

# Anterocentral Portal in Ankle Arthroscopy

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Christoph Stotter, MD, PhD<sup>1,2</sup>, Thomas Klestil, MD, PhD<sup>1,2</sup>,  
Andreas Chemelli, MD<sup>3</sup>, Vahid Naderi, MD<sup>3</sup>,  
Stefan Nehrer, MD<sup>2</sup>, and Philippe Reuter, MD<sup>1</sup>

## Abstract

**Background:** The anterocentral portal is not a standard portal in anterior ankle arthroscopy due to its proximity to the anterior neurovascular bundle. However, it provides certain advantages, including a wide field of vision, and portal changes become redundant. The purpose of this study was to evaluate the neurovascular complications after anterior ankle arthroscopy using the anterocentral portal.

**Methods:** We retrospectively identified patients who had undergone anterior ankle arthroscopy with an anterocentral portal at our institution from 2013 to 2018. Medical record data were reviewed and patients were invited for clinical follow-up, where a clinical examination, quantitative sensory testing for the deep peroneal nerve, and ultrasonography of the structures at risk were performed. A total of 101 patients (105 arthroscopies) were identified and evaluated at a mean follow-up of  $31.5 \pm 17.7$  months.

**Results:** Leading indications to surgery were heterogeneous and included anterior impingement (48.6%), osteochondral lesions of the talus (24.8%), chronic ankle instability (14.3%), and fractures (8.6%). The overall complication rate was 7.6%, and no major complications were observed. In 1.9% (2/105) of the cases, the complications were associated with the anterocentral portal and included injury to the medial branch of the superficial nerve (1/105) and to the deep peroneal nerve (1/105). Injury to the deep peroneal nerve was associated with a loss of detection and nociception. There were no injuries to the anterior tibial artery. In 41.9% (44/105) of the cases, only 1 working portal was used in addition to the anterocentral portal, and in 19% (20/105) the anterolateral portal could be avoided. Ultrasonography confirmed the integrity of the deep peroneal nerve, the medial branch of the superficial peroneal nerve, and the anterior tibial artery in all patients. Patients with nerve injuries associated with the anterocentral portal showed no signs of neuroma or pseudoaneurysm.

**Conclusion:** Using a standardized technique, the anterocentral portal in ankle arthroscopy is safe with a low number of neurovascular injuries and can be recommended as a standard portal. The anterolateral portal remains associated with a high number of injuries to the superficial peroneal nerve.

**Level of Evidence:** Level III, retrospective cohort study.

**Keywords:** ankle arthroscopy, anterocentral portal, neurovascular complication, nerve injury, deep peroneal nerve, superficial peroneal nerve

<sup>1</sup>Department of Orthopedics and Traumatology, LK Baden-Mödling, Baden, Austria

<sup>2</sup>Faculty of Health and Medicine, Department for Health Sciences, Medicine and Research, Center for Regenerative Medicine, Danube University Krems, Krems, Austria

<sup>3</sup>Department of Radiology, LK Baden-Mödling, Baden, Austria

## Corresponding Author:

Christoph Stotter, MD, PhD, Faculty of Health and Medicine, Department for Health Sciences, Medicine and Research, Center for Regenerative Medicine, Danube University Krems, Dr. Karl-Dorrek-Str. 30, Krems, A-3500 Austria.

Email: christoph.stotter@donau-uni.ac.at

## Introduction

Ankle arthroscopy is a standard diagnostic and therapeutic tool for the foot and ankle surgeon. For anterior ankle arthroscopy, various anterior portals have been described.<sup>11</sup> The anteromedial and anterolateral portals are the primary working portals, but the anterocentral, medial midline,<sup>2</sup> and accessory anteromedial and anterolateral portals might also be used.

The average overall complication rate in ankle arthroscopy is reported to be between 3.4% and 10.3%,<sup>3,7,8,34-36</sup> with a substantial drop due to advances in operative equipment and technique. Through use of the dorsiflexion method, Zengerink and van Dijk<sup>36</sup> reported a significant decrease of the overall complication rate to 3.5%. Neurovascular injuries are most frequently reported, accounting for half of all complications.<sup>35,36</sup> Depending on the portals that are used, certain structures are at risk. Most authors discourage the use of the anterocentral portal because it is deemed to be associated with a higher risk of neurovascular injury.<sup>3,20,28</sup> It is located at the joint level, between the extensor digitorum longus (EDL) and extensor hallucis longus (EHL) tendons in proximity to the anterior neurovascular bundle.<sup>11</sup> Accordingly, structures at risk are the deep peroneal nerve (DPN) and the anterior tibial artery (ATA) and vein.<sup>11,28</sup> Furthermore, the medial branch of the superficial peroneal nerve (SPN) might be at risk.<sup>6</sup> The mean distance to the anterior neurovascular bundle is 3.3 mm.<sup>9</sup>

However, the anterocentral portal offers certain advantages during surgery, like a wide field of vision, the possibility to visualize posterior pathologies, and the redundancy of portal changes.<sup>4,12</sup> Because of these benefits, the anterocentral portal has been used as the standard optic portal at our institution. Working portals are created depending on the pathologies that are addressed.

While most studies report data on the anteromedial and anterolateral portals,<sup>7,21</sup> data on the complication rate of the anterocentral portal are limited. The purpose of this study was to investigate the risk for neurovascular complication of the anterocentral portal using a standardized technique. The hypothesis was that the anterocentral portal would not be associated with a higher risk of neurovascular complications, compared with standard anteromedial and anterolateral portals.

