Confirmation of intramuscular nerve distribution pattern and clinical application through Sihler's staining

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Confirmation of intramuscular nerve distribution pattern and clinical application through Sihler's staining

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This certifies that the Master's Thesis
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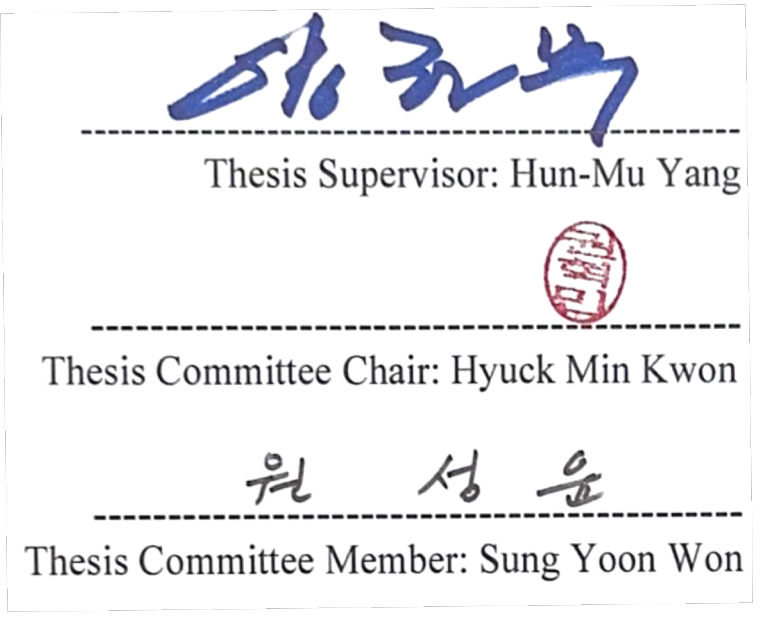

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ABSTRACT

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This study aimed to clarify the extra- and intramuscular branching patterns of tensor fascia latae (TFL) with reference to surface landmarks on the thigh and to thus suggest a safety approach region for the total hip arthroplasty. The sixteen fixed and four fresh cadavers were dissected and subjected to modified Sihler's method to reveal the extra- and intramuscular innervation patterns and findings were matched with and referred to surface landmarks. The landmarks were measured from the anterior superior iliac spine (ASIS) to the patella and divided the 20 parts of the total length. We confirmed that the vertical length of the TFL was measured with an average length of 15.92±1.61 cm, and 38.79□2.73% when converted as a percentage. The entry point of the superior gluteal

nerve (SGN) from the ASIS is at an average of 6.87±1.26 cm (16.71±2.55%). In all cases, the SGN entered parts 3 to 5 (10.1-25%). As the intramuscular nerve branches travel distally, it is observed a common tendency to innervate more deeply and inferiorly. In all cases, the main branches of SGN were intramuscularly distributed in parts 4 and 5 (15.1-25%). Most tiny branches of the SGN traveled in parts 6 and 7 (25.1-35%), inferiorly. The three of the ten cases, very tiny branches of the SGN were observed in part 8 (35.1-38.79%). We could not observe nerve branches of the SGN in parts 1, 2, and 3 (0-15%). When information on the extra- and intramuscular nerve distribution was combined, we found that the nerves were concentrated in parts 3 to 5 (10.1-25%). We propose that damage to the SGN can be prevented if parts 3 to 5 (10.1-25%) are avoided during surgical, treatment, particularly surgical approach, and incision.

Keywords: Arthroplasty, Innervation, Muscular atrophy, Sihler's staining

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I. INTRODUCTION

Acute and chronic pain in the hip joint may have a multitude of causes, including infection, abrasion, dislocation, necrosis, arthritis, and fracture of the hip joint[9,16,21]. Total hip arthroplasty (THA) is the most common method to control pain and is one of the most effective surgical treatment strategies[2,19]. As such, it is performed in more than 1 million cases worldwide each year[12]. Although there are a variety of possible surgical approaches, including posterior, direct anterior, anterolateral, and direct lateral THA, the direct anterior approach (DAA) is the most widely used for its several considerable advantages[4,11,19].

DAA is a minimally invasive approach that operates between the sartorius muscle and fascia tensor (TFL)[2,30]. Many studies have reported that

patients prefer it as it does not require direct muscle incision[9,10]. Furthermore, this approach has been reported to cause less damage to the skin and muscles, resulting in faster recovery, lower dislocation rates, and shorter hospitalization periods due to less pain[19,30].

