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ORIGINAL STUDY

The anterolateral incision for pilon fracture surgery : An anatomic study of cutaneous blood supply

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The purpose of this study was to examine the blood supply to the adjacent skin and its vulnerability to anterolateral tibial plating performed with fibular plating through a single surgical incision. Ten lightly embalmed cadaver legs without a history of lower extremity trauma or surgery with a mean age of 71 years (range, 57 to 87 years) were used for this investigation. Each specimen was injected with a commercially available silicone compound through the popliteal artery. The left leg was plated through a modified extensile Böhler approach and the right leg served as the control. Each leg was anatomically dissected. All measurements were taken using a digital caliper by a single investigator. A mean of 9.3 (range, 4 to 17) perforating arteries were present and in the proximity of the fibula plate. Our findings suggest the potential for iatrogenic soft tissue breakdown along the posterior border of the anterolateral surgical incision in this procedure as a result of compromised blood supply to the skin.

Keywords : pilon ; wound complications ; arterial supply.

INTRODUCTION

Pilon fractures are frequently treated with antero-lateral plating and concurrent fibular plating through a single incision. One of the major complications of open reduction and internal fixation of pilon fractures is wound breakdown and subsequent infection (*8,19*). The effects of medial tibial plating on the local vasculature have been studied (*5*). The anterior tibial neurovascular bundle at the end of the distal tibia has been studied in association with tibial nailing (*14*). Several studies (*7,13,21*) have examined the vasculature associated with flap creation in this anatomic region. However, to our knowledge, no studies have investigated the blood supply to the skin and its vulnerability to single-incision anterolateral plating of pilon fractures with concurrent fibular plating. The purpose of this study was to examine the blood supply to the skin associated with the anterolateral surgical approach to the distal tibia and to determine its vulnerability from concurrent anterolateral tibia plating and fibular plating through a single incision for a pilon fracture.

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MATERIALS AND METHODS

This was an Institutional Review Board exempt study performed at a university affiliated level I trauma centre. Ten lightly embalmed cadaver legs (2) (four pairs and two individual) without a history of lower extremity trauma or surgery were obtained from the trauma centre's affiliated university bequeathal program. There were five male and one female specimen with a mean age of 71 years (range : 57 to 87 years). The causes of death included drug-induced rhabdomyolysis, pancreatic cancer, lithium-induced multisystem organ failure, renal failure, and Alzheimer's associated failure to thrive. The bodies were stored in a refrigerator at 4.4°C (40°F). A careful examination was made of each leg noting size, shape, and any superficial markings or defects. Each specimen was injected with commercially available Microfil MV-130 (Flow Tech Inc, P.O. Box 834 Carver, MA 02330-0834 USA) to allow for visualisation of the arteries.

We performed multiple pilot dissections to refine our injection and dissection techniques before beginning this investigation. These included using paired lower extremities to compare an injected leg without plating to a leg with the tibia plated in order to confirm the viability of our technique.

For each dissection, we first placed the specimen in the prone position to facilitate access to the popliteal fossa. We mixed the Microfil diluent and MV-130 red silicone latex solutions at a 10:9 ratio using a 30 ml syringe which was then set aside. The Microfil curing agent was added and mixed in with this solution at a 1:19 ratio after the popliteal artery was prepared and ready for injection, making a 30 ml solution.

We used a standard posterior approach to the popliteal fossa to access the popliteal artery. The vessel proximal to the injection site was ligated. Distal to the injection site, a tie was placed loosely around the artery. A small nick was made in the vessel of sufficient size to insert a 14 gauge metal cannula. After mixing the solution, the 30 ml syringe filled with gel was attached to the cannula. One assistant held the distal suture wrapped around the artery tightly as the silicone gel was slowly injected into the popliteal artery in a pulsating manner. Upon completion of the injection, the catheter was removed and the distal suture quickly tied off on the artery. The preparation was performed a minimum of one day before the dissection to allow time for the gel to cure overnight in the refrigerator.

On the day of the dissection, the specimen was placed in the supine position and the left leg was prepped to perform a modified extensile Böhler approach as described by Herscovici *et al* (10). All right leg specimens served as controls. The topographic landmarks of Chaput's tubercle and the area between the shafts of the third and fourth metatarsals were identified. The incision started 5 cm proximal to the ankle joint and slightly medial to Chaput's tubercle, and extended distally in a straight line toward the base of the third and fourth metatarsals. Preventing the creation of thin skin flaps, the superficial peroneal nerve was identified and protected whilst the dissection proceeded through the subcutaneous tissue. We exposed the superior and inferior extensor retinaculum and the tendons of the extensor digitorum longus, peroneus tertius, extensor hallucis brevis, and extensor hallucis longus.