## Methods

### Patients

Patients who underwent ankle arthroscopy at our institution between January 2013 and October 2018 were retrospectively included. The inclusion criteria were patients of any age who had undergone anterior ankle arthroscopy with an anterocentral portal. Patients with preexisting injuries to the DPN or ATA or with scars in the area of the anterocentral

portal were excluded. The study was approved by the local ethics committee, and all patients provided written informed consent. Data were collected from patient electronic medical record charts and supplemented by the follow-up examination. Collected information included patient age, sex, weight, height, prior surgeries about the foot and ankle, relevant concomitant diseases, indication for surgery, used arthroscopic portals, concomitant procedures, and duration of surgery.

### Surgical Technique

Anterior ankle arthroscopy was performed following a standardized technique without distraction in all patients. The patient was secured in a supine position with a thigh holder and the ankle in the hanging position. A well-padded tourniquet was placed around the thigh and inflated just prior to surgery. Preoperatively, the SPN was identified by plantarflexion and inversion of the foot and marked with a sterile pen. Additionally, the medial and lateral malleolus, joint line, EHL, EDL and tibialis anterior tendons, and arthroscopic portals were identified and marked out by palpation (Figure 1). The anterocentral portal was established first, just lateral to the EHL tendon. The ankle joint was placed in dorsiflexion<sup>36</sup> and 5 to 10 mL of sterile irrigation fluid was infused into the joint with an 18-gauge needle. Joint distension was confirmed by slight dorsiflexion during injection (lift-off test). A No. 11 blade was used to make a 5-mm longitudinal skin incision and blunt dissection of the subcutaneous tissue to the joint capsule was carried out using a mosquito clamp with the ankle joint in dorsiflexion. A blunt trocar with the arthroscopic canula was placed in the joint, and a 2.7-mm arthroscope with short shaft was introduced. The other portals were established as needed under arthroscopic view after placing a spinal needle with the outside-in technique. Concomitant procedures were performed after arthroscopy, if necessary.

### Clinical Examination

At the clinical follow-up, a detailed medical history was obtained and clinical examination was performed following a dedicated case report form. Relevant comorbidities and long-term medication were documented. Patients were asked if they had experienced or were experiencing impaired sensitivity or pain of the dorsum of the foot, or tenderness or sensitivity to touch of the arthroscopic portals, following the ankle arthroscopy. A rough sensitivity map of the dorsum of the foot was established using touch sensitivity to pinprick for the SPN and DPN. In the case of hyposensitivity or dysesthesia, the affected area was marked out on the skin and documented in the case report form. Furthermore, the arthroscopic portals were inspected and sensitivity to touch was recorded.



**Figure 1.** (Left) Patient positioning and (right) marked-out anatomical landmarks and arthroscopic portals. The anterocentral portal is located between the extensor hallucis longus and extensor digitorum longus tendon.

### Quantitative Sensory Testing

Quantitative sensory testing (QST) was carried out at the first web space for the DPN based on the DFNS (German Research Network on Neuropathic Pain) protocol,<sup>17</sup> where 5 of the QST parameters were assessed.

**Thermal Detection and Pain Thresholds.** Thermal sensory and pain thresholds were performed using a TSA II NeuroSensory Analyzer (Medoc, Ramat Yishai, Israel). The tests for thermal sensation were performed at the beginning of the test procedure, prior to any of the mechanical tests. The thermal electrode was placed in the first web space, which is solely innervated by the DPN. At first, cold (CDT) and warm (WDT) detection thresholds were measured with an initial thermode temperature of 32°C. For each threshold test, 4 repetitions were performed at each site. Furthermore, cold (CPT) and heat (HPT) pain thresholds were assessed. For each pain threshold test, 3 repetitions were performed at each site. The actual threshold was determined by the arithmetic mean of the results using the absolute temperature values (in °C). The thresholds were compared with the unaffected side to detect gain or loss of sensory function.

**Vibration Detection Threshold.** The vibration detection threshold (VDT) was performed using a VSA-3000 Vibratory Sensory Analyzer (Medoc, Ramat Yishai, Israel). The vibration unit was placed in the first web space and ascending amplitudes were applied. The threshold was determined when the patient first perceived vibration. Five repetitions were performed at each side, and the actual threshold was determined by the arithmetic mean. When automatic measurement was not feasible due to forefoot deformities, the VDT was determined by 3 series of descending stimulus

intensities using a Rydel-Seiffer graded tuning fork (64 Hz, 8/8 scale). The actual threshold was determined by the arithmetic mean of 3 serial tests when the participant just stopped perceiving vibration (in  $x/8$ ). The thresholds were compared with the unaffected side to detect gain or loss of sensory function.

### Ultrasonography

For the sonographic study, the patients were placed in the supine position with the foot free, allowing manipulation during examination. All the ultrasound examinations were performed by 1 of 2 experienced musculoskeletal radiologists (A.C., V.N.) using a linear transducer (Philips EPIQ 5G, 18-4 PureWave linear transducer). The anterior aspect of the ankle was examined and the structures at risk by the anterocentral portal (EHL, EDL, ATA, DPN, medial branch of the SPN) were assessed. First, the probe was placed on an axial plane at the anterocentral scar to identify potential excessive scar tissue. In the same plane, the TA, EHL, and EDL tendons (medial to lateral) were identified and examined in their full length from the myotendinous junction to their insertions distally. The tendons were assessed in the axial and longitudinal plane for integrity and signs of tenosynovitis. Subsequently, the anterior neurovascular bundle (including the ATA and adjacent veins and the DPN) was identified at the joint level. Color Doppler imaging was used in all examinations to identify vessels and investigate blood flow. The ATA and adjacent veins are located below the anterior tendons and run between the EHL and EDL. The DPN runs adjacent to the ATA and the dorsalis pedis artery and provides sole sensory innervation for the first web space in 98%.<sup>31</sup> The ATA was examined for integrity, the presence of pseudoaneurysm, and intact blood flow. The

