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Chapter 2.4

# The surgical anatomy of the infrapatellar branch of the saphenous nerve in relation to incisions for anteromedial knee surgery.

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## ABSTRACT

**Background:** Iatrogenic injury to the infrapatellar branch of the saphenous nerve is a common complication of surgical approaches to the anteromedial side of the knee. A detailed description of the relative anatomic course of the nerve is important to define clinical guidelines and minimize iatrogenic damage during anterior knee surgery.

**Methods:** In twenty embalmed knees, the infrapatellar branch of the saphenous nerve was dissected. With use of a computer-assisted surgical anatomy mapping tool, safe and risk zones, as well as the location-dependent direction of the nerve, were calculated.

**Results:** The location of the infrapatellar branch of the saphenous nerve is highly variable, and no definite safe zone could be identified. The infrapatellar branch runs in neither a purely horizontal nor a vertical course. The course of the branch is location-dependent. Medially, it runs a nearly vertical course; medial to the patellar tendon, it has a –45° distal-lateral course; and on the patella and patellar tendon, it runs a close to horizontal-lateral course. Three low risk zones for iatrogenic nerve injury were identified: one is on the medial side of the knee, at the level of the tibial tuberosity, where a –45° oblique incision is least prone to damage the nerves, and two zones are located medial to the patellar apex (cranial and caudal), where close to horizontal incisions are least prone to damage the nerves.

**Conclusions:** The infrapatellar branch of the saphenous nerve is at risk for iatrogenic damage in anteromedial knee surgery, especially when longitudinal incisions are made. There are three low risk zones for a safer anterior approach to the knee. The direction of the infrapatellar branch of the saphenous nerve is location-dependent. To minimize iatrogenic damage to the nerve, the direction of incisions should be parallel to the direction of the nerve when technically possible.

**Clinical Relevance:** These findings suggest that iatrogenic damage of the infrapatellar branch of the saphenous nerve can be minimized in anteromedial knee surgery when both the location and the location-dependent direction of the nerve are considered when making the skin incision.

# INTRODUCTION

The infrapatellar branch of the saphenous nerve is a sensory nerve innervating the anterior aspect of the knee, the anterolateral aspect of the proximal part of the lower leg, and the anteroinferior part of the knee joint capsule[1,2]. The infrapatellar branch of the saphenous nerve originates from the saphenous nerve and arizses distal to the adductor canal[3]. It pierces the sartorius muscle, after which it runs a superficial course and generally forms two branches[4,5]. Both branches cross the patellar tendon in a transverse way to form the infrapatellar plexus[1,6]. These small superficial branches are at risk for transection, especially when longitudinal surgical incisions are made.

Injury to the infrapatellar branch of the saphenous nerve usually results in numbness on the anterior aspect of the knee and the proximal lateral part of the lower leg. Neuropathic pain and symptomatic neuroma can develop even without noxious stimuli[7,8]. A relationship between damage to the infrapatellar branch of

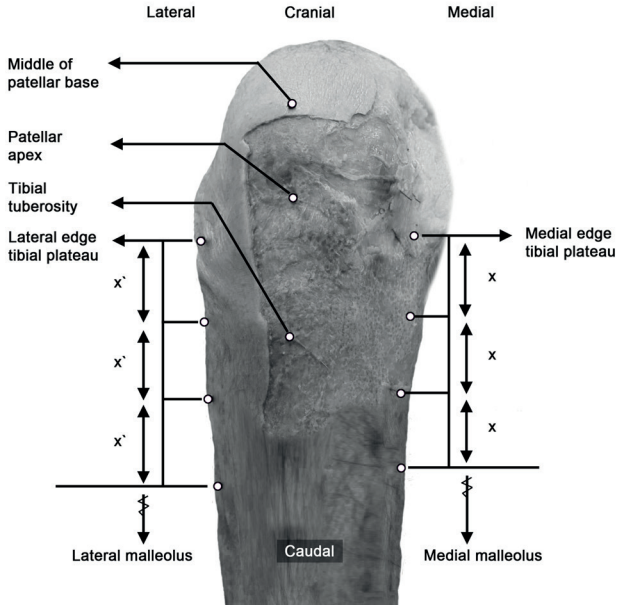


Figure 1. Anatomical landmarks. Osseous landmarks include the patellar apex, the highest, most prominent palpable point of the tibial tuberosity; the medial and lateral edge of the tibial plateau; and the medial and lateral malleoli. Nonosseous landmarks are placed at one-tenth of the distance between the tibial plateau and both the medial (X) and lateral (X`) malleoli. The cranial three landmarks on the medial and lateral side are used for CASAM (computer-assisted surgical anatomy mapping) calculations. Test-retest reproducibility of all landmarks was determined by two authors.