DAA is a comparatively efficient and safe surgical method, nevertheless, damage to the cutaneous and motor nerves is known to sometimes occur during the approach[19,20]. Lateral femoral cutaneous nerve (LFCN) damage was the most common complication of DAA, reported in up to 81% of cases, and femoral nerve lesion was reported in 0.26-5%[19,21]. In addition, Rachbauer reported that LFCN and superior gluteal nerve (SGN) damage can occur[14], while other studies have reported that regions of the SGN distributed in the TFL could potentially be damaged during DAA[15,19,21].

The DAA approach can cause unexpected nerve damage due to difficulty visualizing during a minimally invasive approach[2]. Cha et al. and Grob et al. stated that insufficient exposure of the femur may cause direct damage to the SGN and TFL muscle fibers[2,6]. There is also a high possibility of damage to the site where the SGN enters at the surface of the TFL during the surgical procedure. Starke et al. reported that the branch of the SGN entering the TFL could be damaged during DAA[19].

Previous studies analyzed the travel of the SGN between the anterior superior iliac spine (ASIS) and greater trochanter (GT) during DAA. Putzer et al. reported that the SGN has located an average of 3.9 cm away

from the tip of the GT[13], while Starke et al. reported that it was located at an average distance of 7.25±1.42 cm[19]. In the results of these two studies, the distance of the SGN from the GT was measured but it was to be different great. Clinically, the location of the GT is roughly confirmed through palpation, but it is unsuitable as a criterion as its location can only be located accurately when the part is exposed through the incision. However, if the ASIS could be located using the origin of the TFL as a reference point, it could be easily used by many clinicians.

In studies by Grob et al. and Starke et al., THA through the DAA was successful without side effects[6,19], but muscle atrophy occurred as a postoperative complication. Researchers have since used various methods to identify the terminal branch of the inferior SGN as the cause of muscle atrophy[20,21]. There is no doubt that SGN damage causes muscle atrophy in the TFL, and damage to the intramuscular nerve can also cause similar symptoms. Damage to regions of the muscle and intramuscular nerve during the separation of the sartorius and TFL using a retractor may result in damage to the SGN. However, few studies have examined how the SGN travels into the muscle in the TFL, or where it is predominantly distributed. If the nerves distributed to the TFL in the entire part are identified, the damage during the surgical procedure can be further reduced. Therefore, an investigation of both the nerves branching from the SGN to the outside of the muscle and the innervation of the inner muscle is important to

minimize complications during DAA.

Botulinum neurotoxin (BoNT) is administered as an injection treatment for patients with poor muscle function[1]. Spastic paralysis in the TFL is relatively common in patients with central nervous system damage. BoNT injection relieves muscles and facilitates walking[1]. Fish and Chang (2007) injected BoNT into a patient who developed persistent leg pain as a complication after THA, achieving recovery of the hip joint[5]. As such, the confirmation of the intramuscular nerve will provide useful injection point data.

Intramuscular innervation has been confirmed through a macroscopic approach in various studies, but there are many limitations. Modified Sihler's staining can confirm innervation in the muscle as a whole and has been applied in many studies. Won et al. outlined the simplest method to observe innervation patterns using modified Sihler's staining[23], which is used in the present study.

This study was performed to provide basic anatomical data for clinicians performing DAA by clearly analyzing the region where the SGN was distributed in the TFL, as well as the pattern of nerve travel and distribution within the muscle. This information will help to develop an effective approach to minimize complications that occur during DAA.

II. MATERIALS AND METHODS

1. Harvesting specimens

This study used forty specimens of the TFL from sixteen fixed and four fresh cadavers (fourteen males and six females; mean age at death, 83.1 years; age range 62-99 years). None of the cadavers had a history of trauma or surgical procedures. In this study, both sides of fifteen cadavers were used to analyze how the SGN enters and travels extramuscularly to the TFL. In addition, ten specimens of five cadavers were subjected to modified Sihler's staining to observe how the nerves travel in the TFL. The subjects had provided consent for donating their bodies for research purposes. The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research[7]. All cadavers had been legally donated to the Surgical Anatomy Education Centre at Yonsei University College of Medicine (Approval number: YSAEC 23-001).

2. Dissection procedure

After The skin was incised from the ASIS to the lateral thigh of the patella, the skin, subcutaneous tissue, and deep fascia covering the TFL were carefully removed to expose and clear the surface of the TFL. For the travel distribution analysis of SGN, we separated the TFL and the sartorius and then observed the internal surface of the TFL. The place where the SGN enters the TFL was identified by dissecting the surface

of the nerves intact. After confirming the entry point of the SGN, the ASIS at the entry point of the nerve was measured vertically.