**Table 1.** Demographic and General Data for Patients With and Without Nerve Injury.

Parameter	All arthroscopies (N = 105)	DPN injury (n = 1)	SPN injuries (n = 7)	P value
Age, mean (range), y	37.3 (13-82)	51	39.1 (17-70)	.410
Follow-up, mean $\pm$ SD, mo	31.5 $\pm$ 17.7	43.1	34.1 $\pm$ 19.9	.692
Sex, no. (%)				
Male	63 (60.0)	1 (100)	5 (71.4)	
Female	42 (40.0)		2 (28.6)	
Weight, mean $\pm$ SD, kg	78.8 $\pm$ 16.2	68	88.6 $\pm$ 14.1	.100
Height, mean $\pm$ SD, cm	175.0 $\pm$ 9.2	170	176.3 $\pm$ 7.5	.697
Side, no. (%)				
Left	50 (47.6)	1 (100)	1 (14.3)	
Right	55 (52.4)		6 (85.7)	
Surgery duration, mean $\pm$ SD, min	68.21 $\pm$ 30.8	139	55.9 $\pm$ 17.4	.265
Working portals, no. (%)				
1	43 (41.0)		0 (0)	
AM	20 (19.1)			
AL	23 (21.9)			
2	59 (56.2)	1 (100)	6 (85.7)	
AM+AL	58 (55.2)	1 (100)	6 (85.7)	
AL+aAL	1 (1.0)		0 (0)	
3	3 (2.9)	0 (0)	1 (14.3)	
AL+PL+aAC	1 (1.0)		0 (0)	
AM+AL+aAL	2 (1.9)		1 (14.3)	

Abbreviations: aAC, accessory anterocentral; aAL, accessory anterolateral; AL, anterolateral; AM, anteromedial; DPN, deep peroneal nerve; SPN, superficial peroneal nerve.

DPN was assessed for structural integrity, changes in diameter, and the presence of neuroma. Then, the SPN was identified at the location where it pierces the crural fascia, proximal to the ankle joint, and followed distally. The medial and intermediate dorsal cutaneous branches were identified and imaged for the presence of neuroma. In cases of pathologic conditions, the nerves and vessels were imaged in the long axis.

### Statistical Analysis

Descriptive data are presented as the mean values  $\pm$  standard deviations (SDs) for continuous variables. To determine whether the means of the groups of patients with and without complications were equal to each other, a Student *t* test was performed. For QST, thermal and pain thresholds were expressed as the means  $\pm$  SD. To account for subject variability, data were compared with the contralateral foot. Normality was tested with the Shapiro-Wilk test and homogeneity of variance with the Brown and Forsythe test. The QST data were analyzed using a 2-way analysis of variance (ANOVA) with repeated ANOVA, with the groups of patients with and without DPN injury. A Bonferroni test was used for post hoc comparisons. Outliers were defined as a deviation of Q1 and Q3 of more than 1.5 interquartile ranges. All statistical

analyses were performed using the GraphPad Prism software (version 8.0.1; GraphPad Software Inc, San Diego, CA). A *P* < .05 denoted statistical significance.

### Results

A total of 101 patients (105 arthroscopies) with a mean follow-up of 31.5  $\pm$  17.7 months were included in the study. Four patients (3.81%) were not available for the clinical examination. Two patients were untraceable by letter and phone, 1 patient was an asylum seeker at the time of surgery and left the country because he was not granted asylum, and 1 patient was pregnant at the time of follow-up and refused to attend. For these patients, data could be collected from patient electronic medical record charts at a mean follow-up of 31.5 days and showed normal sensory function of the DPN and SPN and normal perfusion of the foot. The average age of the patients was 37.3 years (range, 13-82 years), and the male-to-female ratio was 3:2. Table 1 shows demographic data for all patients and for patients with nerve injuries, along with statistical significances. There were no significant differences regarding the demographic criteria compared with patients without a complication. Leading indications to surgery were heterogeneous and included anterior impingement (48.6%), osteochondral

lesions of the talus (24.8%), chronic ankle instability (14.3%), and fractures (8.6%). In 41% (43/105) only 1 working portal was used in addition to the anterocentral portal, and in 19% (20/105) the anterolateral portal could be avoided.

The overall complication rate was 7.6% (8/105). No major complications (superficial or deep infection, venous thromboembolism, ATA injury) and no tendon injuries were observed. All complications involved nerve injuries and were accompanied by impaired sensitivity of the dorsum of the foot and in most cases sensitivity to touch of the arthroscopic portals. Table 2 shows detailed information on all patients with nerve injuries. Complications caused by the anterocentral portal occurred in 1.90% (2/105) of the cases and included injury to the medial branch of the superficial nerve and to the DPN. Figure 2 shows a schematic sensitivity map of these 2 patients. Injury to the DPN was observed in only 1% (1/105) of all patients and was associated with a loss of detection and nociception.

