ACCURACY OF GENICULAR NERVE BLOCK BY ULTRASOUND GUIDED VERSUS LANDMARK GUIDED TECHNIQUES- A CADAVERIC STUDY

THESIS

Submitted to

All India Institute of Medical Sciences, Jodhpur

In partial fulfillment of the requirement for the degree of

DOCTOR OF MEDICINE (MD)

(PHYSICAL MEDICINE AND REHABILITATION)

JULY, 2020 **DR. CHINCHU K**

AIIMS, JODHPUR

DECLARATION

I hereby declare that the thesis titled **“Accuracy of Genicular nerve block by Ultrasound guided versus Landmark guided techniques- A Cadaveric Study”** embodies the original work carried out by the undersigned in All India Institute of Medical Sciences, Jodhpur.

DR. CHINCHU K
Department of Physical Medicine and Rehabilitation
All India Institute of Medical SciencesJodhpur

ALL INDIA INSTITUTE OF MEDICAL SCIENCES, JODHPUR

CERTIFICATE

This is to certify that the thesis titled **"Accuracy of Genicular nerve block by Ultrasound guided versus Landmark guided techniques- A Cadaveric Study"** is the bonafide work of Dr. Chinchu K, in the Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur.

Dr. Abhay Elhence

Professor and Head

Department of Physical Medicine and Rehabilitation

AIIMS, Jodhpur

All India Institute of Medical Sciences, Jodhpur

CERTIFICATE

This is to certify that the thesis titled **"Accuracy of Genicular nerve block by Ultrasound guided versus Landmark guided techniques- A Cadaveric Study"** is the bonafide work of Dr. Chinchu K carried out under our guidance and supervision, in the Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur.

Guide:

Dr. Nitesh Manohar Gonnade
Associate Professor
Department of Physical Medicine and Rehabilitation
AIIMS, Jodhpur

All India Institute of Medical Sciences, Jodhpur

CERTIFICATE

This is to certify that the thesis titled **"Accuracy of Genicular nerve block by Ultrasound guided versus Landmark guided techniques- A Cadaveric Study"** is the bonafide work of Dr. Chinchu K, carried out under our guidance and supervision, in the Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur.

Co-Guides:

Dr. Ravi Gaur

Additional Professor, Department of Physical Medicine and Rehabilitation

All India Institute of Medical Sciences, Jodhpur

Dr. Ashish Kumar Nayyar

Additional Professor, Department of Anatomy

All India Institute of Medical Sciences, Jodhpur

Dr. Pawan Kumar Garg

Additional Professor, Department of Diagnostic and Interventional Radiology

All India Institute of Medical Sciences, Jodhpur

DEDICATED TO MY GRANDMOTHER
LATE PATERI JANAKI AMMA

Acknowledgment

"Great things in business are never done by one person. They're done by a team of people."

-Steve Jobs

Nothing would be achievable without our professor's guidance and the support of our family and friends.

I would like to dedicate this thesis to my guide Dr. Nitesh Manohar Gonnade, Associate Professor, Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur, without whose motivation and constant support, this wouldn't have been possible. Thank you for those countless discussions, and for being constantly available for guidance without which, this would have been more arduous. Thank you for all your guidance and your faith in me. I will cherish everything that you have taught me.

I owe my special thanks to Dr. Ravi Gaur, Additional Professor, Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur, for his constant support and guidance at every phase of this thesis-related work. And for being available with his guidance and support throughout the thesis and the duration of my course. The influence you have on my work and perspectives is high, and I will cherish them forever.

I would like to thank Dr. Abhay Elhence, Professor and Head, Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur, for his patronage and for allowing me to carry the work under this thesis project.

I am grateful to Dr. Ashish Kumar Nayyar, Additional Professor, Department of Anatomy, All India Institute of Medical Sciences, Jodhpur, for his constant guidance, and encouragement, without which this thesis wouldn't have been possible.

I am grateful to Dr. Pawan Kumar Garg, Additional Professor, Department of Diagnostic and Interventional Radiology, All India Institute of Medical Sciences, Jodhpur, for his guidance.

I would like to acknowledge Dr. Prakash Chandra Kala, Additional Professor, the Department of Burns and Plastic Surgery, for providing me with loupes microscope and dissection instruments. I would also like to acknowledge Dr. Nikhilesh Kumar, Assistant Professor, Department of Burns and Plastic Surgery, AIIMS Jodhpur, for helping me with microdissection under loupes microscope.

I would like to express my sincere gratitude to all the Senior Residents of the Department of Physical Medicine and Rehabilitation, All India Institute of Medical Sciences, Jodhpur, with special mention to Dr. Rambeer Gulelia, Dr. Sandeepan Hazra, Dr. Satyasheel Singh Asthana, Dr. Samantak Sahu, Dr. Minhaj Akhtar, Dr. Chandrakant Pilania, Dr. Himanshu Agrawal, Dr. Sentimoa Jamir, and Dr. Rajesh Saha, for sincerely helping and guiding me throughout the process. I would also like to express my sincere gratitude towards the senior residents of the Anatomy department with special mention to Dr. Faizal, Dr. Suyashi, and Dr. Sambhav for helping me with dissection.

I express my sincere gratitude towards Dr. Bharath, my friend and colleague, and Dr. Mukul Maheshwari, senior resident department of community medicine, and family medicine, for helping me with the statistical analysis. I would like to acknowledge my friend and colleague, Dr. Abins T K, my senior Dr. Merrin M Mathew, my juniors Dr. Dhaval, Dr. Nagma, Dr. Swarup, Dr. Abdulla, Dr. Saran, and Dr. Megha for their constant support throughout. I would like to acknowledge my friend and colleague, Dr. Rishi for providing me with technical assistance in Photography. My friend Dr. Thoyyib Parammal Karat, needs special mention for his constant support and help. I am blessed to have you in my life.

I am highly obliged to all the staff in the Anatomy Dissection Hall, with special mention to Mr. Arif Ahmed, Mr. Devender, Mr. Mukesh, Mr. Sudarshan, and Mr. Sreekanth for being highly cooperative and helping me with the positioning of the cadavers for dissection. I express my sincere gratitude towards, all staff in the PMR department with special mention to Mr. Bhajan Lal, Mr. Shakti Singh, Mr. Shiv Singh, Mr. Manish, Mr. Pawan Kumar, Mr. Pawan Borana, Mr. Ravi Varma, Mrs. Jeenu, and Miss Tabumsum Parveen.

I am highly obliged to all the deceased, who have donated their body, to the department of anatomy, without whom, I would not be able to complete my thesis.

I cannot express in words my appreciation and love for my parents Mr. Mustafa K, and Mrs. Sreedevi C, my brother Mr. Rinchu K, my grandparents, and my family, for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis.

Finally, my thanks go to all the people who have supported me to complete the research work directly or indirectly.

INDEX

LIST OF ABBREVIATIONS

SMGN	Superomedial genicular nerve
IMGN	Inferomedial genicular nerve
SLGN	Superolateral genicular nerve
MGN	Middle genicular nerve
IPBSN	Infrapatellar branch of the saphenous nerve
ILGN	Inferolateral genicular nerve
MCL	Medial collateral ligament
W/V	Weight by volume
USG	Ultrasonography
OA	Osteoarthritis
ACR	American College of Rheumatology
NSAIDs	Non-steroidal Anti-Inflammatory Drugs
TKA	Total knee arthroplasty
RFA	Radiofrequency ablation
K-L	Kellgren- Lawrence
VAS	Visual Analogue Scale
RA	Rheumatoid arthritis
ACL	Anterior cruciate ligament
JIA	Juvenile Idiopathic Arthritis
G	Gauge
RFN	Recurrent fibular nerve
NVI	Nerve to vastus intermedius
NVL	Nerve to vastus intermedius
NVM	Nerve to vastus medialis
LCL	Lateral collateral ligament
CPN	Common Peroneal nerve
DPN	Deep peroneal nerve
AT	Adductor tubercle
ITB	Iliotibial band
RF	Radiofrequency
WOMAC	Western Ontario and McMaster Universities

ICG	Indocyanine green
DGA	Descending genicular artery
CFN	Common fibular nerve
MHz	Mega Hertz
RT	Right
LAT	Lateral
POST	Posterior
LT	Left
TRANS	Transverse
LOG	Longitudinal
MED	Medial
DSLR	Digital Single lens reflex
TT	Tibial tuberosity
GT	Gerdy's tubercle
SUP	Superior
INF	Inferior
VM	Vastus medialis
QT	Quadriceps tendon
FH	Fibular head
FHNJ	Fibular head- neck junction
MFCDE	Medial femoral condyle distal end
MTCPE	Medial tibial condyle proximal end
JSC	Junction of shaft and condyle
SMGA	Superior medial genicular artery
SMPP	Superomedial pole of patella
MPSP	Midpoint of superior surface of patella
LFCDE	Lateral femoral condyle distal end
LTCPE	Lateral tibial condyle proximal end
JSLEF	Junction of shaft and lateral epicondyle of femur
SLGA	Superior lateral genicular artery
SLPP	Superolateral pole of patella
MPSP	Midpoint of superior surface of patella

IMCL	Insertion of medial collateral ligament
MTCPE	Medial tibial condyle proximal end
JSMET	Junction of shaft and medial epicondyle of tibia
MFCDE	Medial femoral condyle distal end
IMGA	Inferior medial genicular artery
IPP	Inferior pole of patella
JSLET	Junction of shaft and lateral epicondyle of tibia
TTPP	Tibial tuberosity proximal point
GTMP	Gerdy's tubercle medial point
CPND	Common peroneal nerve division
ILGA	Inferior lateral genicular artery
MPPS	Midpoint of patellar surface
MPSBP	Midpoint of superior border of patella
SMPP	Superomedial pole of patella
MGA	Middle genicular artery
ANT	Anterior
SUP	Superior
INF	Inferior
IQR	Interquartile range
S. LAND	Surface landmark
NND	Nerve-to-needle distance

LIST OF TABLES

LIST OF FIGURES

Summary of Project

Background: For treating knee pain, the constantly targeted genicular nerves are SMGN, IMGN, SLGN, ILGN, MGN, and IPBSN. There is more than one landmark described for the same genicular nerve. The defined targets can be identified with surface landmarks, ultrasound guidance, or with C- arm guidance. There is great variability in the course of the genicular nerves.

Aim: To determine and compare the accuracy of genicular nerve block by ultrasound guided versus landmark guided techniques.