the saphenous nerve and reflex sympathetic dystrophy has been described[9-11]. Finally, as the infrapatellar branch of the saphenous nerve innervates the anterior medial ligaments of the knee, it is important for proprioception[12] and thus knee stability and balance. Impaired joint proprioception might in theory contribute toward osteoarthritis[13-15].

After total knee arthroplasty, numbness due to damage of the infrapatellar branch of the saphenous nerve has been reported in 55% to 100% of patients when a longitudinal incision was used[16,17]. Ojima et al. found significantly fewer subjectively and objectively assessed areas of hypoesthesia when a transverse incision was used. Furthermore, they found significantly more patients who were able to kneel and stated this might partially be due to less pain and numbness as the infrapatellar nerve remained intact[18].

Damage to the infrapatellar branch of the saphenous nerve has also been reported after surgical meniscectomy (up to 28% of patients report irritating paresthesia[19]), in arthroscopy[6,9,20], after anterior cruciate ligament reconstruction (anesthesia was found in 37% to 86% of patients[21,22]), and even in resections of the prepatellar bursa[23,24]. Although damage to the infrapatellar nerve in tibial nailing has been mentioned by only a few authors[25,26], it can be a causative factor for chronic anterior knee pain[27-29] and a frequent and invalidating complication in tibial nailing (10% to 86%)[30,31] and retrograde femoral nailing (26%)[25].

The clinical importance of damage to the infrapatellar branch of the saphenous nerve is amplified by the fact that recent studies on arthroplasty[32] and tibial nailing[29] have shown that patient satisfaction is inversely correlated to the presence of injury to the infrapatellar nerve.

Although the infrapatellar branch of the saphenous nerve is a known anatomic structure, its relevance in daily clinical practice is underestimated as of yet, since longitudinal incisions in the anteromedial region of the knee are still commonly used. Therefore, the purpose of this study was to further describe and visualize the relative anatomic course of the infrapatellar branch of the saphenous nerve in the flexed knee to provide the surgeon with a safe zone and clinical guidelines to minimize iatrogenic injury during anterior knee surgery.

## METHODS

### Materials

Twenty unpaired embalmed legs (ten left and ten right) from adult donors were dissected in the knee region to study the course of the infrapatellar branch of the saphenous nerve. The specimens had been flushed with AnubiFiX[33]

(Department of Neuroscience and Anatomy, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands) to regain joint flexibility and were embalmed with a mixture of 6% formaldehyde and 5% phenol. None of the limbs showed macroscopic signs of disease or scarring. The saphenous nerve and the main infrapatellar branch(es) of the nerve were localized by careful dissection and followed peripherally with a magnifying glass (5 dioptre) until branches were too small for further dissection (<1 mm). All knees were then flexed into a 90° angle, simulating the intraoperative position for most anteromedial knee surgical procedures. Osseous landmarks (Figure 1) were placed as a reference for measurements and calculations.

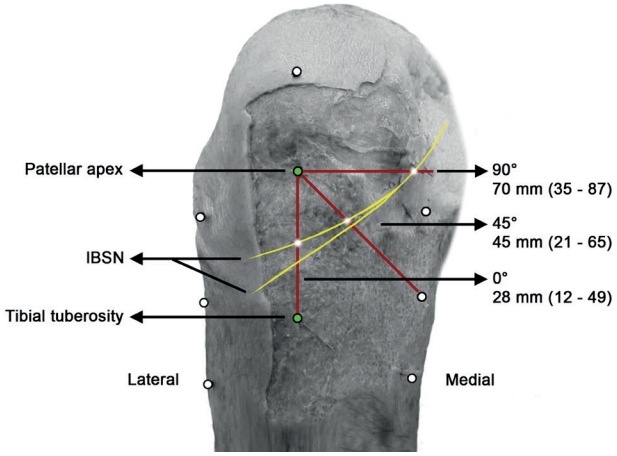


Figure 2. Measurements of the distance to the closest infrapatellar branch of the saphenous nerve (IBSN) over three reference lines are shown. The mean distance was 70 mm (range, 35 to 87 mm) over the 90° reference line, 45 mm (range, 21 to 65 mm) over the 45° reference line, and 28 mm (range, 12 to 49 mm) over the 0° reference line.