### Quantitative Sensory Testing

QST was available for 93.1% (94/101) of all patients. In 3 patients, forefoot deformities would not allow automatic measurement. In these cases, tuning fork testing showed no significant difference of the VDT between the affected and nonaffected sides. The QST was performed in the first web space, which is solely innervated by the DPN. Figure 3 shows the QST results for all patients. Gain and loss of function on the affected side were observed in patients without clinical signs of nerve injury. Injury to the DPN resulted in loss of mechanical detection and decreased nociception. In this patient, the values for VDT, CDT, CPT, and HPT showed a deviation of Q3 of more than 1.5 interquartile ranges and were hence identified as outliers. The WDT was not altered significantly. Further statistical analyses were not feasible due to the small number of injuries to the DPN.

### Ultrasonography

Of all patients, 96.0% (97/101) were available for ultrasonography. In all patients, all structures at risk could be identified and imaged (Figure 4). There were no injuries to the ATA and to the EDL and EHL tendons. The integrity of the SPN and DPN was confirmed in all patients without any clinical signs of nerve injury. Of the 7 patients suffering from an SPN injury, a neuroma of the affected nerve was present in 3 patients (Figure 5). In these cases, the neuroma was located adjacent to the anterolateral portal. However, the patient with an injury of the DPN and 4 out of 7 patients with an SPN injury showed no pathological findings in the sonography, without signs of neuroma.

## Discussion

The current study is the first to investigate the neurovascular complications of the anterocentral portal in ankle arthroscopy. The most important finding was that with proper operative technique, the anterocentral portal was a safe arthroscopic approach to the ankle joint. Injuries to neurovascular structures caused by the anterocentral portal occurred in 2%. The overall complication rate of ankle arthroscopy has been reported to be between 3.4% and 10.3%.<sup>3,7,8,34-36</sup> Nerve injuries account for approximately half of the complications.<sup>36</sup> Most studies report on data for anterolateral and anteromedial portals.<sup>21,27</sup> The SPN is the most frequently affected structure, usually injured when using an anterolateral portal.<sup>7</sup> The anterocentral portal is discouraged by many authors, based on cadaveric studies that demonstrated its proximity to the anterior neurovascular bundle.<sup>3,9,20,24</sup> It is deemed to be unsuitable for ankle arthroscopy because of a high risk for injury to the DPN and SPN.<sup>3</sup> Furthermore, case reports of pseudoaneurysms of the ATA following ankle arthroscopy have been reported.<sup>5,15,16,18,25</sup>

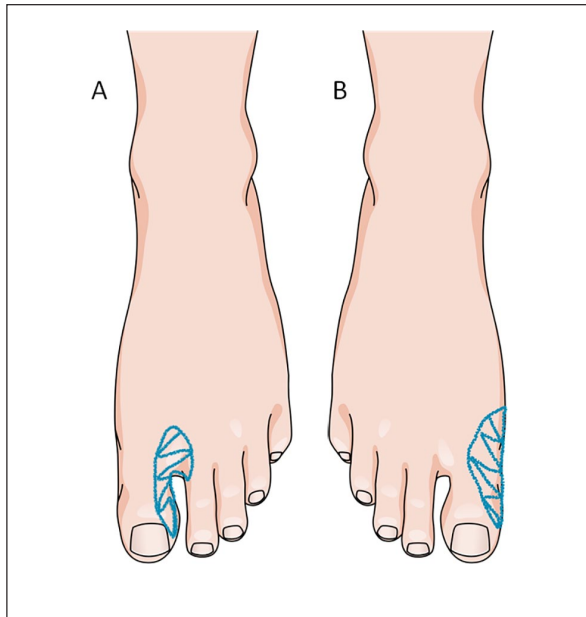
The anterocentral portal is established between the EHL and EDL tendons at the joint level.<sup>11</sup> Accordingly, structures at risk include the medial dorsal cutaneous nerve (medial branch of the SPN), the DPN, and the anterior tibial artery and veins.<sup>11</sup> The recommendations not to use the anterocentral portal are mainly based on anatomical and cadaveric interventional studies.<sup>9,24,34</sup> In such a study, the mean distance from the anterocentral portal to the anterior neurovascular bundle was 3.3 mm. In 22% (4/18), the arthroscope was in direct contact with the neurovascular bundle.<sup>9</sup> Scheibling et al<sup>19</sup> performed anterocentral portal placement in cadaveric ankles with and without ultrasonography and reported distances between the arthroscope and the anterior neurovascular bundle of 6.1 and 3.7 mm, respectively. However, Buckingham et al<sup>2</sup> found a mean distance of 0.7 mm for the artery with direct contact of the arthroscope in 90% and a 1.1-mm mean distance for the DPN. Furthermore, the arthroscope touched branches of the SPN in all cases and lacerations occurred in 15% (3/20). The average distance between the lateral border of the EHL tendon, which serves as an anatomical landmark during portal placement, and the DPN was reported to be 4.2 mm.<sup>24</sup>

As the anterocentral portal is currently not recommended, data on associated complications in a clinical setting are limited. Generally, it is suggested that injury to anterocentral neurovascular structures does not occur during establishment of the anterocentral portal, but rather during removal of tibial osteophytes and anterior synovectomy.<sup>15,18</sup> While the DPN crosses the ankle joint between the EHL and EDL muscles, adjacent to the ATA, and is always in proximity to the anterocentral portal, the SPN has a higher variability. It divides into the medial and lateral branches (medial and intermediate dorsal cutaneous nerves) and is purely sensory.