Methods: 10 cadaveric knee specimens were studied in a lot, with a total of three lots, studied during the period of study. These were randomly distributed into two groups, by envelop method. The genicular nerves studied are the SMGN, IMGN, SLGN, ILGN, and the middle genicular nerve. In group 1, ultrasound scanning was performed. The SMGN was targeted at 1cm anterior to the adductor tubercle. The IMGN, at the midpoint of the peak of medial tibial condyle and insertion of deep MCL. The SLGN, at the junction of lateral femoral condyle and shaft, in coronal view, and the crest between the lateral and posterior cortex in axial view. The ILGN, was targeted, at the lateral tibial condyle, just medial to the insertion of the coronary ligament. For the middle genicular nerve, at the roof of the suprapatellar fossa. In the second group, the surface landmarks were used. The SMGN at just proximal to the medial femoral epicondyle. The IMGN at just distal to the medial tibial condyle. The SLGN at just proximal to the lateral femoral condyle. The ILGN, at the junction of the vertical line through the peak of Gerdy's tubercle and the horizontal line through the peak of the tibial tuberosity. The middle genicular nerve at 5 cm above the superior pole of the patella. In both groups 22-gauge 38 mm spinal needle was inserted, and 0.1 ml eosin (2% W/V) was injected. In both groups, dissection was carried visualizing through a loupes microscope carefully, with keeping the needle in situ. The staining of the nerve was documented and the nerve-to-needle distance was documented. Further, the distance of each nerve from the nearby identifiable landmark was measured and documented. 15 specimens in each group were studied. Data were analysed using R version 4.2.2. Fisher's exact test was used for comparing the staining of nerves in two groups. Wilcoxon rank-sum test was used to compare nerve to needle distance in two groups. The relationship between nerve distance to nearby landmarks and cadaver length was analysed using linear regression. A p-value < 0.05 was considered statistically significant.

Results: A total of 30 knee specimens were studied (15 in the USG group and 15 in the Surface landmark group). Group 1 showed more accuracy for SMGN, IMGN, SLGN, and MGN, in terms of staining and nerve-to-needle distance, for the specified landmarks. ($p < 0.05$) The ILGN landmarks were shown to target the recurrent fibular nerve, on dissection. The ultrasound landmark targeted the more distal part whereas the surface landmark guided targeted the more proximal portion. It was stained in 100% of specimens in both groups, even though the nerve-to-needle distance, showed a significant difference among both groups, with group 1 targeting closer to the nerve. ($p < 0.05$) The recurrent fibular nerve was found to be around 1 cm below Gerdy's tubercle, and is being joined by the anterior tibial recurrent artery, in 100% of the specimens.

Conclusion: Ultrasound guided landmarks, used in this study are more accurate than landmark-guided landmarks for SMGN, IMGN, SLGN, and MGN. The recurrent fibular nerve can be targeted between Gerdy's tubercle and tibial tuberosity. And can also be targeted below Gerdy's tubercle, visualizing the anterior tibial recurrent artery pulsation.

INTRODUCTION

INTRODUCTION

Chronic knee pain affects approximately 25% of adults, and is the second most complaint, after low back pain, with which patients seek medical help. (1) In the advanced age group chronic knee pain due to osteoarthritis (OA) ranks among the most common symptom. (2) The estimate of the lifetime risk of developing symptomatic OA of the knee was approximately 40 percent in men and an increased risk of 47 percent in women. (3)

In the Global Burden of Disease Study conducted in 2017, the age-standardized point prevalence of OA, globally was 3.75%. An increase of 9.3% was reported from 1990.(3) Despite of having considerable international variation in the prevalence of OA, the burden of this disease is increasing in all most all countries; this is expected to continue with increased life expectancy and aging of the global population.(4)

20-30 % of the elderly population, aged more than 65 years are suffering from symptomatic OA, with pain being their primary concern. This has become more prevalent than in previous decades, as the population of elderly persons and obesity, has increased.(5) The chronic pain due to OA knee, is further a major cause of exhaustion, obesity, depression, sedentary life style and social isolation. (4) Hence the vicious cycle continuous.

The management of OA consist of conservative and surgical options. The ACR 2019 guidelines for management of OA knee divided the conservative treatment options in to pharmacological, and physical-psychosocial. The strongly recommended pharmacological treatments are topical and oral NSAIDs (Non-steroidal anti-inflammatory drugs), and intraarticular glucocorticoid injection. The strongly recommended physical and psychosocial modalities of treatment includes exercises, weight loss, Tai-chi, Cane and tibio-femoral brace. And the conditionally recommended options includes balance training, yoga, cognitive behavioural therapy, kinesiotaping, thermal interventions, and radiofrequency ablation of the sensory nerves of knee. (6) The surgical options for OA knee should be considered only if the joint symptoms like pain, stiffness, and reduced function are refractory to nonsurgical treatment and are significantly affecting the quality of life.(7) (8) If there is a clear history of mechanical locking, then arthroscopic lavage and debridement can also be tried.(9) (7) When all the conservative, minimally invasive non-surgical and surgical procedures are not giving adequate pain relief and functional improvement, TKA(Total Knee Arthroplasty) is considered.(10)

Even after fulfilling the criteria for the aforementioned surgeries, some individuals are not ideal candidates for surgery, due to their medical conditions, comorbidities, or sleep apnoea.(11) Some patients are also reluctant for surgery and prefer nonsurgical options, or at least want to give a trial of conservative methods before opting surgery. (12,13) In these patients, even if the disease is present, suffering should be optional. And they have the full right to a pain-free life. Hence for pain relief, the sensory nerve of knee called genicular nerves can be blocked with steroid injection or can do RFA (Radiofrequency Ablation) of these nerves. (14) The principle of management with genicular nerve block is that disrupting the sensory innervation to a painful structure will alleviate the pain, resulting in secondary restoration of function.(2) Studies have shown that genicular nerve block, can be done in grade 2 to 4 OA of K-L (Kellgren-Lawrence) classification, who are refractory to conservative management for 6 months,(15) or for 3 months with moderate to severe pain and not eligible for total knee replacement. (16) It can be also done in grade 3 and 4 OA of K-L classification, and VAS (Visual Analogue Scale) score ≥ five, and refractory to six months of conservative management. (17)

Patients also suffer pain after TKA. It has been reported that 44% of patients have persistent pain after TKA, with 15% having extremely severe pain. Thus, a total of 20% of the 35% of patients with knee OA after TKA also suffer from chronic pain lasting more than 6 months after surgery. In these patients, RFA has proven to be a promising option for pain management.(18–21) It has been found that the patients who underwent RFA of genicular nerves, prior to TKA, are having lower rate of opioid use post operatively, as compared to those who underwent TKA alone. (22)

Genicular nerve block with steroid, is a good alternative to RFA, in a resource poor setting, and has been found to be as effective as RFA, in some studies, with effect lasting 3-6 months. (15,23,24) It can be done with either 1 ml (25–27) or 2 ml (14,28) of steroid and local anaesthetic solution. More precisely we are targeting the nerve, more the chance for successful block, with less volume, less side effects, and long duration of action.

Apart from OA knee patients, cooled RFA was also used for subchondral insufficiency fracture of the knee,(29) rheumatoid arthritis(RA),(30) post ACL reconstruction, (31) juvenile idiopathic arthritis(JIA), (32) with chronic knee pain.

Therefore, for patients with chronic knee pain—of which the majority is due to osteoarthritis (OA)—the pain should be managed when present, with RFA or genicular nerve block with steroid. Whether not opting for surgery, momentarily after surgery, or to prevent revision surgery to treat persistent pain.

There are some randomised trials (21,23,27) and multiple longitudinal cohort studies determining the effectiveness of genicular nerve RFA on chronic knee pain.(15,17,25,33,34) There are four meta-analysis stating that RFA is an effective and safe treatment for relieving knee pain and improving function in OA knee patients.(35–38) Long term effect up to 6 months,(34–36,39) and 1 year,(17,34,40) have been well established, if the nerves are adequately targeted. In our practise also we have seen single RFA session resulting in nearly 1 year of pain free period.

The factors that can determine the effect of RFA, apart from disease severity, are genicular nerve anatomy, nerve needle proximity, and the gauge of the RFA needle used. The size of lesion produced by a RFA needle is proportional to its electrode width. (41,42) As a practical rule, the nerve has to be within twice the electrode width. For adequate nerve lesion, using smaller electrodes of 20G or 22G the electrode should be on the nerve, and a change in 1 mm can miss the nerve. But with larger electrodes of 18 and 16 G, there can be more flexibility.(43)

So, either with nerve block or RFA, the genicular nerves should be precisely localised. But in practise it is challenging due to the complex anatomy and interpatient variability of nerves that supply the knee joint capsule.

Articular branches of several nerves including the femoral, saphenous, sciatic, common peroneal, tibial, and obturator nerve innervate the joint capsule. (44–50) The genicular nerves that are frequently blocked are the superior medial genicular nerve(SMGN), the inferior medial genicular nerve(IMGN), and the superolateral genicular nerve(SLGN).(16,51–59) Some studies, also target the middle genicular nerve(MGN) (60–63), the infrapatellar branch of the saphenous nerve(IPBSN)(64), the inferolateral genicular nerve(ILGN)(61,62) and the recurrent fibular nerve(RFN)(64,65). (Figure 1)

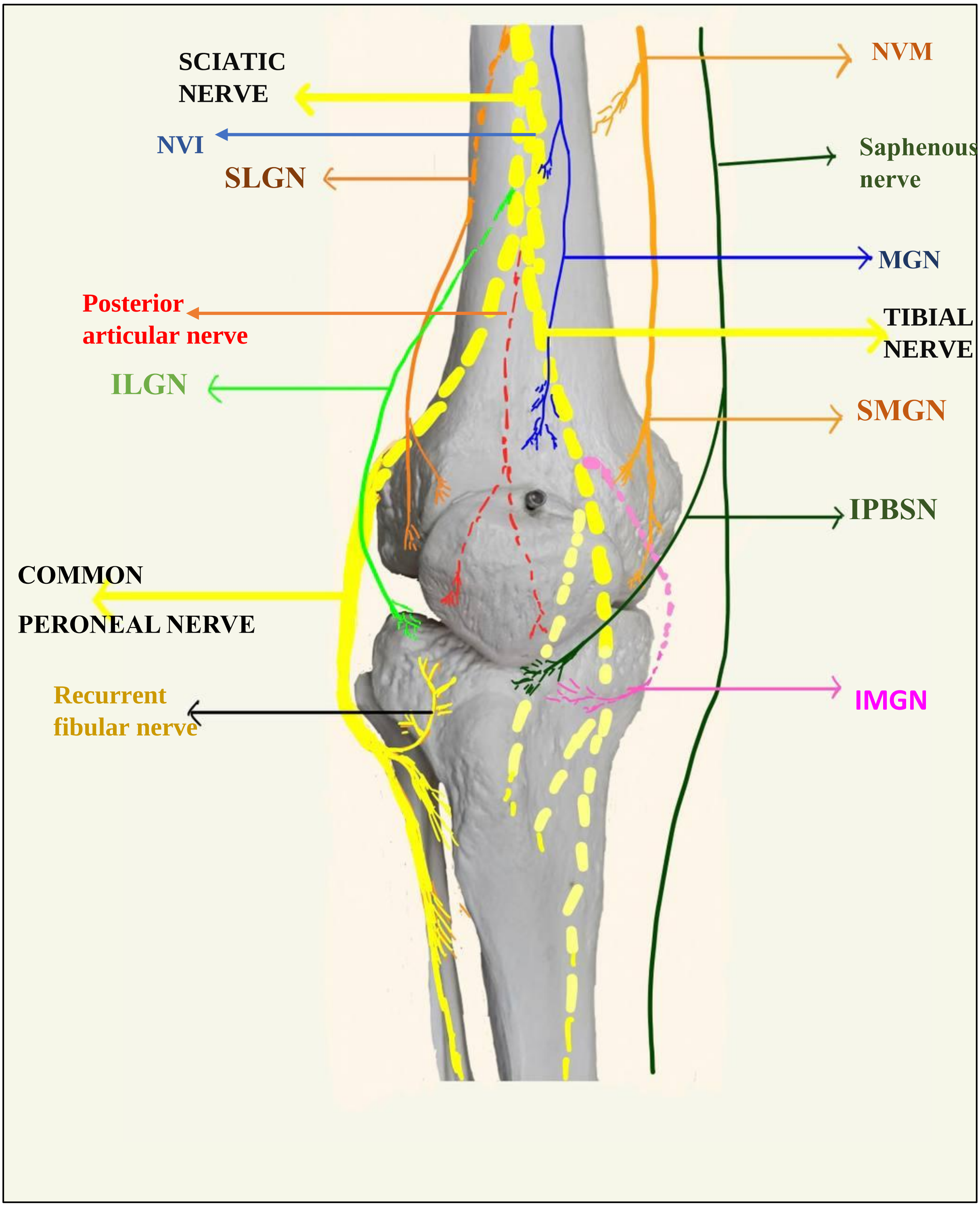


Figure 1- Genicular nerve anatomy*: Schematic diagram showing the anterior view of knee, with Genicular nerves around the knee. The dotted lines show the posterior structures (sciatic nerve, common peroneal nerve, tibial nerve and their genicular branches) SMGN- superior medial genicular nerve, IMGN- inferior medial genicular nerve, SLGN- superior lateral genicular nerve, ILGN- inferolateral genicular nerve, IPBSN- infra patellar branch of saphenous nerve. NVI- Nerve to vastus intermedius, NVM- Nerve to vastus medialis*