Bone and muscle distances were measured using digital calipers (Mitutoyo, Kawasaki City, Japan) to indicate the actual measurement and percentage of the position of the nerve entry into the muscle. For reference, landmarks during measurement were measured based on the ASIS and patella. The total length from the ASIS to the patella was measured on the thigh of the lateral side. The TFL length from the origin (ASIS) and insertion (before the iliotibial tract, IT tract) was measured.

3. Modified Sihler's staining protocol

Modified Sihler's staining was used to confirm the intramuscular branch travel pattern and the distribution pattern of SGN branches. We subsequently proceeded according to the Sihler staining protocol, modified by Won et al.[24]. Modified Sihler's staining consists of seven steps, the most important of which is to observe frequently and replace reagents in a timely manner. After modified Sihler's staining, the nerve distribution pattern in the muscle on the view box (Seba, Ansan, Korea) was confirmed **(Fig. 4)**. Because the sample decreases in size after modified Sihler's staining, it should be verified by converting it to the size before it decreases based on the total length measured earlier. It was expressed in 20 parts to identify parts with dense nerve distribution and travel patterns in the TFL.

Sihler's staining process consists of 7 steps, and the staining period is proportional to the size and thickness of the specimen. The staining period takes 3-4 months, and the quality may vary depending on the researcher's experience.

Figure 1. TFL harvesting to decalcification
The process of acquiring and staining for TFL Sihler's staining
a. Harvesting, b. Fixation, c. Maceration, d. Decalcification and depigmentation

A. Fixation (Fig. 1)

The harvested specimen for intramuscular innervation in 10% unneutralized formalin solution. The specimens are fixed for 1 month, but the fixation duration varies depending on the specimen size. the 10% formalin solution must be replaced once a week or cloudy, replace the solution.

B. Maceration (Fig. 1)

The fixed specimen is washed in running tap water for 1 hour and then immersed in 3% maceration and depigmentation solution (3% aqueous potassium hydroxide solution containing 0.2 ml 3% hydrogen peroxide per 100 ml). This solution should be replaced with a fresh solution every 1-2 days until the specimen is translucent. This process takes approximately 1 month, depending on the condition or size of the specimen.

C. Decalcification and depigmentation (Fig. 1)

Maceration specimens are changed to Sihler's solution I (1: 1: 6=glacial acetic acid: glycerin: 1% aqueous chloral hydrate). This solution is changed once a week and takes about 1 month, depending on the size of the specimen.

D. Staining (Fig. 2)

Properly decalcified specimens are stained by immersion in Sihler's II (1: 1: 6=Ehrlich's hematoxylin: glycerin: 1% aqueous chloral hydrate). After two weeks in Sihler's II, the entire specimen will stain purple. This duration is proportional to the size and density of the specimen and takes about 1 month. The staining condition can be evaluated by observing the degree of penetration by Ehrlich's hematoxylin on a viewing box with enough light transmission. This is the standard that decides progress to the next step.

E. Destaining (Fig. 2)

The stained specimen is then immersed in the Sihler's I solution used in the decalcification step. This solution is used to re-decolorize the stained specimen, which takes away the dark stain from the staining. The color of the connective and muscle tissue is subtracted, leaving only the nerves stained. This step continues until the traveling and intramuscular distribution in the specimen is visible, and the specimen is placed on the view box to observe and check the condition. This step determines to stop usually depending on specimen size and the experience of the technician.

F. Neutralization (Fig. 2)

After destaining, the specimens are acidic and should be neutralized by placing them in a 0.05 lithium carbonate solution for 1 hour. The specimen is then placed under running tap water for 1 hour.

G. Clearing (Fig. 2)

The specimens are immersed in glycerin and then the concentration of glycerin is gradually increased to 30%, 50%, 70%, and 100%. Each concentration should be changed once every 1-2 days to move to a high concentration gradually. After all steps, the specimen is stored in pure glycerin. The specimen should be observed over the view box often to ensure that the nerve branches are visible.