**Table 2.** Patient Characteristics of All Patients With a Complication.

Patient no.	FU (mo)	Age at time		Height (cm)	Weight (kg)	Sex	Previous surgery	Side	Duration of surgery (min)	Portals used	Treatment	Indication	Nerve involved	Location of nerve injury	Sonographic findings
		(y)	(y)												
1	21	49	65	166	75	F	None	Left	65	AM, AL	Soft tissue debridement, anterior osteophyte removal, bone marrow stimulation	OCLT, anterior impingement	SPN	AL portal	Without pathological findings
2	14	42	45	181	92	M	None	Right	45	AM, AL, DAL	Soft tissue debridement, anterior osteophyte removal, removal of loose body	Anterior impingement, loose body	SPN	AL portal	Neuroma of the SPN adjacent to the AL portal
3	8	70	34	176	104	M	none	Right	34	AM, AL	Soft tissue debridement, bone marrow stimulation	OCLT, impingement	SPN	AL portal	Neuroma of the SPN adjacent to the AL portal
4	64	34	85	175	71	M	Osteosynthesis of medial and lateral malleolus	Right	85	AM, AL	Soft tissue debridement, hardware removal, correction of lateral scar	Posttraumatic arthrofibrosis, scar adhesion lateral malleolus	SPN	AL portal, lateral approach	Without pathological findings
5	57	17	36	178	100	M	Ankle arthroscopy	Right	36	AM, AL	Soft tissue debridement	Anterior impingement	SPN	AL portal	Without pathological findings
6	44	32	56	168	73	F	None	Right	56	AM, AL	Soft tissue debridement, anterior osteophyte removal, bone marrow stimulation, open Broström-Gould repair	Chronic instability, impingement, OCLT	SPN	AL portal, Broström-Gould approach	Neuroma of SPN
7	30	30	70	190	105	M	None	Right	70	AM, AL	Soft tissue debridement, open Broström-Gould repair	Chronic instability, anterior impingement	SPN	AC portal	Without pathological findings
8	43	51	139	170	68	M	Osteosynthesis of medial malleolus	Left	139	AM, AL	Soft tissue debridement, anterior osteophyte removal, open TP and FDL tendon debridement	Posttraumatic arthrofibrosis, anterior impingement, TP and FDL tendon adhesion	DPN	AC portal	Without pathological findings

Abbreviations: AC, anterocentral; AL, anterolateral; AM, anteromedial; DAL, deep anterolateral; DPN, deep peroneal nerve; FU, follow-up; OCLT, osteochondral lesion of the talus; SPN, superficial peroneal nerve; TP, tibialis posterior.



**Figure 2.** Schematic of the affected skin area of 2 patients with nerve injury associated with the anterocentral portal. The affected area was marked out using the pinprick test. (A) Injury to the deep peroneal nerve (DPN) with hyposensitivity in the first web space. (B) Injury to the medial branch of the superficial peroneal nerve (SPN).

Branching occurs proximal to the talocrural joint in most people, and the 2 main branches will cross the joint level.<sup>27</sup> In these cases, the medial branch might be at risk during anterocentral portal placement. In 25% of cases, branching occurs distal to the talocrural joint<sup>24</sup> and the SPN is located more laterally.

In our study cohort, injury to the DPN and medial branch of the SPN caused by the anterocentral portal occurred in <1% each. Our results refute the high complication rate of the anterocentral portal suggested by cadaveric studies. However, injury to the SPN caused by the anterolateral portal occurred in 5.7%. This is in line with complication rates reported in the literature.<sup>3,12,36</sup> Furthermore, no major complications, such as superficial or deep infection and venous thromboembolism, occurred. The low rates of complications may be attributed the specific technique of portal placement without the use of traction where neurovascular structures are relaxed. Dorsiflexion during portal placement further decreases strain of neurovascular structures. Ankle arthroscopy for impingement or posttraumatic stiffness was not associated with a higher rate of nerve injury when compared with other indications. In contrast to previous reports,<sup>6</sup> body mass index could not be identified as a risk factor for nerve injury. However, preoperative identification of the SPN might be difficult.

In our institution the anterocentral portal is used as standard optic portal as it offers certain advantages during surgery, like a wide field of vision, the possibility to address posterior pathologies, and the redundancy of portal changes.<sup>4,12</sup> It provides excellent arthroscopic visualization of the articular surface of the talus and the whole joint. An arthroscopic examination<sup>29</sup> of the anterior, central, and posterior compartments can be performed without changing the vision portal and without traction.