There are several studies describing the target for these nerves under the guidance of surface landmarks, under the guidance of c-arm, and under the guidance of ultrasound. Even though there are number of studies explaining RFA under fluoroscopy guidance,(14,27,40,63,66,67) ultrasound being radiation free, a real time procedure, and being easy to handle, has increased the acceptance of USG for genicular nerve block, in the recent years. (28,30,52,54–56,59–61,68–72)

In some studies the genicular nerves were also targeted with surface landmarks, and surprisingly, patients in this group had comparable pain relief to patients in the ultrasound-guided group.(57,58)

Hence, the aim of this study is to compare the efficacy of ultrasound-guided genicular nerve block with surface landmark guided genicular nerve block, for the specified landmarks, in human cadaveric knee specimens. The genicular nerves targeted are superomedial genicular nerve (SMGN), inferomedial genicular nerve (IMGN), superolateral genicular nerve (SLGN), inferolateral genicular nerve (ILGN), and the middle genicular nerve (MGN).

There are some discrepancies between the target points of the genicular nerves. For example, current practise describes two target points for SMGN. The conventionally practised target point is, the junction of the medial epicondyle and shaft of the femur.(14,54,59,60) There is another target point, that has become popular in recent years, which is one centimetre anterior to the adductor tubercle.(52,53,55,57,61,62,69) Both of these targets were found to be effective in relieving pain. Similar to this, there are minor differences between the targets described for the commonly ablated or blocked genicular nerves.

Hence, the study also aims to determine the distance of these nerves from the identifiable nearby landmarks, so as to increase the accuracy of genicular nerve block, by simultaneously using multiple landmarks for localisation, in further studies.

REVIEW OF LITERATURE

<u>REVIEW OF LITERATURE</u>

Sensory innervation of knee joint capsule- The genicular nerves anatomy

Gardner, in 1948, described the genicular nerves, as arising from femoral, obturator, tibial, common peroneal and recurrent peroneal nerves. He stated that the nerve supply of the knee joint is also in accordance to Hiltons law (1891). The femoral nerve supplies the anterior knee capsule's superior part, patellar periosteum, the infrapatellar fat pad and even the tibial condyle, via branches of saphenous nerve, nerve to vastus intermedius (NVI), nerve to vastus lateralis (NVL), and nerve to vastus medialis (NVM). The tibial nerve supplies the posterior, medial and lateral parts of the joint capsule, the infrapatellar fat pad, the tibial periosteum, and the superior tibio-fibular joint. The common peroneal nerve supplies the anterolateral part of the capsule, and the vessels supplying the lateral tibial and the lateral femoral condyle. The recurrent peroneal nerve supplies the tibial periosteum, tibial tuberosity, infrapatellar fat pad and superior tibio-fibular joint. The obturator nerve supplies the popliteal vessels, the upper part of the posteromedial capsule, the anteromedial part of the capsule, the infrapatellar fat pad and the vessels to the medial femoral condyle.(45)

After **choi et.al**, in 2011, described the possibility of radiofrequency ablation of genicular nerves to alleviate chronic pain in knee,(14) there was a surge in the anatomic and radiologic studies to define the genicular nerves and their target points.

Franco et al., in 2015, dissected 8 cadaveric knees for, assessing Innervation of the anterior capsule of the human knee, with implications for radiofrequency ablation. They described SMGN, as originating from nerve to vastus medialis, and found to be at the junction of medial epicondyle and the shaft of the femur. and is located at the junction between the medial epicondyle and the shaft of the femur. The IMGN has been described as a branch of the saphenous nerve arising from the sub patellar branch and located at the junction between the medial condyle of the tibia and its shaft. The SLGN arises from the vastus lateralis nerve and is located near the junction between the lateral epicondyle and the shaft of the femur. The middle geniculate nerve has been termed the medial retinacular branch, which arises from the vastus intermedius nerve and descends between the vastus intermedius and the distal femur towards the suprapatellar pouch. The recurrent branch of the fibular nerve has been described as innervating the inferolateral part of the anterior capsule. The lateral retinacular nerve, which branches from the common peroneal nerve, supplies the lateral joint capsule.(73)

Valls et al., in 2017, explored the sensory innervation of the knee anatomically and ultrasonographically to identify anatomic targets for the treatment of chronic knee pain. Separately, they discussed the medial and lateral innervations. The infrapatellar branch of the saphenous nerve, the sensory distal branch of the femoral nerve to the vastus medialis or medial retinacular nerve, the anterior branch of the obturator nerve (cutaneous portion), and sensory branches of the tibial nerve all supply sensory innervation to the medial aspect of the knee. The vastus lateralis, vastus intermedius, and branches from the peroneal nerve (lateral retinacular and recurrent peroneal nerves), are the sources of the sensory innervation for the lateral part of the knee. The sensory innervation of the posterior aspect of the knee capsule is derived from articular branches of the tibial nerve, with variable contributions from branches derived from the obturator nerve's posterior branch. They also described how to identify these branches under ultrasound guidance. The NVM was identified in the proximal third of thigh, in the plane between sartorius and vastus medialis. It was followed distally, and at the distal adductor canal, the nerve branches to give several muscular branches and an articular branch, which descend down to supply the medial retinaculum. The saphenous nerve was identified at the hunter's canal between adductor longus and vastus medialis muscles. As it descends down, and when it becomes underneath the sartorius, it gives IPBSN. The cutaneous portion of anterior obturator nerve innervates the medial aspect of the knee. The nerve was seen in between fascia between adductor longus and vastus medialis muscle.

The NVL branches from common peroneal nerve, and is identified as a hyperechoic structure, in the plane between biceps femoris and vastus lateralis muscle. It descends down till the superolateral quadrant of patella. The lateral retinacular branch arises from the common peroneal nerve, in the popliteal fossa, and it goes beneath the biceps femoris to enter the anterior aspect of knee. The recurrent peroneal nerve originates from common peroneal nerve adjacent to head of fibula. They found that this was recognised in eight of 25 specimens. In the popliteal fossa, the tibial nerve gives two-four branches, to supply the posterior articular capsule. (74)

Tran et al., in 2018, in their anatomical study of the innervation of anterior knee joint capsule: implication for image-guided intervention, described the SMGN as the distal branch of the femoral nerve, which lies near the NVM and descends together with the genicular vessels and the adductor magnus tendon, to supply the posteromedial knee joint. The NVM, was described as giving two to three branches to anterior knee joint capsule, and it overlapped with the NVI and SMGN. The IMGN was arising from the tibial nerve, together with the IMG vessels, deep to the medial collateral ligament (MCL), beneath the medial tibial condyle. The SLGN was running together with the superolateral genicular vessels, just above the lateral femoral condyle. The ILGN was described, as a continuation of the long articular branch of the common fibular nerve, running deep to the LCL (lateral collateral ligament) to join the ILGN vessels and coming anteriorly just below the lateral femoral condyle. This innervates the upper part of the inferolateral quadrant.(47)

Fonkoue et al., in 2019 conducted a study on distribution of sensory nerves supplying the knee joint capsule and implications for genicular blockade and radiofrequency ablation on 21 cadaveric lower limbs. They described 13 sensory nerves around knee. These are branches arising from femoral, sciatic, tibial, common peroneal and obturator nerve.

The described genicular nerves are the following.(44)

Anterior innervating branches

1. Superomedial genicular nerve branching from nerve to vastus medialis.
2. Infrapatellar branch of saphenous nerve from saphenous nerve
3. Middle genicular nerve from nerve to vastus intermedius
4. Articular branch from nerve to vastus lateralis
5. Anterior obturator nerve articular branches
6. Superolateral genicular nerve arising from sciatic nerve or the common peroneal nerve (CPN)
7. Lateral recurrent genicular nerve
8. Inferolateral genicular nerve from common peroneal nerve
9. Inferomedial genicular nerve from posterior articular nerve or directly from the tibial part of sciatic nerve

Posterior innervating branches

1. Articular branches from posterior obturator nerve
2. Posterior articular nerve from sciatic nerve
3. Articular branches from tibial nerve
4. Articular branches from common peroneal nerve.

They described that only 5 genicular nerves were constantly present. These were SMGN, SLGN, IMGN, ILGN and the IPBSN. (Figure-2) They also defined the fluoroscopic landmarks for these 5 nerves.

