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Minimally invasive Akin osteotomy and lateral release: Anatomical structures at risk—A cadaveric study

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HIGHLIGHTS

- This study analyzed the anatomical relationships and the risks for soft tissue lesions when performing the dorsomedial MIS portal for the Akin osteotomy of the proximal phalanx of the hallux, and the MIS dorsolateral portal for soft tissue release.
- The possibility of tendon lesion was seen in 12.5% and 18% of cases, the first figure corresponds to EDB detachment. No lesions involving nerves and vessels were reported.
- The dorso-medial portal must be performed as close as possible to the extensor tendon to reduce the risk of nervous lesion.
- This type of percutaneous procedures should be conducted by surgeons with experience in foot surgery, and extensive knowledge of the anatomy of the region.

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ABSTRACT

Background: Among the many surgical techniques used for hallux valgus correction, different osteotomies may be performed in the proximal phalanx as well as lateral release as associated procedures. The aim of this study is to analyze the anatomical relationships and the risks for the soft tissue lessions when performing the dorsomedial minimally invasive surgery (MIS) portal for the Akin osteotomy, and the MIS dorsolateral portal for lateral release, in order to define a safety zone when conducting the procedure in order to avoid complications.
Materials and methods: The procedures were carried out on 16 fresh-frozen cadaveric feet. A MIS dorsomedial and dorsolateral portals were performed. The anatomical dissection of the cadaveric pieces was carried out and the different anatomic and surgical relationships were analyzed and measured.
Results: No nerve injury was found. Injury of the extensor hallucis longus (EHL) paratendon were seen in 9 cases (56%). There was no injury of the flexor hallucis longus (FHL) tendon and or collateral plantar nerves. A partial injury of the FHL sheath was observed in 44% of the samples.
Conclusions: Although percutaneous Akin osteotomy is clinically effective, the possibility of injury of anatomic structures is high (9–55%), however injuries upon vascular or nerve structures were not seen.

1. Introduction

Among the many surgical techniques used for hallux valgus correction, different osteotomies may be performed in the proximal phalanx. The most widely used type of proximal phalanx osteotomy is still that described as early as 1925 by Akin [1], who depicted the treatment of hallux valgus as a resection of the medial exostosis of the first metatarsal, a medial wedge osteotomy of the proximal phalanx of the hallux, associated with the lateral release of the abductor tendon. Indicated in the past as the only procedure for the treatment of hallux valgus, it is at present, indicated unusually as the only surgical procedure [2]. However, it is often performed in association with other osteotomies of the first metatarsal (Chevron, Scarf, etc.) [3] and with surgical procedures involving soft tissues.

Some minimally invasive surgery (MIS) techniques [4] have been developed in recent years in order to perform osteotomies of the metatarsals and phalanges. These techniques are conducted by means of small incisions or "portals", using power instruments together with specific burrs for both cutting and trimming. The surgical planes are not directly exposed, and radiological guidance is

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required during the procedure. The pioneers [5] of the MIS perform the Akin osteotomy which represents a regular surgical procedure.

Dhukaram et al. [6], recently assessed the risk of iatrogenic injury while performing MIS techniques. They included the lateral release, a minimally invasive Chevron and Akin (MICA) and a minimally invasive distal metatarsal extra-articular osteotomy (DMO) on his cadaveric study.

The aim of this study is to analyze the anatomical relationships and the risks for soft tissue lesions when performing the dorsomedial MIS portal for the Akin osteotomy of the proximal phalanx of the hallux, and the MIS dorsolateral portal for soft tissue release, in order to define the safety zone when conducting the procedure in order to avoid complications.

2. Materials and methods

The procedures were carried out in a cadaveric laboratory on 16 fresh-frozen cadaveric feet. The cadaveric specimens were ethically approved for surgical validation and research purpose by the Research Committee of the Austral University Hospital. An Akin MIS osteotomy was conducted using a dorsomedial portal in combination with the release of the lateral joint tendon through a second lateral percutaneous portal. The surgical procedure was conducted by two foot and ankle surgeons with experience in forefoot MIS. The phalangeal osteotomy was conducted through a paratendinous dorso-medial portal medial to the extensor hallucis longus tendon, using specific instruments for percutaneous surgery; a short Shannon cutting burr for the bony section was used. No fluoroscopy was used during the surgical procedures.