## Measurements

The distance between the apex of the patella and the tibial tuberosity (the most distal part of the patellar apex and the palpatory center of the tuberosity) was measured. From the apex of the patella, three reference lines (at 90°, 45°, and 0° relative to the line between the apex of the patella and the tibial tuberosity) were projected over the knees for distance measurements to the closest branch of the infrapatellar nerve (Figure 2). At the intersection of an infrapatellar branch of the nerve with the projected lines, a pin was placed and the distance to the patellar apex was measured along the circumference of the limb. The position of the nerve was also related to the distance between the apex of the patella and the

tibial tuberosity. When the nerve was split into two or more branches, the closest branch to the reference point was used for calculations.

The angle of the nerve related to the midline of the patellar tendon was measured. When more than one branch crossed the patellar tendon, the angles were also noted.

Distances were measured using calipers, and angles were measured using a goniometer. Measurements were repeated, and the mean of both measurements was used for further analysis. Statistical tests were performed using SPSS software (version 17; SPSS, Chicago, Illinois). Nonparametrical tests were used if variables were not normally distributed.

## Computer-Assisted Surgical Anatomy Mapping (CASAM)

The novel anatomy-mapping tool CASAM[34-37] was used to visualize and evaluate the complex and variable anatomy of multiple specimens and to visualize the dissected infrapatellar branch of the saphenous nerve in one image of a knee with average dimensions. First, the knees were photographed, using a standardized protocol, with a Canon 350D camera (Canon USA, Lake Success, New York) with a Canon EF-S 18-55-mm lens (Canon USA). Then, nonosseous landmarks were calculated from osseous landmarks to delineate the different shapes of the individual knees (Figure 1).

The average location of each landmark was calculated from all specimens. Then, with use of Magic Morph 1.9510 software (EffectMatrix Software Studio)[38], each specimen in each original photograph was reshaped (warped) to match the calculated average shape. A thin plate spline was used as a warping algorithm. As the warped specimens had the same calculated average shape, the anatomy of the infrapatellar branch of the saphenous nerve of all specimens could be mapped and visualized in one averagely shaped knee. Photoshop CS4 (Adobe Systems, San Jose, California)[39] was used to highlight relevant anatomy and make renditions. The following four renditions were made:

1. All dissected infrapatellar branches of the saphenous nerve were visualized in one image (Figures 3-A).
2. A risk zone of 5 mm was determined and colored in each specimen. All risk zones were then compiled into one image, and a gradient of risk zones was visualized (Figure 3-B).
3. Zones were identified in the anteromedial aspect of the knee in which a low density of infrapatellar branches of the saphenous nerve was found (Figure 4).

4. A grid of squares was placed over the computerized image depicting all infrapatellar branches of the saphenous nerve (Figure 3). Within each individual square, the direction of all branches was measured in relation to a horizontal line. Each square was given a color corresponding to the average direction of the branches within that square. The result is a grid of squares depicting the location-dependent direction of infrapatellar branches of the saphenous nerve (Figure 5).



## Comparison with Published Literature

A PubMed/MEDLINE search was performed using the search terms "infrapatellar branch of the saphenous nerve" OR "infrapatellar branches of the saphenous nerve." This search revealed forty-nine titles. Abstracts were judged for relevance. In case of doubt, full articles were read and checked for cross-references. Three anatomical studies on the course of the infrapatellar branch of