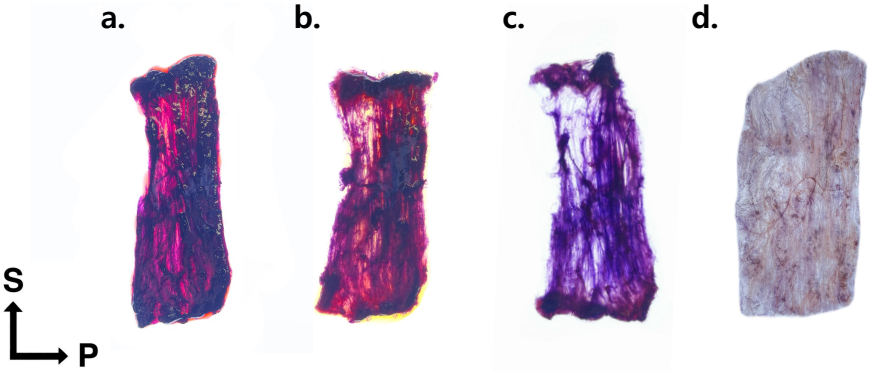


Figure 2. TFL staining to clearing

The process of acquiring and staining for TFL Sihler's staining

a. Harvesting, b. Fixation, c. Maceration, d. Decalcification and depigmentation

III. RESULTS

1. Length and position measurement of the TFL

In this study, we measured the total length from the ASIS to the patella, calculating an average of 41.05□3.48 cm (mean□ SD). The vertical length of the TFL was measured from the ASIS to the superior margin of the IT tract, with an average length of 15.92□1.61 cm.

The total distance from the ASIS to the patella was divided into 20 parts horizontally, with each part representing 5% of the total length, equaling 2.05□0.17 cm. When the distance from the ASIS to the patella was converted as a percentage, the length of the TFL from the ASIS to the insertion was 38.79□2.73%.

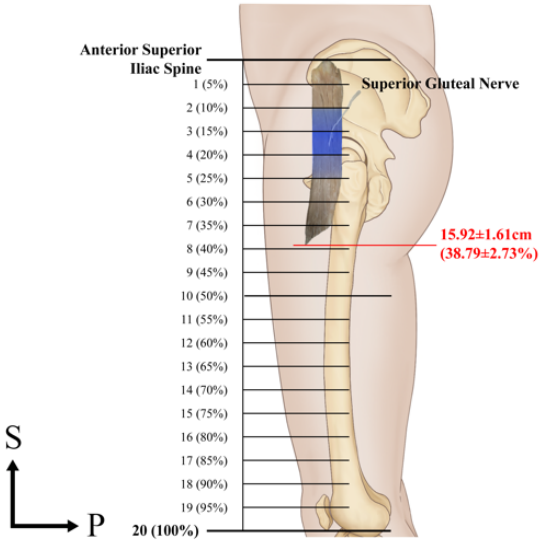
2. Measurement of the path and intramuscular entry point of the SGN

The terminal branch of the inferior branch of the SGN passes through the greater sciatic foramen to the outside of the pelvis and enters the medial surface of the TFL. The part where the SGN entered the TFL was entered vertically from the ASIS at an average of 6.87□1.26 cm, and 16.71□2.55% when converted as a percent.

Among the entry points of the entering nerve, the most common was in part 4 (15.1-20%), and fifteen of thirty specimens were located. The next most entered part was part 3 (10.1-15%), with ten out of thirty

specimens located. In the remaining five specimens, it was entered in part 5 (20.1-25%). Based on this, we stated that the SGN enters 10.1-25% in parts 3 to 5, and nerve branches do not enter parts 1 and 2 (0-10%) and parts 6–8 (25.1-38.79%) **(Fig. 3)**

Figure 3. Measurement of the entry point of the superior gluteal nerve (SGN)



The distance from the anterior superior iliac spine (ASIS) to the patella was divided into 20 parts of equal length, each part 5% of the total length, for analysis. The tensor fascia latae (TFL) is located at 15.92±1.61 cm and

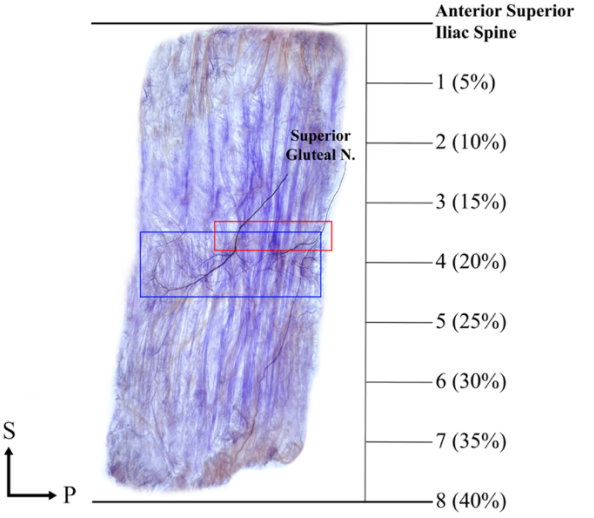
38.79±2.73% of the entire length. This is partly located in parts 1 to 8. The average entry point of the SGN entering the TFL enters mostly at 15–20%. The thirty specimens are represented as 100%, and the distribution is 33.33% for part 3 (10.1–15%), 50% for part 4 (15.1–20%), and 16.67% for part 5 (20.1–25%). S, superior; P, Posterior.