After dividing both the superior and inferior extensor retinaculum, a medial mobilisation of the tendons of the extensor digitorum longus (EDL) and peroneus tertius, the deep peroneal nerve, and the dorsalis pedis artery was performed. In the distal aspect of the incision, the muscle belly of the extensor digitorum brevis was visualised. If greater exposure was required, it was retracted laterally if possible, divided in the direction of its fibers, or detached from its origin and reflected distally. We identified and protected the lateral branch of the deep peroneal nerve and the lateral tarsal artery that arose at this level. The incision was then carried down to the level of the periosteum of the tibia proximally, the capsule of the ankle, and the calcaneocuboid joint distally.

The fibula was approached through the same incision as described by Herscovici *et al* (10). Blunt dissection was performed down to the fibula. The peroneus tertius and EDL were retracted laterally to facilitate this approach. A seven-hole 3.5 mm one-third tubular locking plate (Synthes, Paoli, PA) was placed on the distal fibula, and an anterolateral locking plate (Synthes, Paoli, PA) was used on the tibia. The incision length and location, including its distance between the malleoli and its distance from proximal-to-distal to the ankle joint, were then measured.

The cadavers were positioned prone and a superficial straight line incision was made starting at approximately the junction of the proximal and middle-third of the calf, over the posterior midline, and extended distally to just below the malleolar tips. The dissection was continued in a lateral direction toward the fibula and onward to the crest of the tibia. The perforating arteries were mapped as they were exposed. We measured directly from the perforating artery perpendicular toward the fibula and, from this location, from the fibula to the lateral malleolus. The number of perforating arteries was recorded as well as their location in relation to the skin incision on the leg that was plated if they were in close proximity to the incision. The average values of two measurements taken by the same author (BEF), using a General Ultratech 12” fractional digital caliper (UT-14712, General Tools & Instruments, Co., LLC, New York, NY), were analysed using Microsoft Excel. Any arteries within 180 mm of the lateral malleolus were included (*20*). The length of the foot from the heel to the tip of the third toe was measured to standardise lengths. Digital photographs were taken before cutting away perforating arteries after they had been measured during the initial sessions to ensure uniformity of technique and for later review. Babcocks were used to retract the dissected flap. Anterolateral plating was performed by an orthopaedic trauma fellow who was assisted by an orthopaedic research fellow.

RESULTS

The mean foot length of the ten specimens was 233.84 ± 16.48 mm (Table I) and the mean diameter from malleolus to malleolus was 63.95 ± 3.61 mm. The surgical incision began 192.09 ± 30.45 mm proximal to the joint and extended 22.54 ± 10.55 mm distally in 4 of the 5 left leg specimens. This incision extended much more proximally than the Böhler approach to the ankle in order to access the pilon. The incision was more closely approximated with the lateral malleolus than with the medial malleolus (46.10 ± 9.58 and 52.07 ± 7.57 mm, respectively) and closer to the fibula than the tibia (20.80 ± 11.33 and 26.28 ± 9.52 mm, respectively).

In seven specimens, the superficial peroneal nerve (SPN) point of exit from the fascia was visualised. The SPN exited a mean of 43.46 ± 44.23 mm, or an adjusted value 140.87 ± 38.09 mm from the tip of the lateral malleolus.

A mean of 9.3 ± 3.47 (range : 4 to 17) perforating arteries were identified on the lateral aspect of the specimens (Table I). The location of the arteries was broken down into 10 mm sections based on the distance from the tip of the lateral malleolus (Table II) and the distance from the posterior fibular border (Table III) and a scatter plot was used to visualise location of the vessels (Fig. 1). The most common levels the vessels were located in (based on the adjusted values) were 20 to 30 mm and 120 to 140 mm proximal to the lateral malleolus, 20 mm posterior to the posterior fibular border and the border of the fibula, and 20 to 30 mm anterior to the posterior fibular border. Forty-two percent (39 of 93) of the vessels pierced the fascia between the posterior border of the fibula and 40 mm anterior to this border. Although the vascular supply was

Table I. — Specimen Information

Number	Foot	Gender	Heel/Toe Length (mm)	Number of Vessels	Incision Length (mm)	Superficial Peroneal Nerve (mm)
1	R	M	259.49	7	N/A	180.19
2	L	M	253.31	10	193.26	175.80
3	R	M	237.42	17	N/A	–
4	R	M	229.64	12	N/A	–
5	L	M	232.09	4	–	194.77
6	R	M	221.88	10	N/A	75.52
7	L	M	219.99	7	237.38	–
8	R	M	239.57	8	N/A	150.39
9	L	M	241.84	9	234.17	125.68
10	L	F	203.13	9	213.60	101.89
	Mean		233.84	9.30	219.60	143.46
	Standard deviation		16.48	3.47	20.48	44.23

N/A – not applicable.