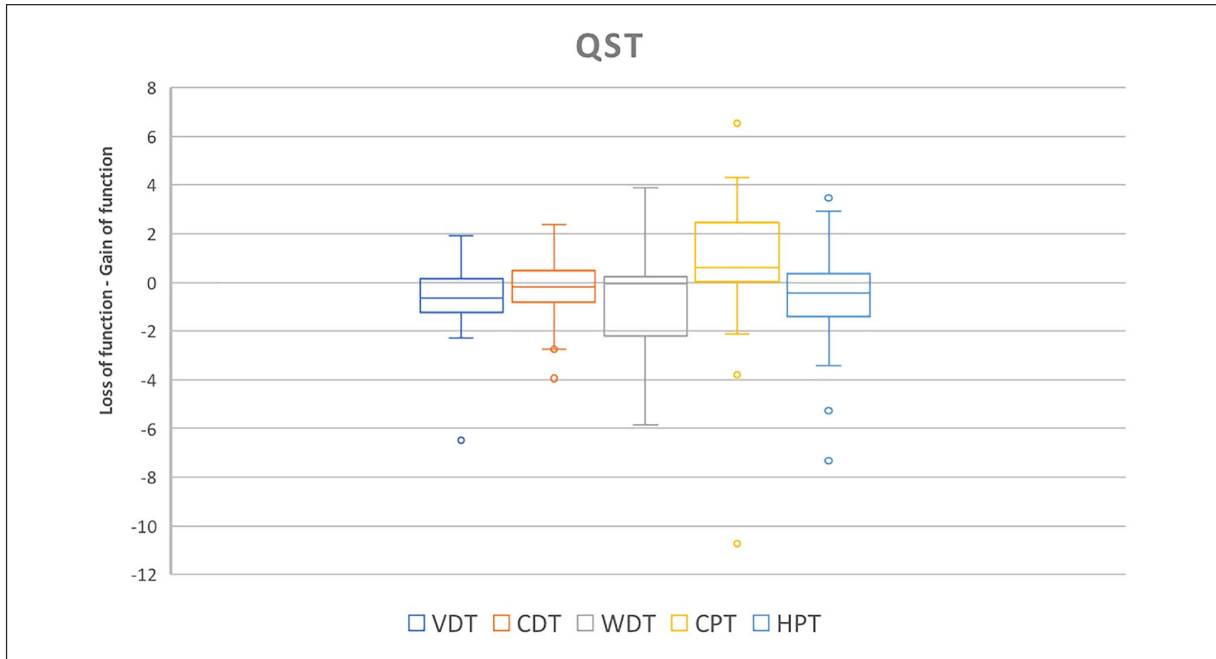
We use the described standardized surgical technique for portal placement with dorsiflexion and blunt dissection after the skin incision. Anatomical landmarks are marked out routinely. Identifying the SPN by plantarflexion and inverting the foot and marking it on the skin might reduce risk of iatrogenic nerve injury.<sup>23</sup> Nevertheless, the anterolateral portal still shows substantial rates of SPN injury. By using the anterocentral portal, the anterolateral portal becomes redundant in some cases. In our cohort, in 40% only 1 working portal was placed in addition to the anterocentral portal. In 19%, the anterolateral portal could be avoided completely. However, in 60% 2 or more working portals were used (Table 1). In these cases, the anterocentral portal might be considered an additional portal with additional risk of neurovascular injury. Complication rates of the used portals might accumulate.

However, we observed no patient with injury of more than 1 nerve and no vascular or tendon injuries.

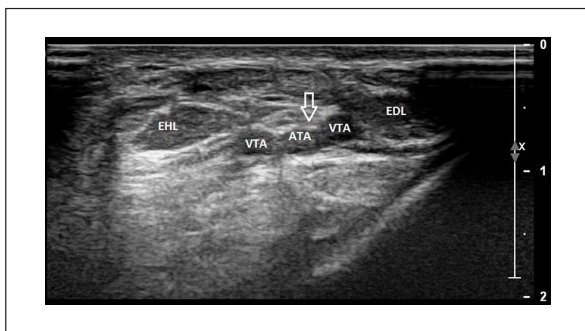
All arthroscopies included in this study were performed by a single experienced orthopedic surgeon (P.R.). It remains unclear whether our low complication rate would be accomplished by low-volume surgeons. Performing ankle arthroscopy requires detailed knowledge of the local anatomy and structures at risk. A strong correlation between educational level and global operative skills has been demonstrated.<sup>13</sup> Dedicated lectures on structures at risk and complications in ankle arthroscopy, in addition to lectures on portal placement, can significantly reduce complication risk.<sup>14</sup> Lower complication rates might be assumed for experienced surgeons. However, Zengerink and van Dijk<sup>36</sup> reported their low complication rate including low-volume surgeons using a standardized technique.

Nevertheless, substantial rates of iatrogenic injuries require attempts to further reduce complication rates. Proper training on the technique is necessary, especially when applying the anterocentral portal. Using a peripheral vein illumination device during portal placement might help reduce complications.<sup>26</sup> Moreover, ultrasonography for portal placement might decrease the risk for iatrogenic injuries.<sup>19</sup>

In this study, we used high-resolution ultrasonography at follow-up to image the structures at risk. Sonography has several advantages for the evaluation of the ankle, such as its dynamic assessment and ability to provide immediate analysis. With high-resolution ultrasound it is possible to image

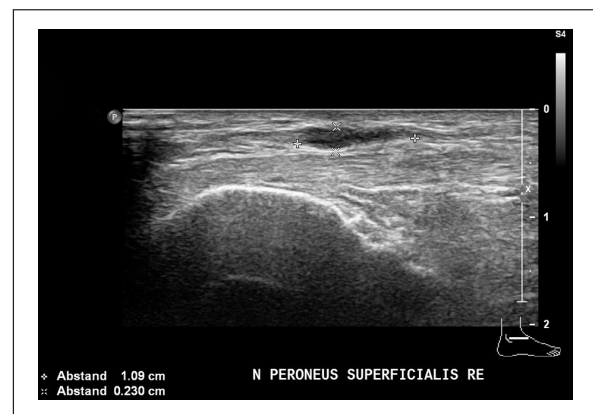


**Figure 3.** Box plots for 5 QST parameters (VDT, CDT, WDT, CPT, HPT) of all patients. Values above zero demonstrate a gain of function on the side that has been operated on, whereas values below zero show a loss of function. Outliers were defined as a deviation of Q1 and Q3 of more than 1.5 interquartile ranges. Injury to the DPN resulted in loss of function on VDT, CDT, CPT, and HPT. CDT, cold detection threshold; CPT, pain threshold; HPT, heat pain threshold; QST, quantitative sensory testing; VDT, vibration detection threshold; WDT, warm detection threshold.