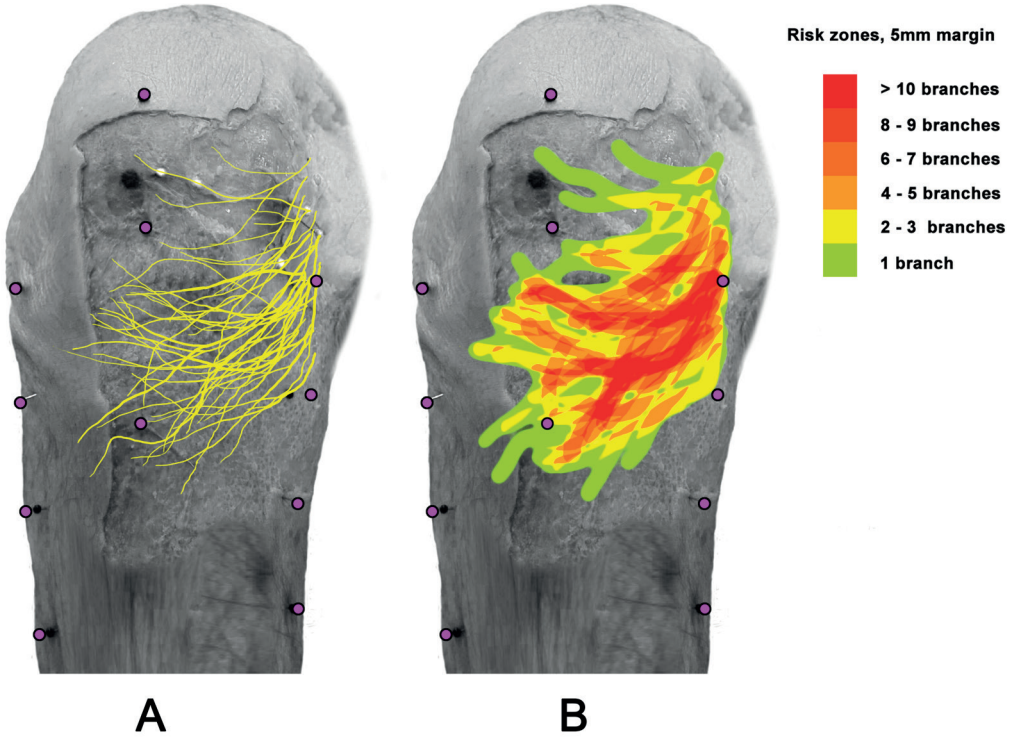


**Figure 3.** The location of the infrapatellar branch of the saphenous nerve with CASAM-generated photographs showing the anatomy of the infrapatellar branch of the saphenous nerve in a knee with average dimensions (n = 20). A Distribution of the infrapatellar branches. B A 5-mm margin around each dissected nerve.

