Ultrasound-guided decompression surgery of the distal tarsal tunnel: a novel technique for the distal tarsal tunnel syndrome—part III

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Fig. 1 Overview of the main components of the proximal and distal tarsal tunnel and all important chambers. TN tibial nerve, mpm medial plantar nerve, lpm lateral plantar nerve; icn inferior calcaneal nerve (i.e., baxter nerve), cbbn calcaneal branch of the baxter nerve, mcn medial calcaneal nerve, ms medial septum, upper chamber blue rounded area bounded by blue dotted line, lower chamber green rounded area bounded by green dotted line; “Baxter chamber”: red rounded area bounded by red dotted line. (Color figure online)
Fig. 2 Nerves (lpn, mpn, bn) entering separated tubes at the distal tarsal tunnel, perforating the medial septum. AHM abductor hallucis muscle, mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter’s nerve, cbbn calcaneal branch of the Baxter’s nerve, ms medial septum and its extension, red arrows nerves entering upper and lower calcaneal tubes.
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Fig. 3 Instruments for the minimally invasive ultrasound-guided procedure. High-resolution ultrasound; dissection material; 20-gauge needle; syringe; V-shape; hooked knife.

Fig. 4 Ultrasound visualization of the terminal branches (lpm, mpm, bn) on the (BC) line. The figure on the right side shows an anatomical overview of the structures including the reference line “Dellon-McKinnon” (A\textsubscript{1}B, malleolar-calcaneal) and the “Triangle of Heimkes” (A\textsubscript{1}B–C). Lpm lateral plantar nerve, mpm medial plantar nerve, bn Baxter’s Nerve, FHL flexor hallucis longus muscle, QPM quadratus plantae muscle, AHM abductor hallucis muscle, mpv medial plantar vein, lpv lateral plantar vein, mp a medial plantar artery, lpu lateral plantar artery, black arrowheads superficial layer of the flexor retinaculum, white stars medial septum (deep fascia of the abductor hallucis muscle), black stars medial septum extension (“interfascicular septum”).
Fig. 5 Presurgical mapping of the distal tarsal tunnel. A2-B line: a line from the anterior tip of the medial malleolus (anterior colliculus) to the center of the posterior calcaneal tuberosity; CB line: a line from the navicular tuberosity to the center of the posterior calcaneal tuberosity. Red dots from C perpendicular to the sole of the foot: reference for the surgical portal; white dots and lines: course of MPN and LPN through A2-B, BC and C projection lines; blue dots and line: skin projection of medial septum extension from its intersection with BC line and its mean proximal point calculated from our anatomical study part I; muscle belly: represents the full dorso-plantar height of the medial intermuscular septum; red line: surgical portal for the medial intermuscular septum release in the upper calcaneal tube; dotted tract of the surgical portal line represents the full cut length for the medial intermuscular septum release. (Color figure online)
**Fig. 6** Algorithm. *BC-line* a line from the navicular tuberosity to the center of the posterior calcaneal tuberosity, *C projection* perpendicular line from the navicular tuberosity to the sole of the foot, MIS medial intermuscular septum

- **STEP I Landmarks-US measures**
  - US-scanning and draw the landmarks, B–C line and C projection.
  - Draw the "safe surgical portal" from C projection point.

- **STEP II US-Hydrodissection**
  - Perform the US-guided hydrodissection lateral to MIS.

- **STEP III US-Surgical procedure**
  - Introduce the V-shape lateral to MIS in increasing order of size.
  - Make the retrograde cut for the entire length of MIS.

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**Fig. 7**

- **a** Dissection routine. A2: medial malleolus B: navicular tuberosity C: center of the posterior calcaneal tuberosity; AHM: exposed abductor hallucis muscle belly; asterisk subcutaneous fat; white arrows: buttoned probe entering the surgical portal and following the course through the surgical line. 
- **b** Gross anatomical findings. A2 medial malleolus; B navicular tuberosity; C center of the posterior calcaneal tuberosity; asterisk abductor hallucis muscle belly over the medial intermuscular septum; 2.5 cm: the mean length of the retrograde cut performed over the MIS which exposes the buttoned probe entering the surgical portal and following the course through the surgical line. 
- **c** Gross anatomical findings. MIS: medial intermuscular septum; AHM abductor hallucis muscle belly over the medial intermuscular septum; number sign plantar fascia; asterisk proof of undamaged medial and lateral plantar nerves. (Color figure online)
Clinical-anatomic mapping of the tarsal tunnel with regard to Baxter’s neuropathy in recalcitrant heel pain syndrome: part I

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Fig. 1 Anatomical dissection of the tibial nerve and its branches running in the TT. tn Tibial nerve, mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter nerve, mcb medial calcaneal branch, ms medial intermuscular septum, red arrows: nerves entering separated tubes
Fig. 2 Measurement grid—Dellon–McKinnon malleolar-calcaneal line and Heimkes triangle. Point $A_1$: center of the medial malleolus, point $A_2$: tip of the medial malleolus, point $B$: center of the calcaneus, point $C$: tuberosity of the navicular bone, green line: Dellon–McKinnon malleolar-calcaneal line (DM line, $[A_1B]$), black triangle: Heimkes triangle.