3. Distribution pattern of the intramuscular branch of the SGN in the TFL

In seven of ten specimens, the intramuscular branch of the SGN entered the muscle as a single branch, dividing it into two branches in the muscle. These two branches showed each pattern of traveling forward and downward. In the remaining three specimens, the SGN was divided into two branches outside of the TFL before entering the muscle. The traveling pattern was the same as that of the aforementioned specimens **(Fig. 4 and 5).**

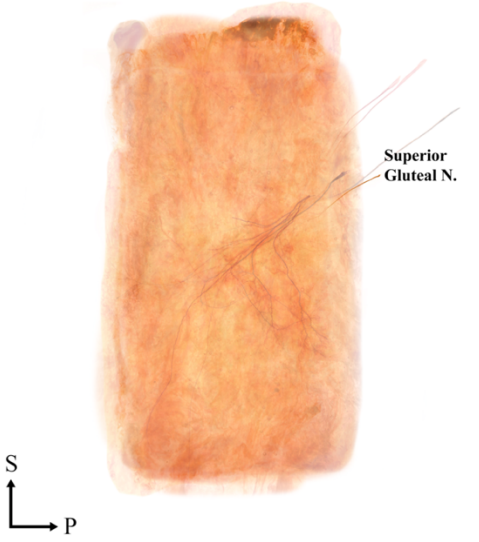
There was a certain tendency for its branches to be traveled more deeply as they proceeded inferiorly and distally. In all cases, the main branches of SGN were intramuscularly distributed in parts 4 and 5 (15.1-25%). Most tiny branches of the SGN traveled in parts 6 and 7, inferiorly. The three of the ten cases, very tiny branches of the SGN were observed in part 8. We could not observe nerve branches of the SGN in parts 1, 2, and 3.

Figure 4. The intramuscular density of SGN revealed by Modified Sihler's staining of the TFL



The red square indicates the average location of the SGN entry point into the muscle. The blue square represents parts where the nerve branches of the SGN entering the muscle are densely distributed. S, superior; P, posterior.

Figure 5. Photograph of superimposed specimens



The modified Sihler's staining for the nerve distribution of the TFL in ten specimens is presented. Ten specimens are placed in the same position, and the images are overlapped. The patterns of the intramuscular branches are very similar. S, superior; P, posterior.

IV. DISCUSSION

Several different THA surgical approaches may be chosen in patients with hip pain[9,12,16,21]. The DAA, which remains popular, was devised by Hueter in 1870 to minimize muscle damage by approaching the TFL and the sartorius[2]. Compared to other approaches, DAA is considered an efficient surgical method, but cases of cutaneous and motor nerve damage during the approach have been previously reported[6,20,21]. DAA is approached as a minimally invasive approach, and it has been reported nerve damage may occur owing to the consequential poor visibility[6]. Grob et al. and Starke et al. were successful without side effects, but postoperative muscle atrophy appeared[6,19]. Muscle atrophy may be caused by damage to the external branches or damage to the intramuscular branches of the TFL that were not identified during DAA. To prevent unexpected nerve damage during DAA, it is necessary to determine the extra- and intramuscular nerve distribution of the SGN in the TFL.

Most prior studies have described the use of the GT as a landmark in DAA[6,13,19]. Putzer et al. and Starke et al. measured the vertical distance of the SGN from the GT, but the results were highly variable[13,19]. Putzer et al. reported that the vertical distance from the tip of the GT to the SGN was an average of 3.9 cm[13], and Starke et al. reported 7.25±1.42 cm[19]. Although the exact reason for this difference in results may not be known, because

the GT is large to measure accurately by each researcher. Although the distance to the GT may be a surgically important indication, during DAA, the approach is performed by widening the gap between the sartorius and TFL, so knowing only the nerve distance in the GT may be difficult.

Grob et al. reported that the part damaged during DAA is exactly the point at which the SGN enters the muscle[6]. Therefore, it is necessary to gain knowledge regarding the point at which the nerve enters the TFL, in addition to the nerve pathway. The distance from the ASIS to the entry point of the nerve was located at 6.87±1.2 cm, which is 16.71±2.55% when converted into a percentage. When the distance from the ASIS to the patella was confirmed by dividing the 20 parts, the nerve entry point was found to be located in parts 3 to 5 (10.1-25%) **(Fig.3)**.