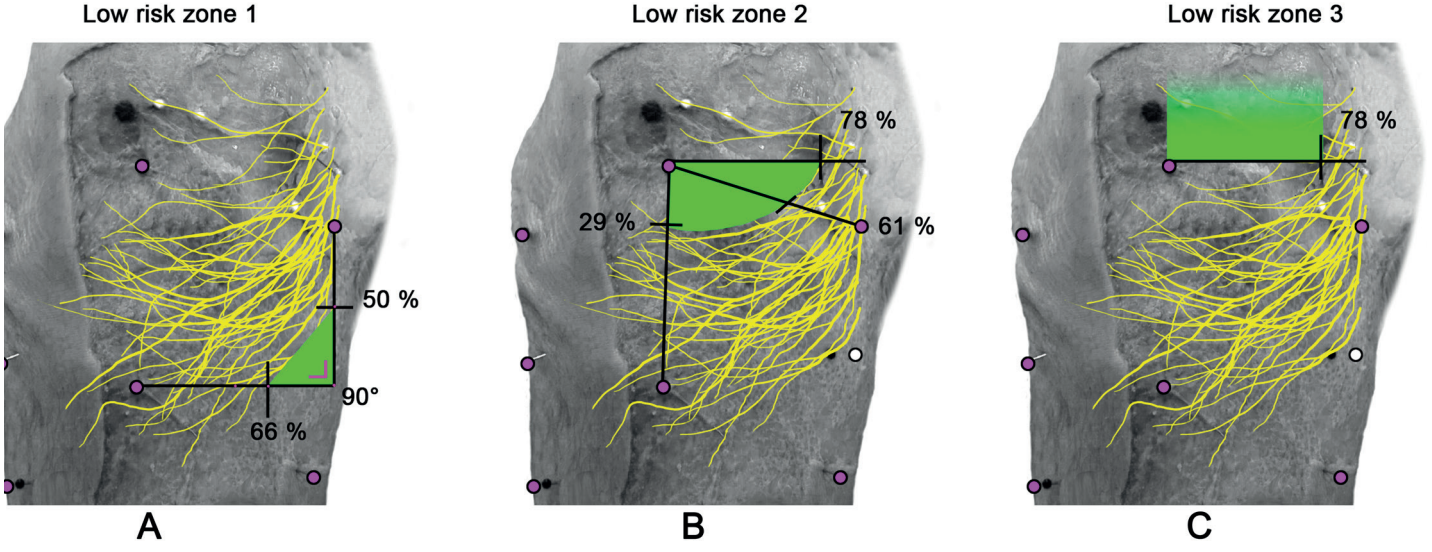


Figure 4.Suggested low risk zones.
A Low risk zone 1. A vertical line is projected downward from the medial edge of the tibial plateau and a horizontal line from the tibial tuberosity to the medial side of the knee. The zone is located distally from 50% of the vertical line and medially from 66% of the horizontal line.
B Low risk zone 2. The zone extends from the patellar apex up to 29% of the distance to the tibial tuberosity, up to 61% of the distance to the medial edge of the tibial plateau, and up to 78% of the distance to a projected vertical line from the medial edge of the tibial plateau.
C Low risk zone 3. Medially and cranially, the zone extends over a horizontally projected line to 78% of the distance between the patellar apex and the level of the medial edge of the tibial plateau.

the saphenous nerve were selected. The anatomic risk and/or safe zones described by Tifford et al[20] (twenty flexed fresh-frozen knees), Mochida and Kikuchi[6] (129 extended, embalmed knees), and Ebraheim and Mekhail[1] (twenty-eight flexed knees) were delineated in three new embalmed specimens. The knees were then photographed (flexed in 90°), and data were mapped with CASAM and compared with the location of the dissected infrapatellar branch of the saphenous nerve (Figures 3 and 6).



## RESULTS

### Topographic Anatomy

The median distance between the apex of the patella and the tibial tuberosity was 64 mm (range, 46 to 78 mm).

The infrapatellar branch of the saphenous nerve consisted of one branch in two specimens, of two branches in twelve specimens, and of three branches in six specimens. The distance between the apex of the patella and the points along the course of the uppermost infrapatellar branch of the saphenous nerve is demonstrated in Figure 2. In all twenty specimens, the infrapatellar branch of the saphenous nerve crossed the 90° reference line at a mean distance of 70 mm (range, 35 to 87 mm). In nineteen specimens, the infrapatellar branch crossed the 45° reference line at a mean distance of 45 mm (range, 21 to 65). In sixteen specimens, the infrapatellar branch crossed the 0° reference line at a mean distance of 28 mm (range, 12 to 49). There was no significant difference between left and right knees for these distances ($p = 0.256$, $p = 0.870$, and $p = 0.447$, respectively). Sixteen proximal branches cross the patellar tendon, and four of them are located on the proximal third; ten, on the middle third; and two, on the distal third of the patellar tendon.

A total of twenty-four branches (in sixteen knees) crossed the sagittal plane of the center of the patellar tendon. On average, these branches run a nearly horizontal course in a −4° downward-lateral direction (range, +28° upward-lateral direction and −58° downward-lateral direction). There was no significant difference between left and right knees for these angles ($p = 0.052$).

### Computer-Assisted Surgical Anatomy Mapping

The dissected infrapatellar branches of the saphenous nerve of all twenty specimens were visualized in a knee with average dimensions (Figure 3-A). The location of the branches demonstrates much variation. The main trunks are located at the medial side of the knee, near the medial edge of the tibial plateau.

