graded as follows: grade 1 = none, grade 2 = mild, slight tingle, grade 3 = moderate, very uncomfortable and grade 4 = severe, severe pain because of any stimulation of the nerve compression site [15]. These measurements were assessed pre- and post-operatively. Patients reported their satisfaction with functional recovery after neurolysis. The result was based on a 5-point response scale that included grade 1 = very satisfied, grade 2 = satisfied, grade 3 = neither satisfied nor dissatisfied, grade 4 = somewhat dissatisfied and grade 5 = very dissatisfied. All tests were performed by an independent senior surgeon.

Results

The post-operative courses were uneventful, and the wounds healed well. No wound infection was observed.

Table 1 Demographics

Case	Age (years)	Gender	Cause	Injured calf	Treatment of ACS	TEF (h)	TIIN (months)
1	33	M	Crush	Right	CT	–	3
2	20	M	Crush	Right	CT	–	4
3	25	F	Crush	Left	F	5	4
4	37	M	Crush	Right	F	8	3
5	29	F	Crush	Left	F	4	6
6	36	M	Crush	Left	F	4	6
7	30	M	Crush	Right	CT	–	5
8	28	M	Crush	Right	F	5	4
9	45	M	Crush	Right	F	6	4
Mean	31.44					5.3	4.3

ACS acute compartment syndrome, CT conservative treatment, F fasciotomy, TEF time from extrication to fasciotomy, TIIN time from the initial injury to neurolysis

Fig. 3 The tibial nerve was compressed beneath the soleal tendinous arch (arrows)

In the preoperative assessment, according to LSUHSC, muscle strength of the flexor hallucis longus was grade 4 in two cases and grade 3 in seven cases. Sensation of the sole was assessed as grade 4 in two cases, grade 3 in five cases and grade 2 in two cases. Based on the VAS, the mean score of the preoperative pain of the injured extremities was 2.7 (range 0–4). Tinel's sign over the soleal tendinous arch revealed four patients were assessed as grade 2 (mild) and five patients as grade 3 (moderate).

At a mean follow-up of 22 months (range 19–25 months), muscle strength of the flexor hallucis longus was grade 5 in five cases, grade 4 in three cases and grade 3 in one case. Sensation of the sole was assessed as grade 5 in two cases, grade 4 in five cases and grade 3 in two cases. Based on the VAS, the mean score of post-operative pain was 0.7 (range 0–3). Tinel's sign showed mild pain (grade 2) in two patients and no pain (grade 1) in seven patients (Table 2).

Fig. 4 An image from a different patient shows visual narrowing (arrows) in the tibial nerve itself as it travelled beneath the soleal tendinous arch

Post-operatively, eight patients (87 %) with weakness of the flexor hallucis longus showed improvement in flexor strength and seven patients (78 %) exhibited improved sensory function in the sole. All patients experienced pain relief. Subjective pain was reduced from an average score of 2.7 to 0.7 based on the VAS. Physical examination for Tinel's sign revealed all patients experienced relief of radiating pain, but two patients still retained a positive Tinel's sign (mild) over the soleal tendinous arch. In summary, four patients were highly satisfied (score 5), four were satisfied (score 4) and one was neither satisfied nor dissatisfied (score 3) with functional recovery after neurolysis.

Discussion

There are few studies on proximal tibial nerve compression by the soleal tendinous arch [5–7, 9]. Most of the articles related to lower extremity nerve compressions do not mention this possible nerve compression site [16–18].

In 2009, Williams et al. [19] dissected 36 cadaver extremities and found that in 8 % (three of 36) of specimens a focal narrowing existed directly under this tendinous arch. Their anatomical study demonstrated that the tendinous arch of the soleus muscle may act as a potential compression site of the tibial nerve. Also, Dellon and Mackinnon's [20] study of MR neurography demonstrated this neurological compression.