Table II. — Vessels in relation to distance from lateral malleolus

Location (mm)	Raw values	Adjusted values
> 190	–	2
180.01-190	–	4
170.01-180	8	1
160.01-170	7	7
150.01-160	4	7
140.01-150	10	4
130.01-140	5	8
120.01-130	8	9
110.01-120	4	4
100.01-110	4	5
90.01-100	8	7
80.01-90	3	5
70.01-80	10	7
60.01-70	4	5
50.01-60	1	1
40.01-50	4	4
30.01-40	1	1
20.01-30	7	8
10.01-20	2	1
0.01-10	1	1
< 0	2	2

extremely varied, there was a constant supply of blood surrounding and travelling with the superficial peroneal and sural nerves. We mapped the area of soft tissue prone to devascularisation (Fig. 2).

Table III. — Vessels in relation to distance from the posterior fibular border

Location (mm)	Raw values	Adjusted values
< -30.01	1	1
-30 to -20.01	6	7
-20 to -10.01	15	14
-10 to 0	16	16
0.01 to 10	7	7
10.01 to 20	11	12
20.01 to 30	16	15
30.01 to 40	6	5
40.01 to 50	1	3
50.01 to 60	11	10
60.01 to 70	3	3

DISCUSSION

Our investigation found a constant and developed vascular supply to both the sural nerve and the SPN. Between the tip of the lateral malleolus and 180 mm proximal to this point, a mean of 9.3 vessels perforated the fascia on the lateral aspect of the leg. Forty-two percent of these vessels exited in the region of the leg where the surgical interval travels along the musculofascial plane, which is the area posterior to the surgical incision that extends superficially over the fibula (Fig. 2). Our findings suggest this area is at great risk of devascularisation with this surgical approach, as our tissue dissection

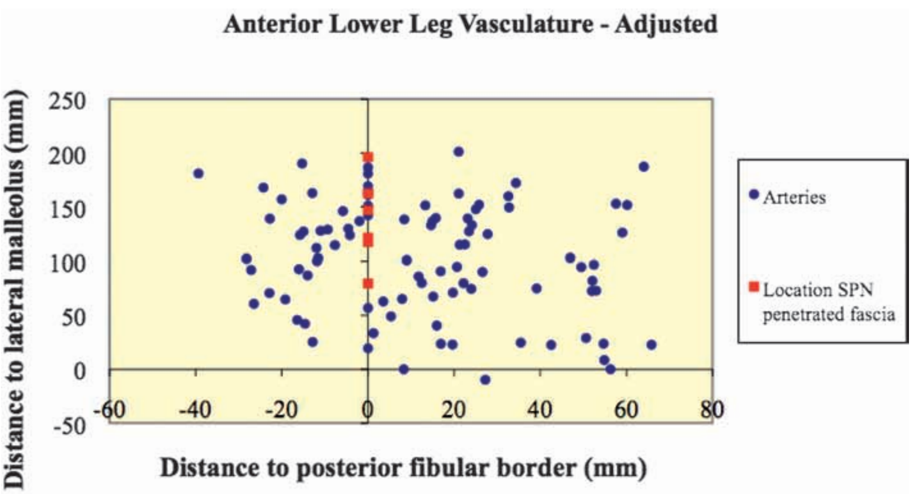

Fig. 1. — Exit points of perforating arteries

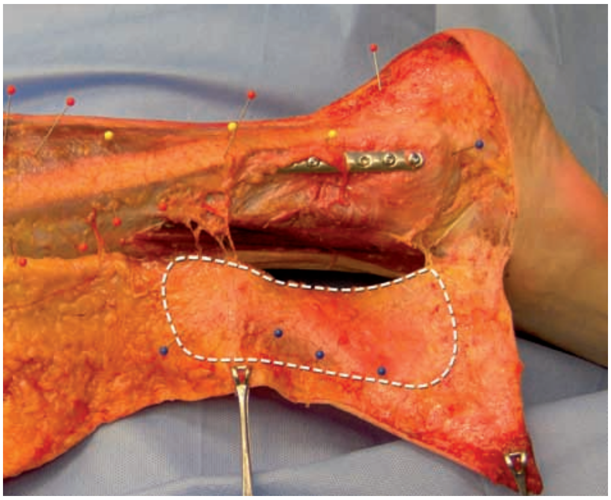

Fig. 2. — Area of soft tissue susceptible to devascularisation. White dotted line : tissue plane used to approach the fibula for plating. Red top pins : perforating vessels. Yellow top pins : posterior fibula border. Blue top pins : outline tissue plane used for fibular plating.

essentially 'degloves' the area in order to access the fibula. The exit points of the vessels varied greatly. Although a few areas showed a slightly higher occurrence of perforators, we were unable to suggest a safe plane through which to approach the fracture.