Even though there were variations in the origin of some of these nerves, the final course of termination was same in all the 21 knees. The SMGN target point was in front of adductor tubercle. The SLGN target point was on the posterior-superior angle of the lateral condyle of femur. The IMGN target point was at the junction of shaft and medial condyle of tibia. The ILGN target point was located at the intersection of longitudinal line through Gerdy's tubercle and the transverse line through top of tibial tuberosity. The target line of infrapatellar branch of saphenous nerve (was a longitudinal line 4 cm medial to apex patellae, and connecting the transverse lines through superior pole of patella and superior tibial tuberosity. They concluded that the pattern of sensory innervation of knee joint capsule allows accurate and safe targeting of these five constant genicular nerves for intervention.(44)

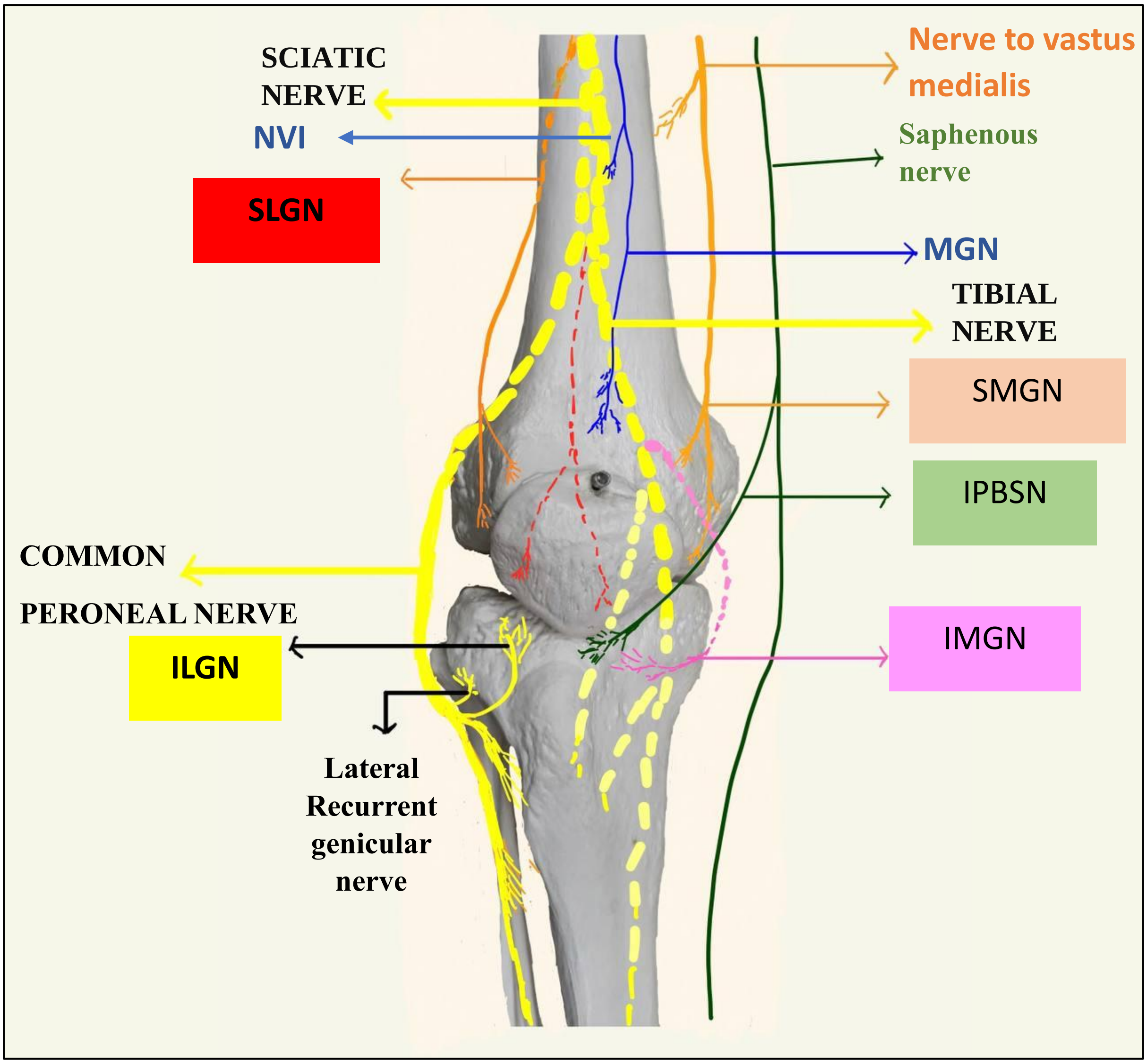


Figure 2- Consistent genicular nerves described by Fonkoue et al*: Schematic representation of the genicular nerves, drawn according to the description by Fonkoue et al in 2019.* (44)*The highlighted ones are referred to as the most consistent ones, and that are clinically targeted. SMGN- superior medial genicular nerve, IMGN- inferior medial genicular nerve, SLGN- superior lateral genicular nerve, ILGN- inferolateral genicular nerve, IPBSN- infra patellar branch of saphenous nerve. NVI- Nerve to vastus intermedius, MGN- Middle genicular nerve.*

Roberts et al., in 2019, published a review of knee joint innervation: implications for diagnostic blocks and radiofrequency ablation. Over the anteromedial part: superomedial quadrant, mainly three nerves were giving sensory supply. The nerve to vastus medialis, intermedius and the superior medial genicular nerve. The variations in the origin of SMGN reported was, originating from tibial nerve, from posterior branch of obturator nerve, and nerve to vastus medialis. The anterior inferomedial part is supplied by infrapatellar branch of saphenous nerve, and inferior medial genicular nerve from tibial nerve. The superolateral quadrant of the knee joint innervation was reported by four nerves: the nerve to vastus lateralis, the nerve to vastus intermedius, the articular branch of the common peroneal nerve (CPN). and the superior lateral genicular. The variation in SLGN origin were noted. Either the nerve arose from, the sciatic nerve just superior to its bifurcation or the common fibular nerve and coursed inferiorly, or from the articular branch of the CPN and coursed superiorly to join the superior lateral genicular artery just superior to the lateral femoral condyle. The inferolateral quadrant of the knee joint has been reported to receive innervation from two nerves, the inferior lateral genicular nerve, and the recurrent fibular nerve (RFN). The ILGN has been found to have two variations, either it arose from the CPN and coursed deep to the biceps femoris tendon to accompany the inferior lateral genicular artery or, it arose from the articular branch of the CPN and traversing deep to the LCL to accompany the inferior lateral genicular artery just inferior to the lateral femoral condyle. The RFN has been reported to divide into one to three branches. RFN innervated the inferolateral quadrant, or coursed anteriorly around the neck of the fibula and then superiorly to innervate the anterolateral part of the knee joint.(49)

Kim et al., in 2022, did a cadaveric study for describing Genicular Nerve Anatomy and Its Implication for New Procedural Approaches for Knee Joint Denervation. The anterosuperior part of the capsule was innervated by SMGN [the terminal branch of the NVM], the NVI, the SLGN from Sciatic nerve, and the NVL. The anteroinferior part is innervated by the IMGN from sciatic nerve, the ILGN from CPN, and the RFN from the deep peroneal nerve (DPN). The SMGN made bony contact anterior to adductor tubercle (AT), and after that it divided to two articular branches before piercing the capsule. The IMGN was arising from the articular branch of sciatic nerve, in the popliteal fossa, and went deep to popliteal vessels and medial gastrocnemius, to emerge on the anteromedial side, along with inferomedial genicular vessels, beneath the MCL. Then it passed superiorly towards the patellar tendon, and pierced the joint capsule. The SLGN arises from the sciatic nerve, before bifurcation, in most of the specimens, and in few from the CPN. Invariable of its origin, it made bony contact at the posterior superior part of the lateral epicondyle, and divided in to 2 branches. ILGN originated from the CPN, in the popliteal fossa, and then passed deep to biceps femoris and iliotibial band (ITB), and innervated the anteroinferior capsule. The RFN was the first branch of the deep peroneal nerve. It supplied the proximal tibiofibular joint, anterior tibial muscles, and ascended up to supply inferolateral knee capsule. They also described articular branch of NVI.(46)

Current landmarks and USG techniques for genicular nerve block

Yasar et al.in 2015, conducted a study to determine accuracy of USG guided genicular nerve block on 10 cadaveric knee specimens. Four out of which was dissected to determine anatomic landmarks for SMGN, and IMGN. It was found that SMGN descends approximately 1 cm anterior to the adductor tubercle, which was identified as the landmark for it. Bony cortex 1 cm anterior to the peak of adductor tubercle was targeted for the injection of SMGN. The IMGN goes around the lower part of medial tibial epicondyle, deep to medial collateral ligament in a horizontal plane midway between the peak of tibial medial epicondyle and the insertion of medial collateral ligament. Therefore, the point of the bony cortex which is at the midpoint between the peak of tibial medial epicondyle and the insertion of the initial fibers of medial collateral ligament on tibial tuberosity, was targeted for injection of IMGN. USG was used to identify these landmarks in six cadaveric knees, and 0.5ml of red ink was injected. Then dissection was done and nerves stained with red ink were considered as accurate. And it was found that ultrasound-guided medial genicular nerve branch block can be performed accurately using the above-stated anatomic landmarks. Small number of cadaveric specimens were a limitation of the study. They targeted only two genicular nerves, that too on the medial side only. (53)

Wong et al., in 2016, in a case report of ultrasound guided genicular nerve, thermal radiofrequency ablation for chronic knee pain, reported the use of ultrasound for RFA of genicular nerves. SMGN was targeted 1 cm anterior to adductor tubercle. They also looked for presence of corresponding artery. SLGN was identified by tracing down along the biceps femoris tendon, from the lateral femoral epicondyle, towards its insertion, and the target was decided at the bony cortex near the SLGNs corresponding artery.
IMGN was targeted at the midpoint of peak of tibial medial epicondyle and initial fibres of medial collateral ligament inserting on tibia, after confirming the corresponding artery.(52)

Kesikburun et al., in 2016, conducted a single-arm prospective study to evaluate the effect of ultrasound-guided genicular nerve pulsed RF treatment on chronic knee pain and function in patients with knee osteoarthritis. A review was made of 29 patients with medial knee OA who had undergone genicular nerve block in the previous 6 months. Patients with at least 50% reduction in the VAS score after genicular nerve block and with no on-going pain relief were selected for the study. Ultrasound-guided genicular nerve pulsed RF of SMGN and IMGN was applied to 15 knees of 9 patients. The landmarks used were that described by Yasar et al in their cadaveric study. Pain and knee function were assessed with 100-mm VAS and Western Ontario and McMaster Universities (WOMAC) index throughout 3 months. A significant reduction in VAS scores was detected, and a significant improvement in the WOMAC scores.(55)

Sari et al., in 2017, described very different landmarks for ultrasound. They targeted only SMGN, IMGN and SLGN. The SMGN was targeted with a landmark set at the lower end of femur 1-1.5 cm from upper lateral edge of patella. The SLGN landmark was set at lower end of femur approximately 1-1.5 cm from medial upper edge of patella. The IMGN landmark was on upper end of tibia 1-1.5 cm from lower medial end of patella.(51)

Sari et al., (16) in 2018, in their study “Which one is more effective for the clinical treatment of chronic pain in knee osteoarthritis: radiofrequency neurotomy of the genicular nerves or intra-articular injection”. They used the same landmarks, as mentioned above in their previous study.(51)

Kim et al., in 2018, in their study, did USG guided genicular nerve block of SMGN, IMGN, SLGN targeting near the corresponding arteries, at the corresponding shaft epicondyle junction.(68)

Ahmed and Arora in 2018, did a case series of ultrasound guided radiofrequency ablation of genicular nerves of knee for relief of intractable pain from knee osteoarthritis, in which he did RFA of 7 genicular nerves- the SMGN, IMGN, SLGN, ILGN, lateral retinacular nerve, middle genicular nerve and posterior genicular nerve. The target for SMGN was 1 cm anterior to adductor tubercle, IMGN and SLGN was junction between respective condyle and shaft. The middle genicular nerve was targeted between the fascia of quadriceps and the suprapatellar bursae. The ILGN was targeted at the anterolateral tibial condyle, close to anastomotic branch of anterior tibial artery. Lateral retinacular nerve is targeted at the lateral condyle of tibia, beneath the lateral collateral ligament, near the inferior lateral genicular artery. Posterior genicular plexus is targeted deep to popliteal artery in the popliteal fossa.(61)

Ahmed and Arora in 2019 did a case series on USG guided alcohol neurolysis of six genicular nerves for chronic intractable pain of OA knee. He used the landmarks of SMGN as adductor tubercle, of IMGN as medial collateral ligament, of SLGN as myotendinous junction of vastus lateralis, of ILGN as lateral tibial condyle near the attachment of lateral coronary ligament, and of middle genicular nerve as between the fascia of quadriceps femoris and the suprapatellar bursae. It was concluded as having significant pain reduction.(62)

Fonkoue, et al., in 2019, in a cadaveric study, concluded that the landmarks mentioned in their previous study, (44) for SMGN, IMGN, IPBSN, ILGN, were 100% accurate. The landmark for SLGN was 90% accurate. The SMGN target point was in front of adductor tubercle. The SLGN target point was on the posterior-superior angle of the lateral condyle of femur. The IMGN target point was at the junction of shaft and medial condyle of tibia. The ILGN target point was located at the intersection of longitudinal line through Gerdy's tubercle (GT) and the transverse line through tibial tuberosity. In this study the nerve with recurrent course, that they previously called as ILGN, was called as recurrent fibular nerve. The target point was same. The target line of infrapatellar branch of saphenous nerve (was a longitudinal line 4 cm medial to apex patellae, and connecting the transverse lines through superior pole of patella and superior tibial tuberosity. (75) Even though this was fluoroscopy guided targeting, this was included, due to the anatomical relevance of the study.

