Vital Structures at Risk During Minimally Invasive Hallux Valgus Surgery with Percutaneous Screw Fixation: A Cadaveric Study

Thomas Milisits B.S.[1,2], Michael Rutkowski B.S.[2], Sherwin Shaju M.S.[2], Lindsay Short B.A.[2]

1. Second year masters in public health student, Mt. Sinai Icahn School of Medicine, New York, NY
2. Third year medical student, New York College of Podiatric Medicine, New York, NY

Statement of Purpose

The specific aims of this study were to identify the vital anatomic structures at risk during minimally invasive hallux valgus surgery with percutaneous screw fixation and to subsequently identify the safest portals of entry for this type of procedure as well as portals you want to avoid. This knowledge would then lead to improved outcomes and patient satisfaction.

Methodology & Procedures

Six cadaveric fresh frozen feet were utilized to perform a minimally invasive Chevron osteotomy. Using a number 11 blade, a stab incision was made over the dorsal medial proximal edge of the flare of the medial eminence of the first metatarsal down to the bone (Figure 1). A periosteal elevator was utilized to bluntly reflect the soft tissue off the bone along the dorsal cortex in line with the proposed osteotomy. Using a burr, the bone was penetrated from medial to lateral creating the apex, followed by the chevron osteotomy. Intraoperative fluoroscopy was utilized to guide the osteotomy.

The metatarsal head was positioned and two stab incisions for the percutaneous screws were created. Two 0.9 mm kirschner wires (k-wires) were driven proximal medial to distal lateral as provisional fixation (Figure 1). The more lateral k-wire sat in the lateral hold of the first metatarsal head, and the more medial wire sat in the medial half. The depth gauge was then utilized to determine the size of the screw, followed by countersinking. Each osteotomy was fixated with two 3.0 mm cannulated screws under fluoroscopic guidance.

The anatomy course director from the NYCPM and the Icahn School of Medicine at Mount Sinai performed the anatomic dissection. Utilizing a number 10 blade, careful layer by layer dissection was performed to each specimen (Figure 2). Pictures were taken at each layer and structures were tagged and identified. Measurements were taken of the vital structures in relation to the portals.

Figure 7: Intraoperative fluoroscopy after the minimally invasive bunion surgery was performed.

Literature Review

The traditional open bunion procedure is still the standard approach and the most commonly performed to correct this deformity. However, minimally invasive surgery (MIS) has been gaining popularity, and several modifications have been developed off of the original procedure. The procedure has a steep learning curve and requires special training.

The major disadvantage of MIS is the lack of direct visualization of tissue layers and structures [1] potentially placing vitals structures at risk. The advantages of minimally invasive hallux valgus surgery include minimal bone and soft tissue disruption, decreased swelling, decreased scar formation, decreased operating room time, decreased cost, earlier weight bearing and rehab, and increased patient satisfaction.

Surface anatomy assists in localizing structures, but occasionally, vital structures are not easily visible or palpated [3]. In the case of hallux valgus MIS, the neurovascular structures around the first ray are rarely palpable and a potential cause for concern. There are only a handful of publications addressing the proper technique in terms of anatomical relationships to the incision sites and approaches to handle a variation in the anatomy [1].

Results

All data were analyzed using MATLAB to establish the most vulnerable structures during this minimally invasive procedure. The DMCN damage rate was 16.67%, while the TA damage rate was 33.33%. An ANOVA test was run for both the DMCN and TA to assess which incision site presents the highest risk to respective structures. For the DMCN, the distal site was significantly farther away from the nerve [$p = 0.812 < 0.10$, CI = 90%] when compared with the overall distances made at all three incision sites [F-Ratio = 2.983, df = 17]. For the TA, the proximal site was significantly more likely to damage the tendon while the distal incision site was significantly less likely to damage the tendon [$p = 0.0008 < 0.05$, CI = 95%] when compared with the overall distances made at all three incision sites [F-Ratio = 59.67, df = 17]. A paired t-test was done to see which structure is most likely to be damaged. The null hypothesis is rejected and there is enough evidence to claim that the TA is significantly less likely ($p = 6.113e\text{-}3$, $a = 0.5$) to be damaged than the DMCN.

Figure 1: Three incision sites: A (proximal portal), B (middle portal), C (distal portal)

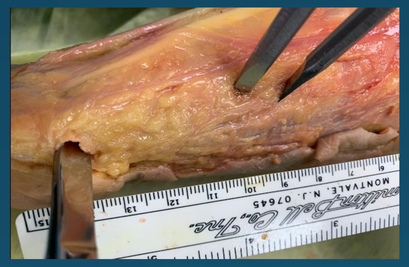

Figure 2: Superficial/ First layer of dissection of the first ray in one of the cadaveric specimens.

Figure 3: The saphenous vein in relation to the portals of entry.