The observation of a consistent vascular supply along the SPN and the sural nerve is in agreement with previous investigations (*6,11,13*), as is the level at which the SPN penetrated the fascia (*1,4*). The mean number of perforators is on the higher end of those observed in prior studies (9.3 versus 3 to 10) (*6,7,13,15,21*) even though our area of measurement did not extend as proximally as some of those investigations.

Whilst the vascular supply to the lower leg is well described in the literature, the focus has almost exclusively been on its relation to flap creation (*3,6, 7,11,13,15,17,18,21*). One of the earliest descriptions of the superficial vasculature of the lower leg was provided by Salmon (*15*) in *Artères de la Peau*. He described two sets of branches of the anterior tibial artery : lateral and medial. The medial branches passed obliquely downward and adhered to the tibial periosteum. The lateral branches from the anterior tibial artery were described as being smaller than the medial branches, with the upper branches passing between the tibialis anterior and the common extensor muscles. The lower branches followed one of two paths, passing either between tibialis anterior and the common extensors, or between the common extensors and extensor hallucis longus.

In the distal portion of the lower leg, Salmon (*15*) found two to three septal branches passing through the intermuscular septum, perforating the deep fascia in front of the lateral peroneal muscles. These arteries were noted to be large with ascending and descending branches. He also described a set of arteries to the lateral peroneal muscles that usually arose from behind the anterior intermuscular septum at the junction of the middle and lower third of the leg. He concluded from dissections and a radiological study that the anterolateral portion of the leg was less well vascularised than its neighboring regions. Carriquiry *et al* (*6*) examined 20 cadavers and reported similar findings, but observed 6 to 10 arteries (0.3 to 0.8 mm in diameter) penetrating the fascia. These authors also noted wide intercommunication along the margins of each septocutaneous artery's territory. Masquelet *et al* (*13*) observed an average of five branches to the lateral aspect of the leg. The proximal two-thirds of the leg was supplied by direct cutaneous branches from the anterior tibial artery.

Chen e*t al* (*7*), in mapping an area for lateral leg flaps, found up to eight musculocutaneous arteries on the lateral leg with the four most proximal vessels being the most consistent. Yoshimura *et al* (*21*) counted an average of 4.8 cutaneous vessels branching from the peroneal artery on the lateral leg.

In Taylor and Palmer's (*17*) 1987 investigation of the vascular supply of the extremities in which the term "angiosomes" was defined, three-dimensional blocks of tissue were described that were supplied by a common source artery. The authors asserted that adjacent source arteries were actually linked by a continuous network of vessels. They observed that most were connected by reduced caliber choke vessels. In a follow-up study, Taylor and Pan (*18*) noted that the anterior compartment muscles were supplied only by the anterior tibial artery angiosome and were therefore at risk of ischaemia. Attinger *et al* (*3*) explored this concept and proposed that if a source artery produced good blood flow, then the safest incision was along the border of the two angiosomes. However, if the flow was compromised, the choke vessels took four to ten days to become patent. Incisions placed too soon after injury could result in poor healing, necrosis, or gangrene.

Soft tissue injury remains a common problem with tibial pilon fractures that may result in postoperative skin slough and infection. The subcutaneous location of the medial tibia creates several problems with placing a plate medially. The advantages and disadvantages of the single incision anterolateral and lateral approaches to the tibial pilon have been discussed previously by others (*9,12,16*).

Our study is limited by the small number of specimens (ten legs from six cadavers). The age of the cadavers and the presence of diabetes and coronary artery disease in two increase the likelihood of vascular changes not typically seen in the younger patient population who most commonly suffer pilon fractures. Visual inspection of the skin and toe nail beds was used to reduce the likelihood of receiving one of these cadavers. The general size difference between cadavers may be a limiting factor, but we accounted for this by standardising our measurements based on foot length. Despite the variability of the vascular anatomy, even between the separate extremities in the same patient, we were able to map certain repetitive structures.

In conclusion, the combination of vascular injury from the fracture itself and the already tenuous blood supply to the distal tibia creates an ideal scenario for wound breakdown. Although others have examined the cutaneous vascular patterns of the distal leg, to our knowledge, the effect on the vascular bed of the single incision lateral approach for concurrent plating of the distal tibia and fibula has not been studied. Our findings suggest the potential for iatrogenic soft tissue breakdown along the posterior border of the anterolateral surgical incision in this procedure as a result of compromised blood supply to the skin.

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