Vanneste et al., in 2019, conducted a study to determine the feasibility of an ultrasound-guided approach to radiofrequency ablation of the SMGN, SLGN and IMGN in five cadavers. The target points for these nerves were at the junction of the shaft and the respective epicondyles for SMGN and SLGN, and junction of tibial shaft and tibial medial condyle for IMGN. After locating the targets with ultrasonography, Indocyanine green (ICG) dye 0.1 mL was infiltrated. An anatomical dissection was performed and the distance from the centre of the ICG mark to the genicular nerve concerned was measured and mean distance calculated. The result of this study was that ultrasound-guided treatment of the genicular nerves is feasible. The limitations of the study were lesser number of cadaveric specimens, and they evaluated only three genicular nerves.(54)

Fonkoue et al in 2020, in a cadaveric study found that, with revised targets for the SMGN, and SLGN, the mean distance from the top of the active tip to the nerve was much lower than current targets (0.7mm vs 17.8mm, p=0.01) and (3.7mm vs 24.4mm, p=0.02), respectively.

The accuracy rate was greater with revised than current targets in SMGN and SLGN: 100% vs 0% and 64% vs 35%, respectively. Additionally, the revised targets for the IPBSN and the RFN were 100% accurate. Hence they concluded that the revised targets are more accurate for genicular nerve block.(76)

Lash et al., in 2020, in their technique paper describing USG guided genicular nerve cooled radiofrequency ablation, used the conventional targets for SMGN, IMGN and SLGN. That is - junction of medial femoral condyle and shaft for SMGN, junction of medial condyle and shaft for IMGN, and junction of lateral condyle of femur and shaft for SLGN. They described either to target at 50 percent depth of bone, in axial plane, or to visualize artery pulsation, or nerve and inject. The suprapatellar genicular nerve also known as the middle genicular nerve, was targeted 5 cm proximal to the superior pole of patella, and needle was inserted deep to quadriceps, up to full depth of prefemoral fat, just superficial to periosteum. 82 % of patients had 50-100% improvement in pain.(60)

Fonkoue et al., in 2020, described that, the descending genicular artery (DGA) supplies three distal branches that run along with the nerves over the medial knee. These were the artery of the SMGN, the artery of the IPBSN and the Saphenous branch of the DGA. This anatomical description suggests that these arteries may act as complementary landmarks for precise localization of the relevant nerves during ultrasound-guided procedures for regional anaesthesia and pain management.(77)

Fonkoue et al., (64) in 2021, did a double-Blinded, randomized controlled trial, comparing the Genicular Nerve Blockade with corticosteroids using either classical anatomical targets vs revised targets for pain and function in knee osteoarthritis. They used fluoroscopy for identification of target points. The revised targets mentioned in previous study, (75) was found to be more effective, compared to classical landmarks, in pain relief one hour post procedure. The landmark for ILGN was described as one centimetre inferior to tip of Gerdy's tubercle. Rest of the revised targets were same as described in the previous study.

Fonkoue et al., in 2021, in their cadaveric study, described the USG guided method for SMGN, IMGN, SLGN, IPBSN, and recurrent genicular nerve. For SMGN, the adductor tubercle was identified in coronal plane and needle was advanced in in-plane approach in axial, from front to back, till posterior cortex, on or above the AT, about 1 mm from the periosteum.

For SLGN, the junction of lateral femoral condyle and shaft was identified in the coronal plane, and in axial view, in in plane approach, the crest separating lateral and posterior cortex was targeted. For IMGN, the junction of medial tibial condyle and shaft in coronal plane and half the girth of tibia in axial plane, was targeted. For recurrent fibular nerve, the Gerdy's tubercle was identified, in coronal plane, and the transducer was translated inferiorly 2 cm, to identify the anterior tibial recurrent artery, and then needle was inserted in coronal view from anterior to posterior up to half of the tibial depth. For IPBSN a treatment line was drawn, 4 cm medial to the apex of patella, and connecting two transverse lines through the apex of patella, and top of tibial tuberosity. The nerve can be visualised as ovoid structure in the subcutaneous plane, just superficial to medial collateral ligament. If not visualised, then to target on the line from proximal to distal, along the subcutaneous plane, superficial to MCL. On subsequent dissection, they found out that all these nerves were accurately blocked.(69)

Yilmaz et al., in 2021, in a randomised study comparing the efficacy of single intraarticular steroid injection and the combination of genicular nerve block and intraarticular steroid injection in patients with knee osteoarthritis, located the corresponding arteries, using colour doppler, for SMGN, IMGN, and SLGN block. (56)

Mittal et al., in 2021, described both fluoroscopic and sonographic approaches for the SMGN, IMGN, and SLGN. For SMGN, they described the junction of medial femoral diaphysis and epiphysis in coronal plane, and to target the same depth in axial view. For SLGN, the junction of lateral epicondyle and shaft of femur in coronal view, and junction of lateral and posterior cortex in axial view, was considered. For IMGN, the inferior medial genicular vessels were identified, deep to the MCL, and the depth was kept same to inject in the axial view.(59)

Elsaman et al., in 2021 in a randomised control trial, comparing the efficacy of genicular nerve block with intraarticular steroid injection, in RA patients, targeted near the genicular arteries, identified by doppler at the junction of shaft and epicondyle, of medial femur, lateral femur and medial upper part of tibia, for SMGN, SLGN, and IMGN respectively.(30)

Guler et al., in 2022, in a prospective randomised study, comparing ultrasound guided genicular nerve block, with physical therapy for chronic knee OA, used the USG landmarks as near to the corresponding arteries, as mentioned above.(28)

Chang et al., in 2022, assessed functional outcomes and physical performance of OA knee patients, after genicular nerve RFA. He targeted SMGN, SLGN, IMGN, at shaft epicondyle junctions, near the corresponding arteries, as mentioned above.(71)

Ghai et al., (2022), described the SMGN as curving around the shaft of femur, between adductor magnus and femoral epicondyle, then descending 1 cm anterior to adductor tubercle. The nerve was targeted by locating the corresponding arterial pulsation. The IMGN was described as being located horizontally, between the tibial medial epicondyle and the MCL attachment. The nerve was targeted here. SLGN was described as located in the superolateral popliteal fossa, medial to biceps femoris tendon, around 2.6 cm proximal to the tip of lateral femoral epicondyle, and was targeted there.(70)

Kose et al., in 2022, in their study, for assessing the predictive factors associated with successful genicular nerve RFA, did the RFA of five genicular nerves. The SMGN, IMGN, SLGN, RFN, and IPBSN. The SMGN, IMGN, and SLGN were targeted at the corresponding shaft and epicondyle junction, with colour doppler confirmation of the corresponding arteries. The RFN was targeted below the Gerdy's tubercle, deep to anterior tibial muscles, near the anterior tibial recurrent artery. The IPBSN was targeted on a line 4 cm medial to the apex of patella, and tibial tuberosity, after identifying the nerve as an ovoid structure in the subcutaneous plane, with axial orientation of the probe.(72)

Comparison of surface landmark guided method to ultrasound guided method

Cankurtaran et al., in 2020, conducted a prospective randomized controlled study, comparing the effectiveness of ultrasound guided versus blind genicular nerve block on pain, muscle strength with isokinetic device, physical function and quality of life in chronic knee OA. They included patients with knee OA based on ACR diagnostic criteria. The patients were evaluated at the baseline, 4 weeks, and 12 weeks after treatment. The SLGN, SMGN, and IMGN were targeted. The landmarks for blind method were made by drawing a line longitudinally from the fibular head to 4 cm above the tip of lateral epicondyle of femur, the transverse line connecting the two epicondyles of femur, and a third line from femur medial epicondyle to tibial epicondyle. The intersections of these lines were considered as landmarks. Nerve blocks were conducted in both groups. When compared with the baseline, both groups showed significant improvement in pain, physical function, and quality of life parameters. Significant differences were observed between the clinical parameters (30-second chair stand test, 6-minute walk test) in favour of the ultrasound-guided group.(57)

Gupta et al., in 2020 conducted a randomized open label comparative study on efficacy of ultrasonography guided and anatomical landmark guided genicular nerve block for pain of knee OA in a tertiary care hospital in eastern India. In group 1 ultrasound guided nerve block was given. In group 2 patients the bony landmarks of medial and lateral femoral condyles and medial tibial condyle were identified and injection administered just proximal to the femoral and distal to the tibial condyles. It was concluded that Genicular nerve block (both Ultrasound guided and anatomical landmark guided) is statistically effective method for pain and stiffness reduction in OA of knee with less severe adverse effects. USG guided procedure is safer and yield better result than the anatomical landmark guided blind method in the long term follow up of OA patients.(58)

Summary of the articles, enlisting the target points, and methods, under ultrasound guidance, for the genicular nerve block, are given in Table 1.

Summary of the articles, enlisting the surface anatomy landmark for genicular nerve block, are given in Table 2.