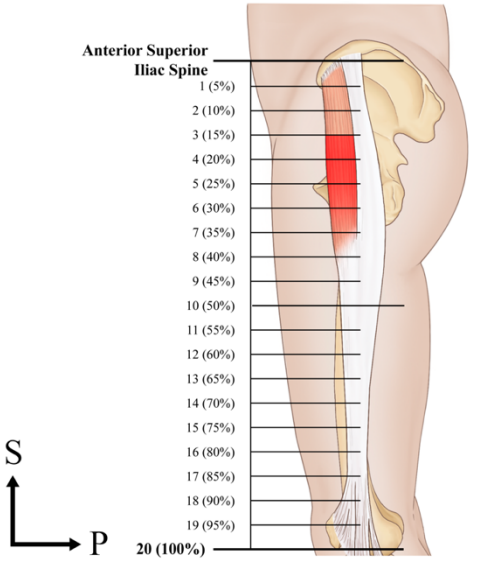
In a study to identify the nerve entry point within the muscle, Grob et al. stated that nerve branches enter only within the upper half of the entire length of the ASIS before the IT tract[6]. In that study, the actual measurements were not calculated in ASIS, but only identified entry points of nerve branches in the entire muscle. This can be confirmed after the skin incision during the surgical procedure, but it was difficult to determine the location before the incision. Therefore, this study can be useful as a reference point for both incision lines and muscle separation.

We found that after the SGN entered the TFL, the nerve branches traveled diagonally posterior to the anterior margin and downward at the

entry point. As shown in Figure 4, the intramuscular nerve distribution was concentrated in parts 4 and 5 (15.1-25%). The SGN intramuscular branches mostly end in part 6 (25.1-30%) Among them, each branch of seven specimens traveled to parts 7 (30.1-35%) or 8 (35.1-38.79%) **(Fig. 6)**. Considering only the distribution pattern of the intramuscular nerve, we propose that regions parts 1 to 3 (0-15%) and 7 and 8 (30.1-38.79%) would be relatively safe parts to perform DAA.

Most of the studies focused on extramuscular nerves on the path and location of the LFCN and SGNs, and there was no study on intramuscular innervation. Since the complications of nerve damage during the approach are clear, it is natural that research is being conducted to prevent them. Further, an increased understanding of SGN distribution may be helpful in understanding cases of intermittent complications such as muscle atrophy in which no direct muscle damage occurred during the DAA.

Figure 6. The intramuscular part density of SGN revealed by staining



Since entering the TFL, the SGN is divided into nerve branches in the muscles and distributed as fine nerve branches. These nerve branches are densely distributed at parts 4 and 5 (15.1–25%). Also, the nerve ending point is mostly identified in parts 4 and 5 (15.1–25%). S, superior; P, posterior.

Additionally, nerve ending points can be used as an indicator of BoNT injection into the TFL A previous study indicated that injection of BoNT into the TFL in a patient with spastic paralysis of the legs can increase PROM during gait and rehabilitation[1]. Bhave et al. further stated that injecting BoNT into the intramuscular nerve ending point would temporarily facilitate muscle relaxation and therapeutic stretching[1]. Our results further indicate that such injection would produce positive results in patients with muscle atrophy, as the terminal branches of the SGN in the TFL are mainly in parts 4 and 5 (15.1-25%).

In this way, similar to the author, other researchers have also employed Sihler's staining to investigate lower limb muscle anatomy, such as for BoNT injection site localization or surgical planning.

One can predominantly find studies utilizing Sihler's staining to verify the injection sites of BoNT. Research aiming to confirm nerve distribution within muscles using Sihler's staining is also frequently encountered, particularly for successful muscle transplantation surgery. Furthermore, Sihler's staining has been employed for aesthetic plastic surgery, proposing safe approaches for joint replacement surgeries, and verifying the placement of FES (Functional Electrical Stimulation) electrodes.

Research using Sihler's staining to identify BoNT injection sites is commonly encountered. BoNT is primarily administered to patients with muscle spasticity due to central nervous system disorders. To achieve the

optimal effect with an appropriate dosage of BoNT, injections should be administered at the sites where motor end plates are most densely concentrated. To ascertain this, many researchers have sought to identify the locations of nerve density within leg muscles.

Won et al., Yan et al., and Jie Wang et al. conducted research on hip adductor muscles[22,24,25], while Rha et al. focused on hamstring muscles[17]. Yi et al. conducted research on the sartorius muscle of the thigh, piriformis muscle, and ankle invertor muscles[26,27,28]. Additionally, Choi et al. investigated the fibularis longus and brevis muscles[3], and V. A. Sheverdin et al. utilized Sihler's staining to confirm the distribution of nerves within the triceps surae muscles[18]. **(Table.1)**

They collectively examined the intramuscular nerve density in leg muscles and proposed injecting BoNT at the site with the highest motor end plate concentration. BoNT should be injected at the area where nerve terminals are most densely packed to inhibit acetylcholine release and achieve the desired effects. The locations suggested by each researcher can serve as valuable reference points for clinicians using BoNT and for anatomical researchers.