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Fig. 4 Algorithm for ultrasound routine implementation. TN tibial nerve, MPN medial plantar nerve, LPN lateral plantar nerve, BN Baxter nerve, MCB medial calcaneal branch, MS medial septum, MSE medial septum extension, PTT posterior tarsal tunnel, DTT distal tarsal tunnel.

**STEP I**
- Place the probe in the transverse axis on the medial lower leg.

**STEP II**
- 3 A: Identify TN in the short axis.
- 3 B: Go distally by elevator technique along the TN in the PTT to the trifurcation.
- 3 C: Follow the course of LPN, MPN, MCB along the DTT and identify the MS, MSE, upper and lower chambers.

**STEP III**
- 3 D: Focusing on the LPN, scan its posterior edge by elevator technique and find the branching off for BN.
- Follow the BN along its course lateral to the MS and find the injection spot (i.e., first entrapment spot).

Fig. 5 Injection proof: diluted colored latex in BN tube. tn tibial nerve, mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter nerve, mcb medial calcaneal branch, ahm abductor hallucis muscle.
Fig. 6 MCB course from depth to surface. tn tibial nerve, mcb medial calcaneal branch, ll extension of lacinate ligament, red arrow: nerve entering tube

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Fig. 7 Most common arising of BN (80%). Mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter nerve, ms medial septum, point A₁: center of the medial malleolus, point A₂: tip of the medial malleolus, point B: center of the calcaneus, point C: tuberosity of the navicular bone, green line: Dellon–McKinnon malleolar-calcaneal line (DM line, [A₁B]), black triangle: Heimkes triangle, red branches: most common BN arising out of LPN
Fig. 8  a Location spots of LPN, MPN and BN on [A,B]. Mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter nerve, point A1: center of the medial malleolus, point A2: tip of the medial malleolus, point B: center of the calcaneus, point C: tuberosity of the navicular bone, green line: Dellon–McKinnon malleolar-calcaneal line (DM line, [A,B]), black triangle: Heimkes triangle yellow circle: location spot (radius 5 mm). b Location spots of LPN/MPN, BN, MCB on [BC]. Mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter nerve, mcb medial calcaneal branch, point A1: center of the medial malleolus, point A2: tip of the medial malleolus, point B: center of the calcaneus, point C: tuberosity of the navicular bone, green line: Dellon–McKinnon malleolar-calcaneal line (DM line, [A,B]), black triangle: Heimkes triangle, yellow circles: location spots (radius 5 mm)
Fig. 9 Nerves (LPN, MPN, BN) entering separated tubes, perforating the medial septum. Mpn medial plantar nerve, lpn lateral plantar nerve, bn Baxter’s nerve, cbbn calcaneal branch of the Baxter’s nerve, ms medial septum, red arrows: nerves entering separated tubes

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Ultrasound-guided decompression surgery of the tarsal tunnel: a novel technique for the proximal tarsal tunnel syndrome—Part II

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Fig. 1 a Anatomical dissection of the tibial nerve and its branches running in the TT. *tn* Tibial nerve, *mpn* medial plantar nerve, *lpn* lateral plantar nerve, *bn* Baxter nerve, *mcb* medial calcaneal branch, *ms* medial intermuscular septum, red arrows: nerves entering separated tubes. b The red circles show the landmarks to sketch the flexor retinaculum; the black lines show the DM-line and the lines ±2 cm (proximal and distal) to the DM-line; the yellow sketched lines show course of the tibial nerve with its branches; the white lines show the courses of the posterior tibial and the flexor digitorum muscles. (Color figure online)
Fig. 2 Instruments for the UGAFDS approach: ultrasound device; dissection material; 20 gauge needles, syringe; V-shape; hook knife.

Fig. 3 a–d The US pictures were taken 2 cm proximal and distal of the DM-line and directly at the level of the DM-line; the red circles are landmarks visualizing the flexor retinaculum; the yellow head arrow mark the surgical portal at the US pictures; TP tibial posterior, FDL flexor digitorum longus; V posterior tibial veins and perforating vein at the 2 cm distal Dellon line, A posterior tibial artery, TN tibial nerve, MPN medial plantar nerve, LPN lateral plantar nerve, FHL flexor hallucis longus muscle. (Color figure online)
Fig. 4 Red circles show the landmarks to sketch the flexor retinaculum; the yellow lines represent the tibial nerve and its branches; the instrument is the hooked knife over the surgical portal. (Color figure online)
The new surgical approach is summarized in five easy steps: the STEP I: take the material; STEP II: perform a US scanning of the tarsal tunnel; STEP III: make the US-hydrodissection with the 20 gauge needle and the syringe; STEP IV: using the needle as a guide, we introduce the V-shapes in increasing order of size; STEP V: with the hook knife, we make the release of the flexor retinaculum.

Ultrasound-guided decompression surgery of the tarsal tunnel: a novel technique for the proximal tarsal tunnel syndrome—Part II

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Fig. 6 Red circles are the landmarks to sketch the flexor retinaculum; after the minimally approach and dissections one can see the result cutting the whole flexor retinaculum at the proximal tarsal tunnel. (Color figure online)

Fig. 7 a Shows an anatomical dissection with the constant perforating vein; in b the sketch shows both a constant and an inconstant perforating vein and their location