**Figure 4.** Transverse ultrasound scan of the anterior ankle at the joint level without pathological findings. The anterior neurovascular bundle is located between the extensor hallucis longus (EHL) and extensor digitorum longus (EDL) tendons. The deep peroneal nerve (void arrow) runs together with the anterior tibial artery (ATA) and adjacent veins (VTA). Scale indicates depth in centimeters.

almost all peripheral nerves, and it is regularly used to assess the peripheral nerves of the lower extremity.<sup>22,33</sup> The sensitivity and specificity of neuroma detection around the foot with this modality are reported to be 90% to 91% and 85% to 88%, respectively.<sup>1,32</sup> Ultrasonography has many advantages



**Figure 5.** Ultrasound scan of the anterolateral ankle showing a neuroma of the lateral branch of the superficial peroneal nerve adjacent to the anterolateral portal. Scale indicates depth in centimeters.

compared with MRI and is at least as accurate as MRI in diagnosing neuroma.<sup>1,32</sup> The advantages include superior soft tissue resolution, transportability, and cost-effectiveness.<sup>33</sup> Furthermore, with high-resolution ultrasound not only nerves but all structures at risk can be evaluated.



Indeed, we were able to identify the SPN and DPN in all patients and confirm integrity. However, not all patients presenting with hyposensitivity on the dorsum of the foot showed signs of neuroma. In these patients, the nerve injury might have been caused by pressure of the surgical instruments or stretch of the nerve. The degree of nerve injury may be classified as axonotmesis with intrafascicular fibrosis, but without sudden change in diameter. Furthermore, patients may not have had a neuroma but rather an entrapment of the nerve by the postoperative adhesions producing similar symptoms. While the transverse diameter could be measured in all patients, individual fascicles of the branches of the SPN could be visualized in only a few cases. Hence, the diagnosis of a nerve injury should be made based on reported symptoms, medical imaging, and qualitative and quantitative testing. For the assessment of such nerve injuries, QST is an efficient objective method.<sup>10,30</sup> QST includes 13 parameters and is recommended for the assessment of neuropathic pain syndromes and peripheral nerve injuries.<sup>17</sup> While it provides extensive information on sensory function and injury of single nerve fibers, it exceeds what is necessary in clinical practice after ankle arthroscopy. Nerve injury can be identified through a thorough clinical examination, and in cases of clinical signs of injury further diagnostics should be advised.

The present study is relevant because it demonstrates a low complication rate for the anterocentral portal in ankle arthroscopy.

As with most retrospective cohort studies, we are aware of some methodological shortcomings that could have biased our results and limit the validity of our conclusions. For example, we relied on medical records and diagnosis and procedure codes to identify eligible patients. Furthermore, due to an average follow-up of more than 2 years, temporary sensory deficits could have been missed. To avoid that, we used medical records to identify complications at an earlier follow-up. Next, all surgeries were performed by a single, experienced foot and ankle surgeon, and the results might not be applicable for surgeons with different experience levels. Finally, we appreciate that our study lacks a control group without an anterocentral portal, because the anterocentral portal was used as the standard portal at our institution. Comparison of our results with other studies might be associated with biases, because the prior investigations could have differed widely from our study protocol.

## Conclusion

We conclude that the use of an anterocentral portal in ankle arthroscopy is safe and can be recommended as a standard portal. It had a low number of neurovascular complications, which allowed us to take advantage of the associated

benefits, such as good joint visibility and no need for change of portals.

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## ORCID iDs

Christoph Stotter, MD, PhD,  <https://orcid.org/0000-0003-4829-2711>

Stefan Nehrer, MD,  <https://orcid.org/0000-0001-8008-2226>

## References

- Bignotti B, Signori A, Sormani MP, Molfetta L, Martinoli C, Tagliafico A. Ultrasound versus magnetic resonance imaging for Morton neuroma: systematic review and meta-analysis. *Eur Radiol*. 2015;25(8):2254-2262.
- Buckingham RA, Winson IG, Kelly AJ. An anatomical study of a new portal for ankle arthroscopy. *J Bone Joint Surg B*. 1997;79(4):650-652.
- Carlson MJ, Ferrel RD. Complications in ankle and foot arthroscopy. *Sports Med Arthrosc*. 2013;21(2):135-139.
- Chida S, Kura H, Kashiwakura T, Nozaka K, Shimada Y. Anatomical positions facilitating of anterocentral portal for ankle arthroscopy on ultrasonography. *Foot Ankle Surg*. 2017;23:100.
- Darwish A, Ehsan O, Marynissen H, Al-Khaffaf H. Pseudoaneurysm of the anterior tibial artery after ankle arthroscopy. *Arthroscopy*. 2004;20(6):63-64.
- de Leeuw PAJ, Golanó P, Sierevelt IN, van Dijk CN. The course of the superficial peroneal nerve in relation to the ankle position: anatomical study with ankle arthroscopic implications. *Knee Surg Sport Traumatol Arthrosc*. 2010;18(5):612-617.
- Deng DF, Hamilton GA, Lee M, Rush S, Ford LA, Patel S. Complications associated with foot and ankle arthroscopy. *J Foot Ankle Surg*. 2012;51(3):281-284.
- Epstein DM, Black BS, Sherman SL. Anterior ankle arthroscopy: indications, pitfalls, and complications. *Foot Ankle Clin*. 2015;20(1):41-57.
- Feiwell LA, Frey C. Anatomic study of arthroscopic portal sites of the ankle. *Foot Ankle*. 1993;14(3):142-147.
- Gierthmühlen J, Maier C, Baron R, et al. Sensory signs in complex regional pain syndrome and peripheral nerve injury. *Pain*. 2012;153(4):765-774.
- Golano P, Vega J, Perez-Carro L, et al. Ankle anatomy for the arthroscopist. Part I: The portals. *Foot Ankle Clin*. 2006;11(2):253-273.
- Guhl JF. New concepts (distraction) in ankle arthroscopy. *Arthroscopy*. 1988;4(3):160-167.
- Johnson JD, Cheng C, Schmidberg B, Cote M, Geaney LE. Assessment of basic ankle arthroscopy skills in orthopedic trainees. *Foot Ankle Int*. 2020;41(2):193-199.