Table 1. List of studies using Sihler's staining to identify Botulinum toxin injection points

Author / Year	Muscle	Objective
Kyu-Ho Yi (2021)	sartorius muscle	To treat hip and knee joint spasticity, confirm the distribution pattern of intramuscular nerves for BoNT injection points
Kyu-Ho Yi et al. (2020)	piriformis muscle	To treat Piriformis syndrome, confirm the distribution pattern of intramuscular nerves for BoNT injection points
Yan Yan et al. (2019)	hip adductor m. (adductor longus, adductor brevis, gracilis, adductor magnus, pectimeus)	For the treatment of spasticity in children with cerebral palsy affecting the hip adductor muscles, identify the densely distributed pattern of intramuscular nerves for BoNT injection points
DONG-WOOK RHA et al. (2016)	Hamstring muscles (biceps femoris long head, biceps femoris short head,	To treat hamstrings affected by central nervous system

	semitendinosus, semimembranosus)	damage-induced spasticity, confirm the densely distributed pattern of intramuscular nerves for BoNT injection points
Sung-Yoon Won et al. (2012)	thigh (gracilis, adductor longus)	For the treatment of spasticity in hip adductor muscles affected by central nervous system damage, confirm the pattern of intramuscular nerves and MEP dense locations for BoNT injection points
Jie Wang et al. (2020)	pectineus, gracilis, adductor magnus, adductor longus, and adductor brevis m.	To treat the medial thigh muscles affected by central nervous system damage-induced spasticity, confirm the dense pattern of intramuscular nerves for BoNT injection points

V. A. Sheverdin et al. (2009)	**triceps surae muscle** gastrocnemius m., soleus m.	To shape the esthetic of the posterior compartment of the leg muscles, assess the distribution pattern of intramuscular nerves for BoNT injection points
YOU-JIN CHOI et al. (2020)	fibularis longus m., fibularis brevis m.	For the treatment of calf muscle spasticity due to central nervous system damage, assess the distribution pattern of intramuscular nerves for BoNT injection points
Kyu-Ho Yi et al. (2016)	**Ankle invertor muscles** flexor hallucis longus, tibialis posterior, flexor digitorum longus m.	To treat patients with spastic equinovarus foot due to central nervous system damage, confirm the densely populated areas of MEP in intramuscular nerves for BoNT injection points

BoNT: botulinum toxin, MEP: motor end plate

In order to perform a successful muscle transplantation surgery, it is essential to have a precise understanding of the compartments within the muscle. Research utilizing Sihler's staining to confirm muscle compartments includes Kurtys et al. study on the gracilis muscle[8] and Yu et al. investigation of the entire calf muscle[29]. Free functional muscle transfer is a complex surgical procedure primarily performed to restore the function of lost muscles by transplanting a portion of a muscle that possesses its own vascular and neural distribution. While numerous studies have explored nerves and blood vessels within many muscles, investigations into the course and distribution of nerves within the muscle itself have been insufficient. Kurtys et al. study revealed that the gracilis muscle possesses distinct nerve compartments, making it suitable for free functional muscle transfer[8]. Yu et al. research presented four different patterns of nerve distribution in calf muscles, offering valuable guidance for muscle transplantation surgery[29]. **(Table.2)**

In conclusion, it can be confirmed that not only in this author's research but also in other related studies, Sihler's staining has been employed. Sihler's staining can be applied in various contexts to visualize nerve distribution within muscles, thereby providing valuable information for clinicians and anatomists in various fields.

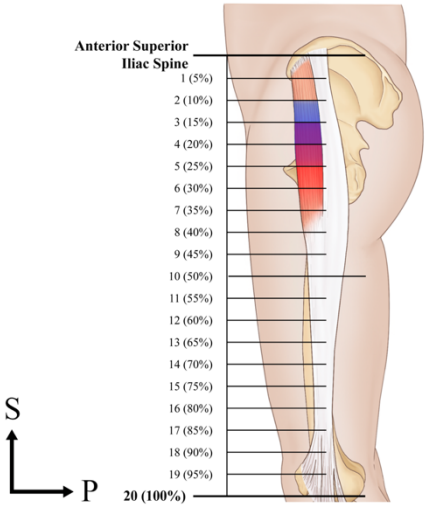
Table 2. List of studies using Sihler's staining to identify intramuscular compartments for muscle transplantation surgery