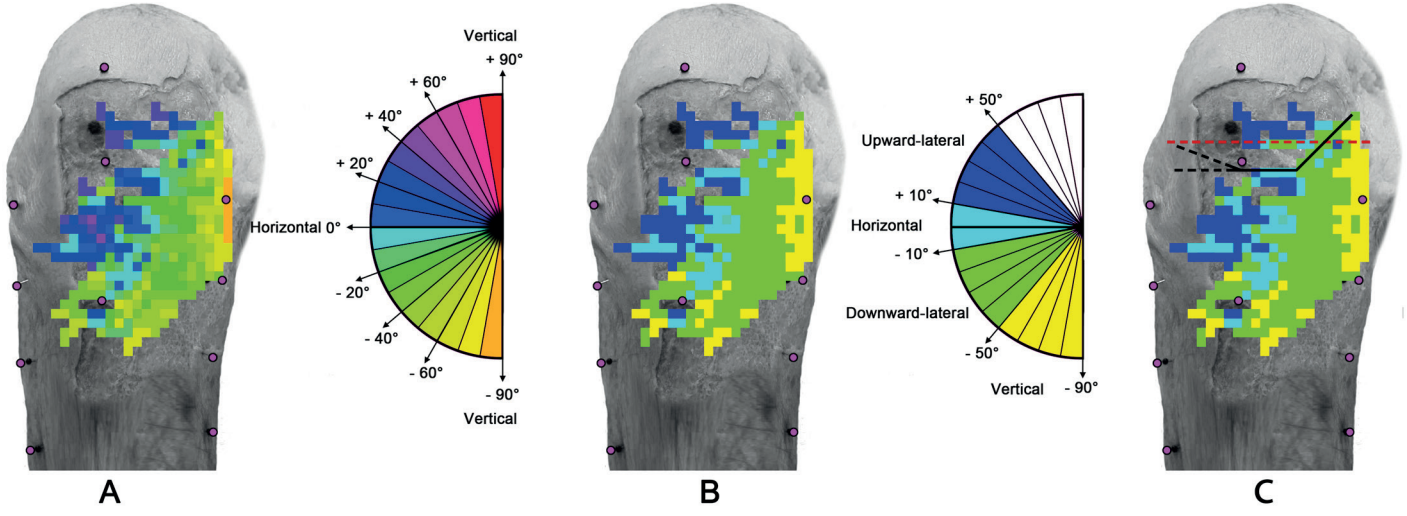


Figure 5. The location-dependent direction of the infrapatellar branch of the saphenous nerve.
A The location-dependent direction of the nerve, divided in 10° increments.
B The location-dependent direction of the nerve, divided in vertical (–90° to approximately –50°), downward-lateral (–50° to approximately –10°), horizontal (–10° to approximately +10°), and upward-lateral (+10° to approximately +50°) directions.
C The red dashed line indicates the transverse incision as proposed by Ojima et al.[18]: "A transverse incision was made at a 90° knee flexion at the level of the lower end of the patella, along the skin crease." The black line shows an adaptation to the incision line proposed by Ojima et al. To make the incision mostly run perpendicular to the infrapatellar branch of the saphenous nerve, the medial part runs in a 45° downward direction. The middle, horizontal part of this incision is located in safe zone 2. The lateral part either runs horizontally or in an upward 20° angle.

Branching mostly occurs on the medial side of the knee at a midpatellar tendon level. Branches then follow a more horizontal course toward the patellar tendon.

When the 5-mm margins around all twenty dissected infrapatellar branches of the saphenous nerve were combined, possible safe zones as well as risk zones (with a higher density of branches) could be identified (Figure 3-B). The location of infrapatellar branches of the saphenous nerve is extremely variable, and there is no definite or unique safe zone in which iatrogenic nerve damage can be prevented completely. However, there are three distinct areas with a low (or lower) density of infrapatellar branches of the saphenous nerve (Figure 4).

The first area is located on the medial side of the knee at the level of the tibial tuberosity (Figure 4-A). The boundaries are formed by a virtual vertical line downward from the medial edge of the tibial plateau and a horizontal line from the tibial tuberosity to the medial side of the knee. This zone is located distally from 50% of the vertical line and medially from 66% of the horizontal line.

The second zone is located medial and distal to the patellar apex (Figure 4-B). Distally, it extends to 29% of the distance between the patellar apex and the tibial tuberosity. Then it extends to 61% of the distance between the patellar apex and the medial edge of the tibial plateau. Medially, it extends over a horizontally projected line to 78% of the distance between the patellar apex and the level of the medial edge of the tibial plateau.

The third zone is located medial and proximal to the patellar apex (Figure 4-C). Medially, it extends over a horizontally projected line to 78% of the distance between the patellar apex and the level of the medial edge of the tibial plateau.

The location-dependent direction of the infrapatellar branches of the saphenous nerve is shown in Figure 5. At the medial edge of the knee, the main trunks of the infrapatellar branches of the saphenous nerve run a close to vertical course. Most branches then continue to follow a curved course, and medial to the patellar tendon, branches run, on average, in a distal-lateral direction. At the medial edge of the patellar tendon, the branches run a close to horizontal course. Then, over the patellar tendon, infrapatellar branches of the saphenous nerve curve to proximal and mostly run a proximal-lateral course. However, branches located near the tibial tuberosity do not run a curved course and continue to run in a distal-lateral direction. The average direction of the infrapatellar branches was −45° in low risk zone 1, −8° in low risk zone 2, and +8° in low risk zone 3 (Figure 4).