The lateral release of the joint tendon was performed through a dorso-lateral portal, using a no. 64 Beaver blade, paratendinous lateral to the extensor hallucis longus tendon.

After a careful anatomical dissection of the cadaver, the technique was conducted, and then the following landmarks/data were assessed and measured; the data collected was included in a study spreadsheet:

(1) Distance between (DB) the lateral release portal and the lateral edge of the extensor hallucis longus tendon.
(2) DB the lateral release portal and the dorsolateral cutaneous nerve (Fig. 1).
(3) DB the portal for the Akin osteotomy ("PA") and the extensor hallucis longus tendon (Fig. 2 - red circle and red line).
(4) Distance between the PA and the dorsomedial cutaneous nerve (Fig. 3 - red line).
(5) Presence of hallux metatarsophalangeal instability after the procedure.

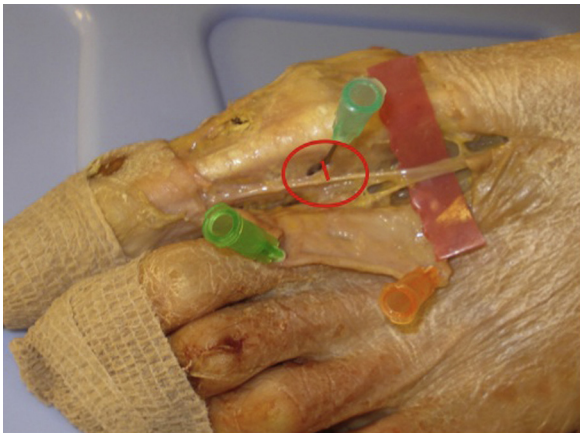

Fig. 1. Lateral release portal-dorsolateral cutaneous nerve.

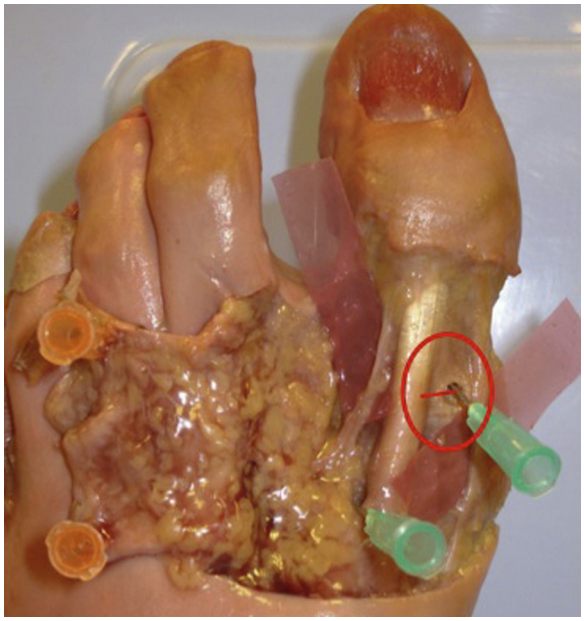

Fig. 2. Akin portal-EHL (red circle, red line) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

(6) DB the "PA" and the metatarsophalangeal joint.
(7) Presence of an overt macroscopic lesion in the dorsomedial cutaneous nerve.
(8) Lesion of the dorsolateral capsular periosteal tissue.
(9) Lesion of the extensor hallucis longus tendon.
(10) Appearance of the plantar aspect of the paratendon of the extensor hallucis longus.