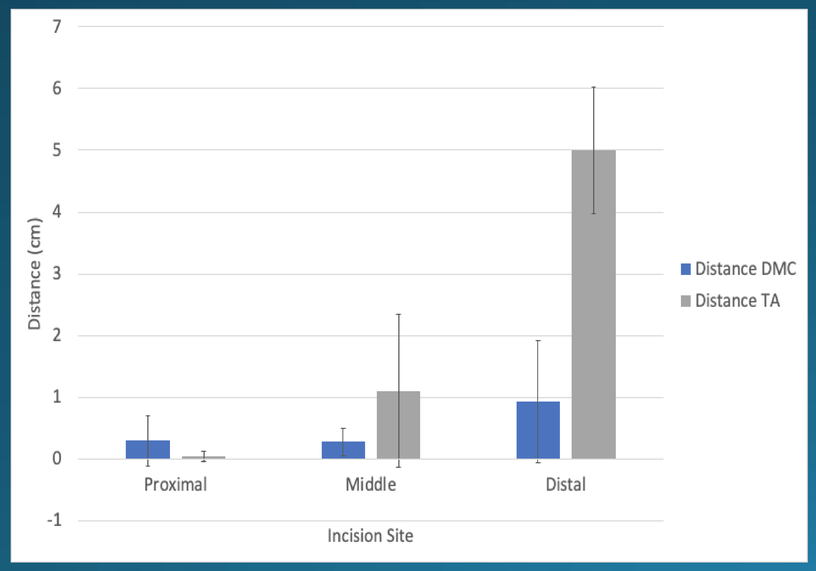

Figure 6: Average distance of structures at risk from each incision site.

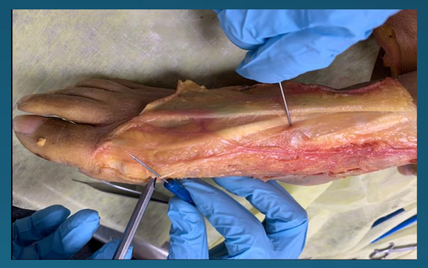

Figure 4: The proximity of the tibialis anterior tendon and the dorsal medial cutaneous nerve to the portals of entry.

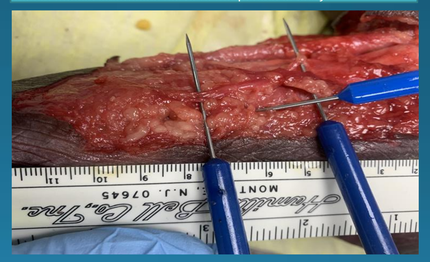

Figure 5: Image of the specimen that had venous disease with inability to adequately visualize the anatomy.

Analysis & Discussion

The resurgence of minimally invasive procedures has led to a new interest in studying the vital structures at risk.

The results of this study identified the DMCN at greatest risk during MIS hallux valgus surgery (Figure 6). The average distance for each portal of entry to the DMCN is less than 1 cm, putting it at increased risk of damage. Though scant literature exists about structures at risk, our data is consistent with current literature.

The concern of damaging vital structures with MIS was addressed by Malagelada in 2018 with the "clock method" [3]. These authors focused on different nerves than we did in our study, however, it's a method that can be adopted for our results in future studies. These authors looked at the dorsomedial digital nerve (DMDN) and the dorsolateral digital nerve (DLDN) in relation to the extensor hallucis longus (EHL) tendon. The DMDN was an average of 26.2° medial to the medial border of the EHL and the DLDN was an average of 32.3° lateral to the medial border of the EHL[3]. Converted to the "clock method", these two structures were consistently between 10 and 2 o'clock on either feet [3]. Future studies looking at methods like this one can be beneficial for surgeons when planning their operative approach during MIS hallux valgus surgery.

There are several limitations to our study. One is that only six fresh frozen specimens were utilized. Due to anatomic variability, it is important that future studies look at a larger cohort. Additionally, one of our specimens had a history of venous disease making it difficult to get a true visualization of the anatomy in this foot.

References

1. Trnka H, Krenn S, et al. Minimally invasive hallux valgus surgery: a critical review of the evidence. *International Orthopedics*. 2013; 37:1731-1735.
2. Kaipel M, Reissig L, et al. Risk of Damaging Anatomical Structures During Minimally Invasive Hallux Valgus Correction (Bösch Technique): An Anatomic Study. *Foot and Ankle International*. 2018; 39(11) 1355-1359.
3. Malagelada F, Dalmau-Pastor M, et al. Increasing the safety of minimally invasive hallux surgery - An anatomical study introducing the clock method. *Foot and Ankle Surgery*. 2018; (24) 40-44.
4. Jowett C, Bedi, H. Preliminary Results and Learning Curve of the Minimally Invasive Chevron Akin Operation for Hallux Valgus. *The Journal of Foot and Ankle Surgery*. 2017; (56) 445-452.
5. Siddiqui N, LaPorta G. Minimally Invasive Bunion Correction. *Clinics of Podiatric Medicine and Surgery*. *2018; (35) 387-402.*

Acknowledgements

We would like to formally thank the New York College of Podiatric Medicine, Matrona Giakoumis DPM, Joy Reidenberg PhD, Eileen Chusid PhD, Anthony Jabra DPM, and Sapan Patel , BS for their contributions to this research project.

Level of Evidence: III Forefoot Reconstruction

No Financial Disclosures