Clinically, Mastaglia et al. [7] reported tibial nerve compression in the popliteal fossa in five cases; four of the five cases were primary compression of the tibial nerve by the soleal tendinous arch and the other one was secondary nerve compression caused by a tributary thrombosis of the popliteal vein. All patients achieved relief of symptoms after surgical division of the soleal tendinous arch. In 2000, the same author reviewed all nine cases of proximal tibial nerve compression and demonstrated popliteal vein varix and dilated popliteal veins were also able to lead to tibial nerve compression [21]. In 2012, Williams et al. [9] described the details of 49 patients with proximal tibial nerve compression and termed it "soleal sling syndrome" so as to distinguish between chronic posterior compartment syndrome [22], popliteal artery entrapment syndrome [11–13] and tarsal tunnel syndrome [4–8]. The authors demonstrated local trauma or prolonged compression, peripheral neuropathy caused by diabetes and idiopathic neuropathy were the causes for soleal sling syndrome. In addition, other causes such as cysts, tumours, the popliteus muscle and iatrogenic injury have been reported [23–25], but lower extremity ACS as a cause for soleal tendinous arch compression has not been reported.

Table 2 Pre- and post-operative assessment

Case	Follow-up (months)	Muscle strength		Sensation		Pain		Tinel's sign		Satisfaction with outcome
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	
1	20	G 3	G 5	G 3	G 4	2	0	G 2	G 1	5
2	23	G 3	G 4	G 4	G 4	3	1	G 3	G 1	4
3	24	G 4	G 5	G 3	G 5	4	0	G 2	G 1	5
4	20	G 3	G 3	G 2	G 3	4	3	G 3	G 2	3
5	20	G 3	G 4	G 4	G 4	2	0	G 2	G 1	4
6	19	G 3	G 5	G 3	G 5	3	0	G 2	G 1	5
7	23	G 3	G 4	G 3	G 4	3	1	G 3	G 1	4
8	23	G 4	G 5	G 3	G 4	0	0	G 3	G 1	5
9	25	G 3	G 5	G 2	G 3	3	2	G 3	G 2	4
Mean	21.8					2.7	0.7			4.4

Pre preoperative, *Post* post-operative, *G* grade

Intraoperatively, we found that there was a great deal of scar tissue around the “inlet” of the deep compartment, i.e. the soleal tendinous arch, and proximal portion of the deep posterior compartment. In this situation, the soleal tendinous arch compression and nerve adhesion existed together. By reviewing the operative medical record database for fasciotomy, we speculate that the incomplete fasciotomy in the proximal lower extremity may be a cause for this neurological compression. For the patients receiving conservative treatment, failure to perform fasciotomy may also lead to this complication.

Usually, a lower extremity ACS is caused by a closed crush injury in an earthquake casualty [26, 27]. Correct management of such an injury is essential for functional recovery of the injured extremity. In such acute conditions, treating ACS is often complicated by limited resources and needs specific knowledge and experience [1]. Our study indicates that sufficient fasciotomy may prevent secondary compression of the tibial nerve by the soleal tendinous arch, especially for the deep posterior compartment. Our experience may be helpful to prevent this secondary neurological compression in future emergency treatment in an earthquake casualty.

Our study demonstrates that the tendinous arch of the soleus muscle may act as a potential compression site of the tibial nerve. Thus, proximal and distal compression of the tibial nerve can be definitely distinguished according to corresponding clinical presentations. When there are numbness in the sole of the foot and strength weakness of the flexor hallucis longus, the tibial nerve may be compressed at the site of the soleal tendinous arch. When there is only numbness in the sole of the foot, the nerve may be compressed at the tarsal tunnel.

Moreover, the finding offers promise for those patients who have persistent plantar numbness after tarsal tunnel decompression [9, 19].

It should be noted that a great deal of scar tissue induced by incomplete fasciotomy leads to both a space-occupying nerve lesion in this anatomical bottleneck and nerve adhesion distal to the tendinous arch. Therefore, sufficient neurolysis in the proximal portion of the deep posterior compartment as well as complete division of the soleal tendinous arch is critical for such nerve injuries. Our results showed pain relief and improvement of sensory and motor function were achieved after neurolysis in our series.

For the diagnosis of soleal tendinous arch compression, a positive Tinel's sign at the level of the soleal tendinous arch is critical because this is existed in all patients in our series. Although EMG can identify the block of nerve conduction, direct compressive lesions caused by the soleal tendinous arch cannot be identified [9]. Therefore, we believe the diagnosis of soleal tendinous arch compression does not require EMG as the physical examination is sufficient. However, newer MR neurography techniques show promising results [20].

The limitations of the study are that it was uncontrolled and had a small sample size. Future studies ideally will be prospective, randomised and blinded to better ascertain the effect of the neurolysis.

Conclusions

Unsuitable treatment of lower extremity ACS can lead to tibial nerve compression beneath the soleal tendinous arch. Neurolysis may improve pain and sensory and motor function.

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