The landmarks that are chosen to be used in this study, are given in Table 3**.**

Table 1 Summary of USG Landmarks and techniques:

SL NO	AUTHOR/STUDY	YEAR	SMGN	IMGN	SLGN	ILGN	MID GN
1	**Yasar et al.,**(53) Accuracy of Ultrasound-Guided Genicular Nerve Block: A Cadaveric Study	2015	Bony cortex 1 cm anterior to the peak of adductor tubercle was targeted	Point of the bony cortex at the midpoint between the peak of tibial medial epicondyle and the insertion of the initial fibres of MCL on tibial tuberosity.	*	*	*
2	**Wong et al.,** (52) Ultrasound-Guided Genicular Nerve Thermal Radiofrequency Ablation for Chronic Knee Pain	2016	1 cm anterior to adductor tubercle. They also looked for presence of corresponding artery	Midpoint of peak of tibial medial epicondyle and initial fibres of medial collateral ligament inserting on tibia, after confirming the corresponding artery	Identified by tracing down along the biceps femoris tendon, from the lateral femoral epicondyle, towards its insertion- target at the bony cortex near the SLGNs corresponding artery	*	*

3	**Kesikburun et al.,**(55) Ultrasound-Guided Genicular Nerve Pulsed Radiofrequency Treatment for Painful Knee Osteoarthritis: A Preliminary Report	2016	Bony cortex 1 cm anterior to the peak of adductor tubercle	The point of the bony cortex at the midpoint between the peak of tibial medial epicondyle and the insertion of the initial fibres of MCL on tibial tuberosity.	*	*	*
4	**Sari et al.,**(51) Which imaging modality should be used for genicular nerves radiofrequency thermocoagulation in chronic knee OA	2017	The lower end of femur 1-1.5 cm from upper lateral edge of patella	Upper end of tibia 1-1.5 cm from lower medial end of patella.	Lower end of femur approximately 1-1.5 cm from medial upper edge of patella	*	*
5	**Sari et al.,**(16) Which one is more effective for the clinical treatment of chronic pain in knee osteoarthritis: radiofrequency neurotomy of the genicular nerves or intra-articular injection?	2018	The lower end of femur 1-1.5 cm from upper lateral edge of patella	Upper end of tibia 1-1.5 cm from lower medial end of patella.	Lower end of femur approximately 1-1.5 cm from medial upper edge of patella	*	*
6	**Kim et al.,**(68) Ultrasound-Guided Genicular Nerve Block for Knee Osteoarthritis: A Double-Blind, Randomized Controlled	2018	Near corresponding artery	Near corresponding artery	Near corresponding artery	*	*

	Trial of Local Anaesthetic Alone or in Combination with Corticosteroid						
7	**Ahmed and Arora.,**(61) Ultrasound-guided radiofrequency ablation of genicular nerves of knee for relief of intractable pain from knee osteoarthritis: a case series	2018	1 cm anterior to adductor tubercle	Junction of medial condyle and shaft of tibia.	Junction of lateral condyle and shaft of femur	At the anterolateral tibial condyle, close to anastomotic branch of anterior tibial artery	Between the fascia of quadriceps and the suprapatellar bursae, at the roof of suprapatellar fossa.
8	**Ahmed and Arora.,**(62) Ultrasound-Guided Neurolysis of Six Genicular Nerves for Intractable Pain from Knee Osteoarthritis: A Case Series	2019	Adductor tubercle	Medial collateral ligament	Myotendinous junction of vastus lateralis	Lateral tibial condyle near the attachment of lateral coronary ligament	Between the fascia of quadriceps femoris and the suprapatellar bursae, at the superior part of suprapatellar fossa.
9	**Vanneste et al.,**(54) Feasibility of an ultrasound-guided approach to radiofrequency ablation of the superolateral, superomedial and inferomedial genicular nerves: a cadaveric study	2019	Junction of shaft and medial condyle of femur	Junction of shaft and medial condyle of tibia	Junction of shaft and lateral condyle of femur	*	*
10	**Lash et al.,**(60) Ultrasound-guided cooled radiofrequency ablation of the genicular nerves: a technique paper	2020	Junction of medial femoral condyle and shaft. Either to target at 50	Junction of medial condyle and shaft. Either to target at 50 percent depth of	Junction of lateral condyle of femur and shaft. Either to target at 50	*	5 cm proximal to the superior pole of patella, and needle was inserted deep to quadriceps, up to

			percent depth of bone, in axial plane, or to visualize artery pulsation.	bone, in axial plane, or to visualize artery pulsation, or nerve and inject	percent depth of bone, in axial plane, or to visualize artery pulsation, or nerve and inject		full depth of prefemoral fat, just superficial to periosteum.
11	**Cankurtaran et al.,**(57) Comparing the effectiveness of ultrasound guided versus blind genicular nerve block on pain, muscle strength with isokinetic device, physical function and quality of life in chronic knee osteoarthritis: a prospective randomized controlled study	2020	Adductor tubercle	Lower parts of the tibial medial epicondyle	Synovial surface of the lateral femoral epicondyle	*	*
12	**Gupta et al.,**(58) A randomized open label comparative study on efficacy of ultrasonography guided vis a vis anatomical landmark guided genicular nerve block in knee osteoarthritis in a tertiary care hospital in Eastern India	2020	Near the corresponding artery	Near the corresponding artery	Near the corresponding artery	*	*
13	**Fonkoue et al.,**(69)	2021	The adductor tubercle was	The junction of medial tibial	The junction of lateral femoral	**Recurrent fibular nerve**,	*

	Validation of a new protocol for ultrasound-guided genicular nerve radiofrequency ablation with accurate anatomical targets: cadaveric study		identified in coronal plane and needle was advanced in in-plane approach in axial, from front to back, till posterior cortex, on or above the AT, about 1 mm from the periosteum	condyle and shaft in coronal plane and half the girth of tibia in axial plane, was targeted	condyle and shaft was identified in the coronal plane, and in axial view, in in plane approach, the crest separating lateral and posterior cortex was targeted	the Gerdy's tubercle was identified, in coronal plane, and the transducer was translated inferiorly 2 cm, to identify the anterior tibial recurrent artery, and then needle was inserted in axial view from anterior to posterior up to half of the tibial depth	
14	**Yilmaz et al.,**(56) The comparison of efficacy of single intraarticular steroid injection versus the combination of genicular nerve block and intraarticular steroid injection in patients with knee osteoarthritis: a randomised study	2021	Near corresponding artery	Near corresponding artery	Near corresponding artery	*	*
15	**Mittal et al.,**(59) Knee ablation approaches	2021	Junction of medial femoral diaphysis and	The inferior medial genicular	The junction of lateral epicondyle and	*	*

			epiphysis in coronal plane, and to target the same depth in axial view	vessels were identified, deep to the MCL, and the depth was kept same to inject in the axial view.	shaft of femur in coronal view, and junction of lateral and posterior cortex in axial view, was considered		
16	**Elsaman et al.,**(30) Genicular nerve block in rheumatoid arthritis: a randomized clinical trial	2021	Junction of medial femoral diaphysis and epiphysis, near the corresponding artery	Junction of medial tibial epicondyle and shaft, near the corresponding artery	The junction of lateral epicondyle and shaft of femur, near the corresponding artery.	*	*
17	**Guler et al.,** (28) Ultrasound-guided genicular nerve block versus physical therapy for chronic knee osteoarthritis: a prospective randomised study	2022	Junction of medial femoral diaphysis and epiphysis, near the corresponding artery	Junction of medial tibial epicondyle and shaft, near the corresponding artery	The junction of lateral epicondyle and shaft of femur, near the corresponding artery.	*	*
18	**Chang et al.,**(71) Functional Outcomes and Physical Performance of Knee Osteoarthritis Patients After Ultrasound-Guided Genicular Nerve Radiofrequency Ablation	2022	Junction of medial femoral diaphysis and epiphysis, near the corresponding artery	Junction of medial tibial epicondyle and shaft, near the corresponding artery	The junction of lateral epicondyle and shaft of femur, near the corresponding artery.	*	*

19	**Ghai et al.,**(70) Comparison of ultrasound guided pulsed radiofrequency of genicular nerve with local anaesthetic and steroid block for management of osteoarthritis knee pain	2022	Curving around the shaft of femur, between adductor magnus tendon and femoral epicondyle- descending 1 cm anterior to adductor tubercle, where, after locating the corresponding arterial pulsation, nerve was targeted.	Described as being located horizontally, between the tibial medial epicondyle and the MCL attachment. The nerve was targeted here.	Described as located in the superolateral popliteal fossa, medial to biceps femoris tendon, around 2.6 cm proximal to the tip of lateral femoral epicondyle, and was targeted here	*	*
20	**Kose et al.,** *(72) Predictive factors associated with successful response to ultrasound guided genicular radiofrequency ablation	2022	Junction of medial femoral diaphysis and epiphysis, near the corresponding artery	Junction of medial tibial epicondyle and shaft, near the corresponding artery	The junction of lateral epicondyle and shaft of femur, near the corresponding artery.	RFN- below the Gerdy's tubercle, deep to anterior tibial muscles, near the anterior tibial recurrent artery	*

***Kose et al.** *described IPBSN- on a line 4 cm medial to the apex of the patella, and tibial tuberosity, after identifying the nerve as an ovoid structure in the subcutaneous plane, with axial orientation of the probe.*

Table 2 Summary of surface anatomy Landmarks and techniques:

SL NO	AUTHOR/STUDY	YEAR	SMGN	IMGN	SLGN	ILGN	MGN
1	**Fonkoue et al.,**(44) Distribution of sensory nerves supplying the knee joint capsule and implications for genicular blockade and radiofrequency ablation: an anatomical study	2019	*	*	*	The intersection of vertical line through Gerdy's tubercle and horizontal line through tibial tuberosity	*
2	**Cankurtaran et al.,**(57) Comparing the effectiveness of ultrasound guided versus blind genicular nerve block on pain, muscle strength with isokinetic device, physical function and quality of life in chronic knee osteoarthritis: a prospective randomized controlled study	2020	The junction two lines, the horizontal line between two femoral epicondyles and vertical line between tibial condyle and medial femoral condyle	Junction of two lines, a vertical line connecting tibial condyle and medial femoral condyle and a horizontal line connecting fibular head and medial condyle of tibia	Junction of the lines connecting fibular head to lateral epicondyle and the horizontal line ruled between two epicondyles of femur		
3	**Gupta et al.,**(58) A randomized open label comparative study on efficacy of ultrasonography guided vis a vis anatomical	2020	Just proximal to the medial epicondyle of femur.	Just distal to medial condyle of tibia	Just above the lateral epicondyle of femur		

	landmark guided genicular nerve block in knee osteoarthritis in a tertiary care hospital in Eastern India						
4	**Lash et al.,**(60) Ultrasound-guided cooled radiofrequency ablation of the genicular nerves: a technique paper	2020	*	*	*	*	5 cm proximal to superior pole of patella, in the midline, and to insert perpendicular to hit the femur

Table 3: Ultrasound and Surface anatomy landmarks that were chosen for this study.

MODALITY	SMGN	IMGN	SLGN	ILGN	MIDDLE GN
USG	Bony cortex 1 cm anterior to the peak of adductor tubercle	Midpoint between the peak of tibial medial epicondyle and the insertion of the initial fibres of MCL	The junction of lateral femoral condyle and shaft was identified in the coronal plane, and in axial view, in in-plane approach, the crest separating lateral and posterior cortex	Lateral tibial condyle near the attachment of lateral coronary ligament.	Between the fascia of quadriceps and the suprapatellar bursae, at the roof of supra patellar fossa.
SURFACE LANDMARK	Just proximal to the medial epicondyle of femur	Just distal to medial condyle of tibia	Just above the lateral epicondyle of femur	The intersection of vertical line through Gerdy's tubercle and horizontal line through tibial tuberosity	5 cm proximal to superior pole of patella, in the midline, and to insert perpendicular to hit the femur

RECURRENT FIBULAR NERVE LANDMARKS (RECENT UPDATES)

USG*- 2 cm inferior to Gerdy's tubercle, near the anterior tibial recurrent artery, to insert needle in anterior to posterior, in axial view, up to half the depth of the tibia.*(69)

SURFACE LANDMARK- *The intersection of vertical line through Gerdy's tubercle and horizontal line through tibial tuberosity*(76)

Course of the genicular nerves included in this study- their target points in ultrasound guided and landmark guided methods.