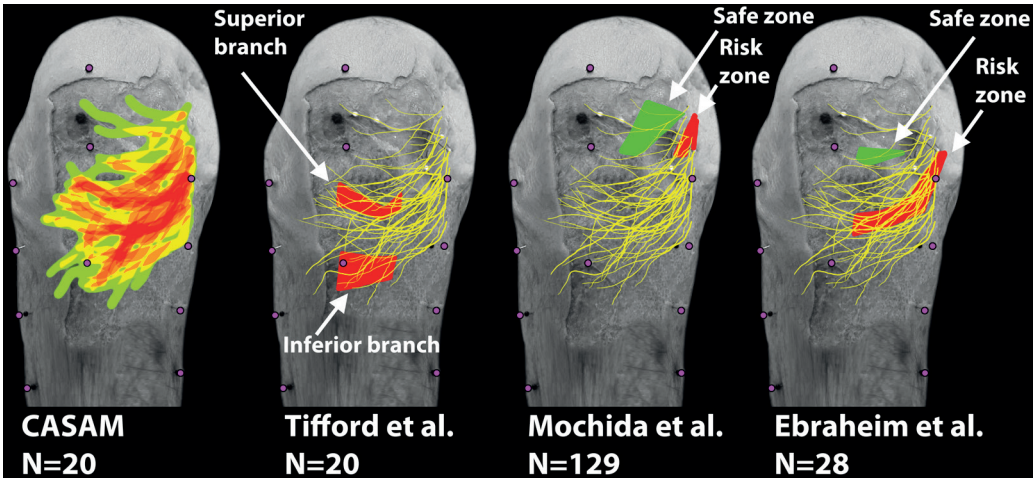


Figure 6. Comparison with reports in the literature. The first image of the infrapatellar branch of the saphenous nerve (left) was made with CASAM visualization and a 5-mm margin and shows the gradient of low risk and high risk zones. The second image shows the findings of Tifford et al.[20], with red indicating risk zones for both the superior and inferior branch of the nerve. The third image shows the findings in the study by Mochida and Kikuchi[6], with red indicating the risk zone and green, the safe zone. The fourth image (right) shows the findings of Ebraheim and Mekhail[1], with red indicating the risk zone and green, the safe zone.

### Comparison with the Literature

Risk and/or safe zones described by Tifford et al.[20], Mochida and Kikuchi[6], and Ebraheim and Mekhail[1] are shown in Figure 6. The location of the superior branch of the infrapatellar nerve described by Tifford et al. corresponds well to the superior part of the high risk zone depicted in Figure 3-B. However, they found the inferior branch to be located more distal than most infrapatellar branches dissected in our study. The safe zones situated medial to the patella, as described by Mochida and Kikuchi and by Ebraheim and Mekhail, mostly overlap the low risk zones 2 and 3, described in Figure 4. The high risk zone that Mochida and Kikuchi described is located medial to our low risk zone 3 (Figure 4) and overlaps the most cranial medial part of the high risk zone described in Figure 3-B. The high risk zone described by Ebraheim and Mekhail overlaps most of the high risk zone depicted in Figure 3, but does not extend to the middle of the patellar tendon.

## DISCUSSION

In accordance with previous anatomical studies[1,4,6], the present study shows that variation in the topographic anatomy of the infrapatellar branch of the

saphenous nerve is high. Therefore, no safe zones were defined, and the nerve is at risk for transection at the initial surgical incision.