Author / Year	Muscle	Objective
Konrad Kurtys et al. (2022)	gracilis muscle	To assess suitability for free functional muscle transfer, confirm the distribution pattern of intramuscular nerves and the neuromuscular compartments
Dazhi Yu et al. (2015)	**Lower leg skeletal muscles** Tibialis anterior, Extensor digitorum longus, Extensor hallucis longus, Fibularis longus, Fibularis brevis, Medial head of gastrocnemius, Lateral head of gastrocnemius, Soleus, Tibialis posterior, Flexor. digitorum longus, Flexor hallucis longus, Popliteus m.	To transplantation surgery, confirm the course of intramuscular nerves, distribution pattern, and muscle compartments of lower leg skeletal muscles

V. CONCLUSION

This study aimed to clarify the distribution of extra- and intramuscular nerves of the SGN in the TFL. The SGN mainly entered the muscle in parts 3 to 5 (10.1-25%) of the TFL, while the intramuscular nerve branches in the muscle were concentrated in parts 4 and 5 (15.1-25%) **(Fig. 7)**. In conclusion, when information on the extra- and intramuscular nerve distribution was combined, we found that the nerves were concentrated in parts 3 to 5 (10.1-25%). We propose that damage to the SGN can be prevented if parts 3 to 5 (10.1-25%) are avoided during surgical, treatment, particularly surgical approach, and incision. Finally, the results of this study provide indicators for safe surgery for clinicians performing DAA and will also be helpful as related research data for anatomists.

Figure 7. The safety zone for TFL surgery



The entry point of the SGN is marked in blue, and the density region of intramuscular branches is marked in red. The blue and red regions are located at tiny branches of the SGN. This part can be considered as a reference during the direct anterior approach (DAA). S, superior; P, posterior.

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ABSTRACT(IN KOREAN)

Sihler's 염색을 통한 근육 내 신경 분포 패턴 확인과 임상에서의 적용 확인

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최 선 의

본 연구의 목적은 넓적다리 표면의 기준점을 참조하여 넙다리근막 긴장근(TFL)의 근육 바깥 신경분포와 근육 속 신경 분포에 대해 명확히하여 엉덩관절 전치환술 시에 안전한 접근 영역을 제시하는 것이였다.

16구의 고정된 사체와 4구에 비고정 사체를 해부학적으로 해부하였고 수정된 Sihler's 염색 방법을 적용하여 근육 바깥 신경분포와 근육 속 신경 분포 패턴을 파악한 후 그 결과를 표면에서 확인할 수 있는 기준점에서 대조하였다. 기준점은 위앞엉덩뼈가시(ASIS)로 부터 무릎뼈까지 측정되었으며 전체길이를 20등분했다.

넙다리 근막 긴장근의 수직 길이는 평균 길이가 15.92±1.61cm이고, 백분율로 변환할 경우 38.79±2.73%로 확인되었다. 위볼기신경(SGN)의 신경진입점은 평균적으로 근육의 이는곳에서 부터 6.87±1.26cm (16.71±2.55%)에 위치하고

있는 것을 확인하였다. 모든 표본에서 위볼기신경은 영역3에서 영역5(10.1-25%) 사이에서 근육 속으로 진입했다. 근육 속 신경 가지가 원거리로 이동함에 따라 더 깊고 아래쪽으로 신경을 공급하는 경향이 관찰되었다. 모든 경우에서 위볼기신경의 근육 속 신경의 주요 가지는 영역4와 영역5(15.1-25%)에서 분포했다. 위볼기신경의 작은 가지들은 대부분 영역 6과 영역7(25.1-35%)을 향해 아래쪽으로 분포했다. 10쪽 중 3쪽의 표본에서는 아주 작은 가지가 영역8 (35.1-38.79%)에서 관찰되었다. 영역1부터 영역3(0-15%)까지에서는 위볼기신경의 신경 가지를 관찰할 수 없었다.

근육 바깥 신경과 근육 속 신경 분포 패턴에 관한 연구 자료를 모두 종합해보면 신경은 영역3에서 영역5(10.1-25%)에 집중적으로 분포하고 있는 것을 확인할 수 있었다. 본 연구에서는 수술, 치료, 특히 외과적 접근 및 절개 시에 영역3부터 영역5(10.1-25%)를 주의한다면 위볼기신경의 손상을 방지할 수 있을 것을 제안하는 바이다.

핵심되는 말: 관절성형술, 신경지배, 근위축, 쉴러염색