It is highly essential to exactly define the target points of the constant genicular nerves, as the expected lesion diameter of the largest 16G RFA needle is only about 1.6 to 2.4 mm.(43) For ablation of nerve and to get adequate pain relief, the needle should be within this distance from the nerve. There are a wide range of controversies prevailing the course and the target points. Since 2011, after Choi et al described the RFA of genicular nerve technique, there have been lot of studies describing the course and the targets of genicular nerves.

SUPEROMEDIAL GENICULAR NERVE

In the old literature, SMGN was described as a branch from the tibial nerve, branching from the upper part of the popliteal fossa and curling around the femur and making bony contact at the shaft and the condyle junction, (14,16,53–55) where it can be targeted according to Choi et. al.(14) Yasar et al., in their cadaveric study published in 2015, described the SMGN as a branch from tibial nerve dividing in the upper part of the popliteal fossa and then curling around the condyle to emerge anteriorly and beneath the adductor magnus tendon and making a bony contact approximately 1 cm anterior to the adductor tubercle, where it can be targeted. They 100% accurately targeted the SMGN, in all specimens.(53) There are literatures describing the SMGN as a branch of tibial nerve.(14,53–55) But with further cadaveric studies it has been revealed that the SMGN is a branch from the nerve to vastus medialis, that descend along with the adductor magnus tendon and making bony contact at around 1 cm anterior to the adductor tubercle, where it could be targeted. (44,73,75) In the recent literatures, the distance from adductor tubercle was not mentioned, and was stated to target just anterior to adductor tubercle. After making bony contact here, the nerve branches in to two branches a transverse and a descending branch. (46) Under fluoroscopic guidance the nerve was targeted at the junction of medial condyle of femur and shaft in AP view and up to midpoint of femur in lateral view, in some studies (2,12) and in relation to adductor tubercle in some studies.(64,75)

Ultrasound guided, landmarks for targeting SMGN

1. Junction of shaft and medial condyle of femur, (54) with confirmation with genicular artery pulsation.(16,58)

2. The lower end of femur 1-1.5 cm from upper lateral edge of patella.(16,51)

3. A point 1 cm anterior to the adductor tubercle.(53,55,62) Yasar et.al in their study "Accuracy of ultrasound- guided genicular nerve block: A cadaveric study" described this landmark as 100 % accurate,(53) and hence **in this study this is used as the ultrasound landmark for SMGN.**

4. The adductor tubercle to be identified in coronal plane and to advance needle in in-plane approach in axial, from front to back, till posterior cortex, on or above the AT, about 1 mm from the periosteum.(69) In this study this method of locating adductor tubercle has been used.

5. Bony cortex near the corresponding artery, at shaft and medial epicondyle junction.(28,30,52,56,68,71)

6. The junction of shaft and medial epicondyle of femur in coronal plane and to target the half of the depth of femur in axial view.(59,60)

The surface anatomy guided landmark for targeting SMGN

1. The junction of the following two lines, a horizontal line drawn connecting the most prominent part of medial and lateral epicondyles, and a vertical line connecting the most prominent part of medial tibial condyle and medial femoral condyle.(57)

2. Just proximal to the medial epicondyle of femur.(58) **In this study this has been used.**

SUPEROLATERAL GENICULAR NERVE

Previously, SLGN was described as a branch from vastus lateralis.(61,62,73) With further anatomical studies, it was found that in 90 % of the studied specimens SLGN originated from sciatic nerve and in the rest from common peroneal nerve.(44,46) Even though there is variation in origin, the distal course is constant. (73)The fluoroscopy landmark was the junction of the lateral condyle of femur and the shaft, and to traverse half girth of femur in lateral image. (2,12)

Ultrasound guided, landmarks for targeting SLGN

1. The junction of shaft and lateral epicondyle of femur in coronal plane and to target the half of the depth of femur in axial view.(54,59,69)

2. The junction of lateral femoral condyle and shaft was identified in the coronal plane, and in axial view, in in-plane approach, the crest separating lateral and posterior cortex was targeted.(69) **In this study this is used as the ultrasound landmark for SLGN.**

3. The lower end of femur approximately 1-1.5 cm from medial upper edge of patella.(16,51)

4. The nerve was identified by tracing down along the biceps femoris tendon, from the lateral femoral epicondyle, towards its insertion, and the target was decided at the bony cortex near the SLGNs corresponding artery.(52,56)

5. At the junction of shaft and epicondyle, visualising the SLG artery.(28,30,61,62,68,71)

6. In the superolateral popliteal fossa, medial to biceps femoris tendon, around 2.6 cm proximal to the tip of lateral femoral epicondyle.(70)

The surface anatomy guided landmark for targeting SLGN

1. Junction of the lines connecting fibular head to lateral epicondyle and the horizontal line ruled between two epicondyles of femur.(57)

2. Just above the lateral epicondyle of femur.(58) **In this study this has been used.**

INFEROMEDIAL GENICULAR NERVE

In majority of the literature, IMGN was described as arises from the tibial nerve in the popliteal fossa and curve around the tibia to emerge deep to medial collateral ligament, at midpoint between the tibial condyle peak and the initial insertion of medial collateral ligament.(14,44,53–55,73,78) The fluoroscopic landmark is the junction of medial condyle and shaft of tibia, and half the girth of tibia in lateral view.(14,75)

Ultrasound guided, landmarks for targeting IMGN

1. The junction of medial tibial condyle and shaft in coronal plane and half the girth of tibia in axial plane.(54,60,69)
2. Half the distance between peak of medial tibial condyle and the insertion of deep fibres of medial collateral ligament.(53,55) Yasar et.al in their study “Accuracy of ultrasound-guided genicular nerve block: A cadaveric study” described this landmark as 100 % accurate,(53) and hence **in this study this is used as the ultrasound landmark for IMGN.**

3. Upper end of tibia 1-1.5 cm from lower medial end of patella.(16,51)
4. Bony cortex, at the junction of medial tibial condyle and shaft near the corresponding artery. (28,30,52,56,59,68,71)

The surface anatomy guided landmark for targeting IMGN

1. Junction of two lines, a vertical line connecting tibial condyle and medial femoral condyle and an horizontal line connecting fibular head and medial condyle of tibia.(57)
2. Just distal to medial condyle of tibia.(58) **In this study this landmark has been used.**

INFEROLATERAL GENICULAR NERVE

ILGN was earlier not targeted due to the risk of common peroneal injury. In the study titled "Distribution of sensory nerves supplying the knee joint capsule and implications for genicular blockade and radiofrequency ablation: an anatomical study", by Fonkoue et al in 2019, they described ILGN as the second branch from common peroneal nerve at the neck of fibula. The first branch, at the neck of fibula was lateral recurrent genicular nerve, supplying the proximal tibiofibular joint. The ILGN travels deep to the anterior tibial muscles, giving many collateral branches to these muscles and ascending with the lateral recurrent genicular vessels, to supply the inferolateral aspect of the anterior knee capsule (figure-1). The ILGN can be targeted between the Gerdy's tubercle and the tibial tuberosity.(44,69,75)

The same authors in their further study, titled "Accuracy of fluoroscopic-guided genicular nerve blockade: a need for revisiting anatomical landmarks" described the landmark for recurrent genicular nerve, as one centimetre below from the inferior edge of Gerdy's tubercle, on a longitudinal line drawn from the Gerdy's tubercle. (75)

Tran et al in their study "Anatomical Study of the Innervation of Anterior Knee Joint Capsule Implication for Image-Guided Intervention" described the ILGN as the continuation of long articular branch of CPN, supplying the superior part of the inferolateral quadrant. The recurrent fibular nerve originated from the CPN, at the neck of fibula, and ascended deep to anterior tibial muscles, between tibial tuberosity and Gerdy's tubercle.(47)

In the 2021 study conducted by Fonkoue et al, they have given the ultrasound guided method for recurrent fibular nerve. The Gerdy's tubercle was identified, in coronal plane, and the transducer is translated inferiorly 2 cm, to identify the anterior tibial recurrent artery, and then insert needle in coronal view from anterior to posterior half of the tibial depth.(69) Kose et al., also blocked the nerve in a similar manner, in 2022.(72)

Kim et al., in 2022, described that, ILGN originated from the CPN, in the popliteal fossa, and then passed deep to biceps femoris and ITB, and innervated the anteroinferior capsule. The RFN was the first branch of the deep peroneal nerve. It supplied the proximal tibiofibular joint, anterior tibial muscles, and ascended up to supply inferolateral knee capsule.

Hence, we have come in to a conclusion that the ILGN that was described by Fonkoue et al in their first study in 2019, was renamed as the recurrent fibular nerve in subsequent studies. And there is another nerve in the inferolateral region called as ILGN, that was branching from the long articular branch of common fibular nerve, and supplying the superior part of inferolateral anterior knee capsule. But there were no subsequent updates regarding the targets for ILGN.

In our study, as the ultrasound and surface landmarks available in the literature at the time of proposition of our study, had termed the nerve as ILGN, we have followed that, even though on subsequent dissection and update of literature, it has been found as targeting recurrent fibular nerve (RFN).

Ultrasound guided, landmarks for targeting ILGN

1. At the insertion of lateral coronary ligament on tibia, along with lateral inferior genicular artery. (62) **In this study this landmark has been used.**

2. Over the anterolateral aspect of tibia, beneath the lateral collateral ligament, near the inferior lateral genicular artery. (61)

The surface anatomy guided landmark for targeting ILGN

1. The intersection of vertical line through the Gerdy's tubercle and horizontal line through tibial tuberosity.(44) **In this study we have used this landmark.**

MIDDLE GENICULAR NERVE

Fonkoue, et al., described it as the terminal branch of the vastus intermedius, travelling deep to the vastus intermedius and supplying the suprapatellar pouch.(44) Lash et al targeted it, under USG guidance 5 cm proximal to the superior pole of patella, by inserting the needle deep to quadriceps, up to full depth of prefemoral fat, just superficial to periosteum.(60) Ahmed et al., targeted the nerve between the fascia of quadriceps femoris and the suprapatellar bursae, at the superior most end of suprapatellar bursa.(62) Kim et al., described an articular branch from the NVI, descends along the periosteum of the femoral shaft, to supply the superior articular capsule. (46) There are only limited anatomic description of this nerve in the literature, and exact characterisation and course of nerve need to be defined further.