However, three low risk zones were identified; in these zones, fewer infrapatellar branches of the saphenous nerve were located, and incorporation of these zones into daily clinical practice may reduce complications related to the nerve. Low risk zones 1 and 3 are relatively rare sites for anteromedial approaches of the knee. Zone 1, however, provides a safer entry site in open meniscectomy and tendon-harvesting. In addition, medial portal placement during arthroscopy might be possible via this area, but the technical feasibility needs further research as it is located distal to the conventional site. Low risk zone 2 can be used as an entry site for a prepatellar bursectomy. Similarly, low risk zones 2 and 3 provide for a safer approach in tibial nailing and retrograde nailing of the femur. In total knee arthroplasty, when the medial edges of low risk zones 2 and 3 are taken into account, the transverse approach described by Ojima et al.[18] may be even more beneficial regarding complications related to the infrapatellar branch of the saphenous nerve. Furthermore, when the location-dependent direction of the infrapatellar branch of the saphenous nerve is taken into account, a cranial deviation of the lateral and medial part of the incision, resulting in a horizontal "smile" incision just distal to the patella, might further reduce iatrogenic damage to the nerve as the incision then mostly runs perpendicular to the infrapatellar nerve (Figure 5-C). The proposed incision may be used, if technically feasible, in total knee arthroplasty. The medial and middle part of the proposed incision can be used in retrograde femoral nailing, tibial nailing, bursectomy, and unicompartmental arthroplasty.

The safe and risk zones described in Figures 3 and 4 correspond with reports in the literature[1,6,20], except for the location of the inferior branch as described by Tifford et al. Apart from the infrapatellar branch of the saphenous nerve, other superficial nerves such as the saphenous nerve, the sartorial branch of the saphenous nerve, the superficial femoral nerve, and the medial retinacular nerve were not dissected.

In accordance with the literature, we hypothesized that horizontal incisions lead to less iatrogenic damage and fewer subsequent postoperative complications than do longitudinal incisions[1,6,18,20,29,40]. Two recent studies have investigated the possibility of transverse or horizontal incisions for various surgical procedures on the anteromedial aspect of the knee[18,41]. A disadvantage of nonlongitudinal incisions in routine surgery on the anteromedial part of the knee is that subsequent total or partial knee replacement is mostly performed using a longitudinal incision, and the patient would have two perpendicular and crossing incisions. However,

Ojima et al. showed that total knee arthroplasty using a transverse incision is technically feasible[18]. Conversely, horizontal incisions cannot be extended and are limited in both length and direction. Therefore, when further exposure for additional surgery, such as quadricepsplasty, is needed, horizontal incisions might be restrictive. Also, the medial retinacular nerve and medial cutaneous femoral nerve[42] might be at risk for transection in a horizontal skin incision.

Since no clear safe zone is identified, the direction of the infrapatellar branches of the saphenous nerve becomes more important; incisions parallel to the nerves exert less risk of damage. Although multiple studies have suggested that horizontal incisions should be made in the anteromedial aspect of the knee, the infrapatellar branch only runs a horizontal course just medial to the patellar tendon. Anteromedially, the infrapatellar branch mostly runs in a downward-lateral angle of −30°, favoring oblique over horizontal incisions. At the medial border of the knee, the infrapatellar nerve, on average, runs a close to vertical course, and longitudinal incisions should be favored. However, in this area, there is a high risk of damage to the infrapatellar branch of the saphenous nerve. On the proximal two-thirds of the patellar tendon and on the patella, the infrapatellar branch mostly runs in an upward-lateral direction of +20°.

In low risk zone 1, the infrapatellar branch of the saphenous nerve runs in a −45° downward-lateral direction, and a parallel oblique incision would be optimal in this area. In low risk zones 2 and 3, a close to horizontal incision would minimize the risk of iatrogenic damage to the infrapatellar branch.

In contrast to previous anatomic studies, the complete course of the infrapatellar branch of the saphenous nerve over the anteromedial side of the knee was mapped and measured using CASAM and was also compared with reports in the current literature. Data gathered with CASAM can be made available via a web-based version, potentially allowing the surgeon to upload a photograph and/or radiographs of a patient. Then, the dissected infrapatellar branch of the saphenous nerve, low risk zones, and location-dependent direction can be displayed over the photograph of the patient's knee.

## Conclusion

In conclusion, the infrapatellar branch of the saphenous nerve is at risk for iatrogenic damage in any surgery on the anteromedial aspect of the knee, especially when longitudinal incisions are used. Three low risk zones for iatrogenic nerve injury were identified: one is located on the medial side of the knee, at the level of the tibial tuberosity, in which a −45° oblique incision is least prone to damage the infrapatellar branch, and two zones are located medial to the

patellar apex (cranial and caudal), in both of which nearly horizontal incisions are least prone to damage the infrapatellar branch. To minimize iatrogenic damage to the infrapatellar branch of the saphenous nerve, the direction of incisions should be parallel to the direction of the nerve when technically possible.



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