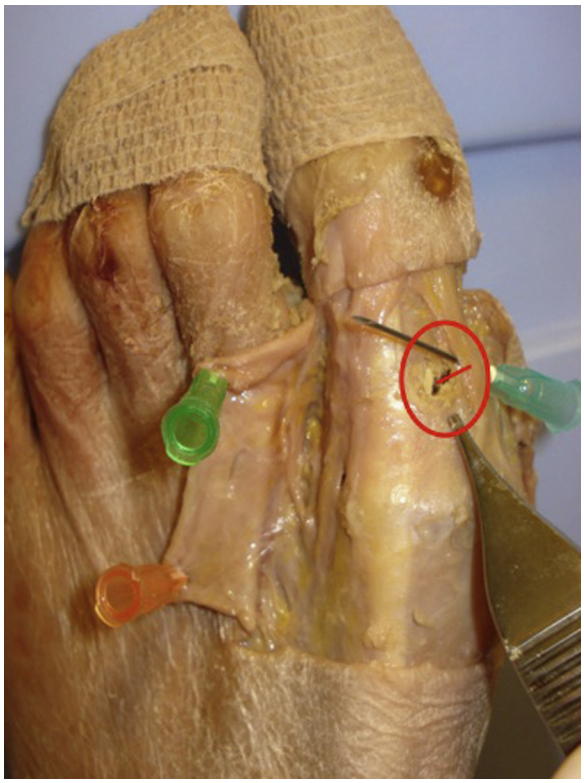

Fig. 3. DB Akin portal-dorsomedial cutaneous nerve (red line) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

(11) Appearance of the plantar aspect of the tendon of the extensor hallucis brevis of the hallux.
(12) Lesion and/or disinsertion of the tendon of the foot muscle.
(13) Lesion of the plantar medial cutaneous nerve.
(14) Appearance of the dorsal aspect of the sheath of the flexor hallucis longus tendon
(15) Lesion of the flexor hallucis longus tendon.
(16) Lesion of the plantar lateral cutaneous nerve.

3. Statistical analysis

The measurements were carried out by three different operators using a millimeter device, the final result is the average of the three measurements made.

The linear model with both fixed effects and random effects applied is:

$$Y_{ij} = \mu + a_i + b_{j(i)} + \varepsilon_{ij}$$

where,

Y_{ij} the response variable in the ith individual on the jth medition
μ expected value for the variable in study
a_i effect of the ith individual
$b_{j(i)}$ random contribution for the j-th measure on the ith individual
ε_{ij} random error of the medition

The response variables considered were: "Distance between (DB) lateral release portal and the lateral edge of the extensor hallucis longus tendon", (Table 1) "DB the lateral release portal and the dorsolateral cutaneous nerve", "Distance between the portal for the Akin osteotomy ("PA") and the extensor hallucis longus tendon", "Distance between the PA and the dorsomedial cutaneous nerve" and "Distance between the PA and the metatarsophalangeal joint". For each variable we constructed a linear mixed effects model to assess if the difference between measures is significant. For all the considered variables the effect of the measure using the Shapiro–Wilks test was not significant and the residuals were normal.

The distance between (DB) the lateral release portal and the lateral edge of the extensor hallucis longus tendon was not significant ($p = 0.99$). Whereas the DB the lateral release portal and the dorsolateral collateral nerve was significant ($p = 0.05$). Distance between the portal for the Akin osteotomy ("PA") and the extensor hallucis longus tendon ($p = 0.6671$), the distance between the PA and the dorsomedial cutaneous nerve ($p = 0.0766$), and the distance between the PA and the metatarsophalangeal joint ($p = 0.4036$) were all not significant.

Table 1
Anatomical lesions found).

Dorso-medial collateral nerve	No lesions
Metatarsophalangeal instability	1 case
Dorso-lateral collateral nerve	No lesions
Dorso-lateral capsular lesion	1 case
Extensor hallucis longus (EHL) tendon plantar aspect lesion	3 cases
EHL sheath lesion	9 cases
Disinsertion of the extensor hallucis brevis	2 cases
Medial plantar nerve	No lesions
Lesion of the FHL dorsal sheath	7 cases
Flexor hallucis longus tendon	No lesion
Lateral plantar nerve	No lesion

4. Results

As for the dorso-lateral portal the following results were obtained:

(a) The average distance between the lateral release portal and the lateral edge of the extensor hallucis longus was 4.3 mm.
(b) The average distance between this portal and the dorso-lateral cutaneous nerve was 0.7 mm.
(c) No macroscopic lesions made by the scalpel involving either the nerve or the tendon were observed.