14. Malagelada F, Vega J, Guelfi M, Kerkhoffs G, Karlsson J, Dalmau-Pastor M. Anatomic lectures on structures at risk prior to cadaveric courses reduce injury to the superficial peroneal nerve, the commonest complication in ankle arthroscopy. *Knee Surg Sport Traumatol Arthrosc.* 2020;28(1):79-85.
15. Mariani PP, Mancini L, Giorgini TL. Pseudoaneurysm as a complication of ankle arthroscopy. *Arthroscopy.* 2001;17(4):400-402.
16. O'Farrell D, Dudeney S, McNally S, Moran R. Pseudoaneurysm formation after ankle arthroscopy. *Foot Ankle Int.* 1997;18(9):578-579.
17. Rolke R, Magerl W, Campbell KA, et al. Quantitative sensory testing: a comprehensive protocol for clinical trials. *Eur J Pain.* 2006;10(1):77-88.
18. Salgado CJ, Mukherjee D, Quist MA, Cero S. Anterior tibial artery pseudoaneurysm after ankle arthroscopy. *Vascular.* 1998;6(6):604-606.
19. Scheibling B, Koch G, Clavert P. Cadaver study of anatomic landmark identification for placing ankle arthroscopy portals. *Orthop Traumatol Surg Res.* 2017;103(3):387-391.
20. Schneppenheim M, Philipps B, Schunck J, Jerosch J. Complications of arthroscopic operations in the upper ankle joint. *Arthroscopie.* 2001;14(3):221-225.
21. Simonson DC, Roukis TS. Safety of ankle arthroscopy for the treatment of anterolateral soft-tissue impingement. *Arthroscopy.* 2014;30(2):256-259.
22. Suk JI, Walker FO, Cartwright MS. Ultrasonography of peripheral nerves. *Curr Neurol Neurosci Rep.* 2013;13(2):328.
23. Suzangar M, Rosenfeld P. Ankle arthroscopy: is preoperative marking of the superficial peroneal nerve important? *J Foot Ankle Surg.* 2012;51(2):179-181.
24. Takao M, Uchio Y, Shu N, Ochi M. Anatomic bases of ankle arthroscopy: study of superficial and deep peroneal nerves around anterolateral and anterocentral approach. *Surg Radiol Anat.* 1998;20(5):317-320.
25. Tonogai I, Matsuura T, Iwame T, et al. Pseudoaneurysm of the anterior tibial artery following ankle arthroscopy in a soccer player. *Case Rep Orthop.* 2017;2017:1-8.
26. Tsuyuguchi Y, Nakasa T, Ishikawa M, et al. A technique for the reduction of complications associated with anterior portal placement during ankle arthroscopy using a peripheral vein illumination device. *Arthrosc Tech.* 2018;7(2):e125-e129.
27. Ucerler H, Ikiz ZAA, Uygur M. A cadaver study on preserving peroneal nerves during ankle arthroscopy. *Foot Ankle Int.* 2007;28(11):1172-1178.
28. Vega J, Dalmau-Pastor M, Malagelada F, Fargues-Polo B, Peña F. Ankle arthroscopy: an update. *J Bone Joint Surg Am.* 2017;99(16):1395-1407.
29. Vega J, Malagelada F, Karlsson J, Kerkhoffs GM, Guelfi M, Dalmau-Pastor M. A step-by-step arthroscopic examination of the anterior ankle compartment. *Knee Surg Sport Traumatol Arthrosc.* 2020;28(1):24-33.
30. Vollert J, Attal N, Baron R, et al. Quantitative sensory testing using DFNS protocol in Europe: an evaluation of heterogeneity across multiple centers in patients with peripheral neuropathic pain and healthy subjects. *Pain.* 2016;157(3):750-758.
31. Wahee P, Aggarwal A, Harjeet, Sahni D. Variable patterns of cutaneous innervation on the dorsum of foot in fetuses. *Surg Radiol Anat.* 2010;32(5):469-475.
32. Xu Z, Duan X, Yu X, Wang H, Dong X, Xiang Z. The accuracy of ultrasonography and magnetic resonance imaging for the diagnosis of Morton's neuroma: a systematic review. *Clin Radiol.* 2015;70(4):351-358.
33. Yablon CM, Hammer MR, Morag Y, Brandon CJ, Fessell DP, Jacobson JA. US of the peripheral nerves of the lower extremity: a landmark approach. *Radiographics.* 2016;36(2):464-478.
34. Yammine K, Assi C. Neurovascular and tendon injuries due to ankle arthroscopy portals: a meta-analysis of interventional cadaveric studies. *Surg Radiol Anat.* 2018;40(5):489-497.
35. Young BH, Flanigan RM, DiGiovanni BF. Complications of ankle arthroscopy utilizing a contemporary noninvasive distraction technique. *J Bone Joint Surg A.* 2011;93(10):963-968.
36. Zengerink M, van Dijk CN. Complications in ankle arthroscopy. *Knee Surg Sport Traumatol Arthrosc.* 2012;20(8):1420-1431.