As for the dorso-medial portal, the study results can be summarized as follows (it should be noted that for this surgical stage a specific blade, a curette for delicate percutaneous surgery and a short Shannon-type of burr were used):

(a) The average distance between the portal and the extensor hallucis longus was 2.2 mm.
(b) The average distance between the portal and the dorsomedial cutaneous nerve was 4.37 mm.
(c) No macroscopic lesions involving either the nerve (dorsomedial cutaneous) or the tendon (extensor hallucis longus) produced by the scalpel were observed (performing the portal).
(d) The average distance between the Akin osteotomy and the metatarsophalangeal joint surface was 7.3 mm.
(e) One case of lateral metatarsophalangeal instability (due to excessive soft tissue release) was detected.
(f) A tear of the plantar aspect of the paratendon of the EHL produced by the burr was seen in 9 cadaveric samples (56%). Eight cases presented a plantar-medial lesion (sample 1: 50%, sample 2; 50%, sample 4: 15%, sample 5: 50%, sample 7: 15%, samples 12 and 14: 20%, and sample 15: 15%); one case exhibited a plantar-lateral lesion (sample 3: 80%).
(g) Two samples (12.5%) presented detachment of the extensor hallucis brevis tendon (samples 2 and 5), three cases presented partial lesions.
(h) Three cases presented minimal lesions in the plantar aspect of the extensor hallucis longus (sample 2; 7% lesion in the medial edge; sample 3: 15% lesion of the lateral edge; and sample 14: 20% lesion).
(i) Hundred percent of the samples presented intact flexor hallucis longus tendon, and both the medial and lateral plantar cutaneous nerves.
(j) Forty-four percent of the samples presented a partial lesion involving the sheath of the flexor hallucis longus.

Table 1 provides a short summary of lesions related to the anatomical structures.

5. Discussion

This study has certain limitations. Only 16 specimens were used; a larger number of specimens may have identified neurovascular or tendon damage or skin burns as a complication frequently seen in MIS surgeries.

The correction of the proximal phalanx deformity as well as the Distal Article Set Angle (DASA), is performed through phalanx osteotomy. This can be done through open surgery or minimally invasive procedures. Different section geometries as well as different phalanx locations may occur, depending on the type of correction to be conducted.

Several publications, such as Magnan et al. [7] report clinical results of the percutaneous surgery of hallux valgus which are comparable to those obtained with the open approach. With regard to

nerve injury, it can be painless and may result in altered or absent sensation in the distribution of the cutaneous nerve, which may be clinically insignificant. However, neuroma formation could have a greater impact on patient satisfaction and may also need other alternative treatments. Nerve injury rates near 2%, including complex regional pain syndrome, have been reported in literature [7]. In this anatomical study, no nerve injuries were found and the dorsal medial cutaneous branch of the superficial peroneal nerve was well preserved in all the specimens.

According to Dhukaram et al. [6], the dorsal medial cutaneous nerve and the plantar interdigital nerves were intact in all of the specimens in their cadaveric study. There was no apparent damage to the arterial plexus supplying the first metatarsal head. We agree with the authors and we would also recommend the use of cadaveric training sessions or courses before implementing such techniques into clinical practice to improve the understanding of the technique and to minimize the risk of complications. The main neurovascular structures at risk during MIS forefoot surgery are the dorsal medial cutaneous branch of the superficial peroneal nerve and the arterial blood supply to the first metatarsal head, although this was not evident in our samples.

6. Conclusions

(1) Lesion of the tendon sheath and/or paratendon is highly likely (ranging between 44% and 50% depending on the case series). This may not have any clinical impact.
(2) The possibility of tendon lesion was seen in 12.5% and 18% of cases, the first figure corresponds to EDB detachment.
(3) In this study, no lesions involving nerves and vessels were reported.
(4) The dorsomedial portal must be performed as close as possible to the extensor tendon to reduce the risk of nervous lesion.
(5) The dorsolateral portal may lead to increased risk of lateral cutaneous branch lesion, so it must be performed close to the extensor tendon.
(6) This type of percutaneous procedures should be conducted by surgeons with experience in foot surgery, and extensive knowledge of the anatomy of the region.

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