Ultrasound guided, landmark for targeting MGN

The roof of suprapatellar fossa, just beneath quadriceps tendon, 5cm above the superior pole of patella. (60–62)

The surface anatomy guided landmark for targeting MGN

5 cm proximal to superior pole of patella, in the midline, and to insert perpendicular to hit the femur.(60)

RATIONALE OF THE STUDY

RATIONALE OF THE STUDY

The genicular nerve block with corticosteroids and radiofrequency ablation has become popular in the last decade. It has become a painless alternative to TKA in terms of pain reduction and disability. The effect of the procedure depends upon the exact localisation of the nerve. The localisation can be done with either surface anatomy landmarks, fluoroscopy, or ultrasound guidance. There are already defined landmarks for the constant genicular nerves under all three methods. The majority of the studies were under fluoroscopic guidance, but the advantage of ultrasound being a real time procedure, with no risk of radiation exposure has made it more acceptable among the pain physicians. From the review of literature, it is evident that there are multiple ultrasound guided landmarks and techniques to target SMGN, IMGN, SLGN, ILGN and MGN. Considering the small size of lesion of RFA, (43) the effect of bone charring, side effects of steroid, and inadvertent muscular blocking, the precise localisation of the genicular nerves are important. There is a huge loophole in the review of literature regarding the validation of USG protocols, with evidence-based approach. We have also noticed that surface anatomy landmarks are still being used in some studies, and are found to be as effective as USG guidance for controlling pain. Although, this could be considered on account of nonavailability of the imaging modalities in resource poor settings, still the accuracy and the effectiveness of this method should be evaluated, considering the safety of the procedure. Hence in this study we are going to validate the accuracy of the commonly used ultrasound landmarks, comparing them with the surface landmark guided method, for genicular nerve block.

There are also discrepancies in the origin and course of genicular nerves, hence an exact definition of a course of the constant genicular nerves are also done by measuring the distance from the nerves bony contact [target points] to the nearby landmarks, so as to precisely localise these nerves. The nearby landmarks of each nerve are chosen in a way that, either it's a well-defined bony landmark for fluoroscopic guidance or a well-defined sonographic landmark. This is done, with the view that, when there is more than one landmark for targeting the same nerve, the accuracy of blockade will be higher.

AIM AND OBJECTIVES

AIM OF THE STUDY

To determine and compare the accuracy of genicular nerve block by ultrasound guided versus landmark guided techniques.

OBJECTIVES

Primary Objective:

To determine the comparative accuracy of ultrasound and landmark guided genicular nerve block in cadaver by physical measurement after dissection from the needle insertion site to the nerve.

Secondary Objectives:

I. To determine the average distance of SMGN, from the medial femoral condyle distal end, medial tibial condyle proximal end, junction of shaft and condyle, superomedial pole of patella, mid-point of superior surface of patella, adductor tubercle and superior medial genicular artery.

II. To determine the average distance of IMGN, from insertion of medial collateral ligament, junction of shaft and medial epicondyle of tibia, medial tibial condyle proximal end, medial femoral condyle distal end, tibial tuberosity, inferior pole of patella, and inferior medial genicular artery.

III. To determine the average distance of SLGN, from the lateral femoral condyle distal end, lateral tibial condyle proximal end, junction of shaft and lateral epicondyle of femur, superolateral pole of patella, and superior lateral genicular artery.

IV. To determine the average distance of ILGN, from lateral tibial condyle proximal end, lateral femoral condyle distal end, junction of shaft and lateral epicondyle of tibia, the fibular head- neck junction, tibial tuberosity proximal point, Gerdy's tubercle medial point, inferior pole of patella, common peroneal nerve division and inferior lateral genicular nerve.

V. To determine the average distance of middle genicular nerve, from the midpoint of patella, midpoint of superior border of patella, superolateral pole of patella, superomedial pole of patella, medial femoral condyle distal end, lateral femoral condyle distal end and middle genicular artery.

MATERIALS AND METHODS

MATERIALS & METHODS

STUDY SETTING- Dissection Hall, Department of Anatomy, AIIMS, Jodhpur

STUDY DESIGN - Analytical Cross-Sectional Study

STUDY DURATION- March 2021 to August 2022

STUDY SUBJECTS- Human Cadaveric knee specimens

Inclusion criteria-

Human cadaveric knees that have no visible major deformities in knee.

Exclusion criteria

1) Cadaveric knees with major visible deformities.

2) Cadaveric knees which were dissected during dissection of lower limb.

SAMPLING

Cadavers available in the Department of Anatomy- 30 cadaveric knee specimens.

STUDY PROCEDURE

After taking permission from Department of Anatomy, a group of 10 cadaveric knee specimens were studied at a time, in a lot. The cadaveric knee specimens were randomly distributed to two equal groups, by envelop method. In the first group ultrasound scanning was performed, using 5-13 MHz frequency linear probe of Venue Go R3 ultrasound machine, and the landmarks were visualized. In second group surface landmarks were identified. In both groups 22-gauge, 38 mm spinal needle was inserted. Then 0.1 ml of eosin 2% W/V, was injected, via an insulin syringe, and dissection was done keeping needle in situ, under visualization through SurgiTel EVK450, loupe microscope. The data according to primary and secondary objectives were measured, using vernier calliper. The data was documented in data collection form. Figure 3 shows the flow diagram of the study.

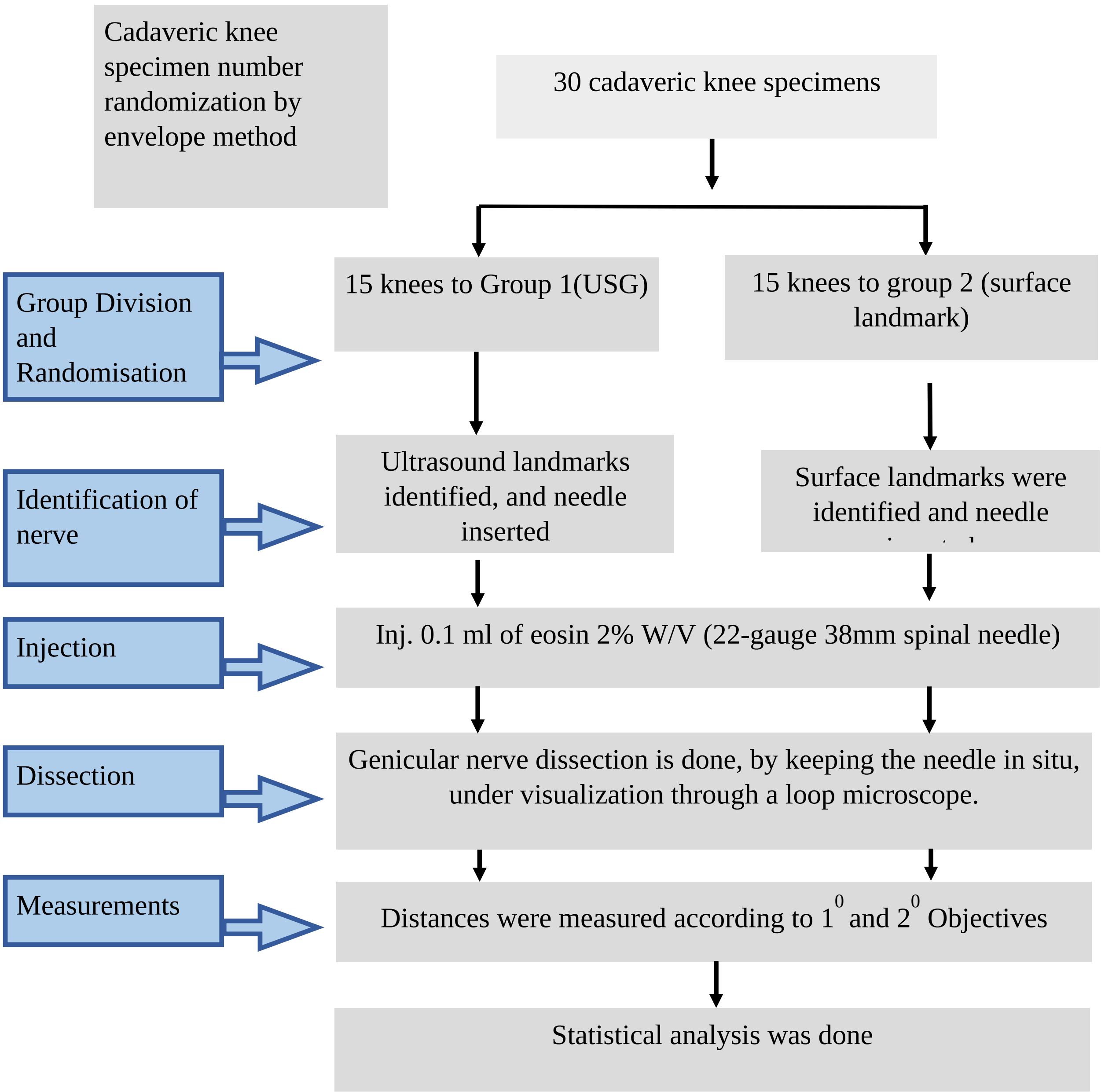


Figure 3: Flow diagram of the study.

ULTRASOUND SCANNING TECHNIQUE AND LANDMARK FOR GENICULAR NERVES

SMGN landmark identification

Figure 4: Schematic representation of SMGN USG landmark.

Figure 4 shows the schematic representation of the target point. The probe was placed in coronal plane, visualising the medial joint line, and it was translated superiorly to identify the adductor tubercle. At this point, the probe orientation was changed to transverse direction, and one cm anterior to the peak of adductor tubercle was measured and identified. Then a 22-gauge spinal needle was inserted in plane from lateral to medial. (Figure 5)

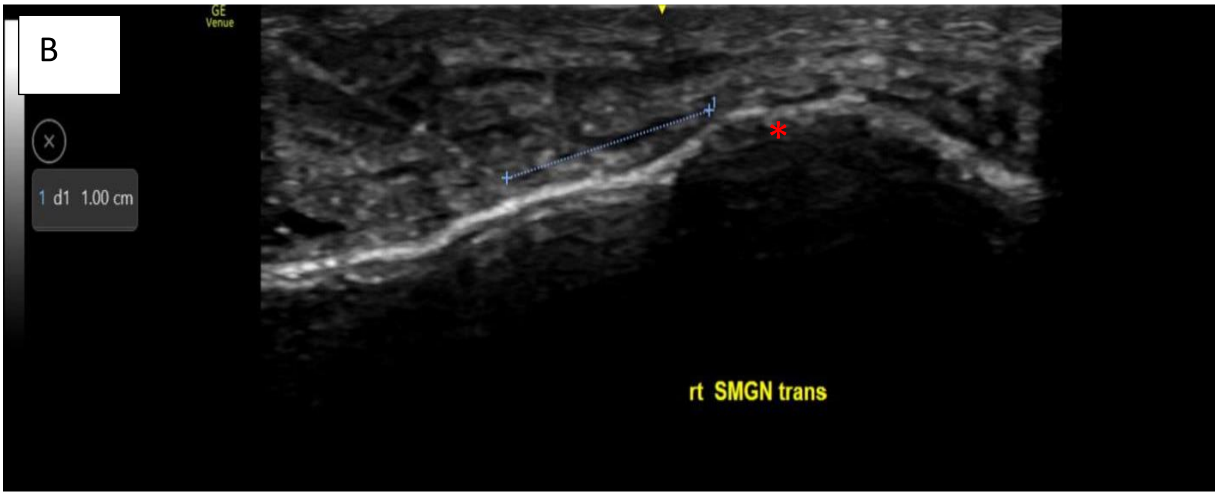


Figure:5 SMGN identification under USG guidance. A: Probe position. B: The transverse view at the level of adductor tubercle. The target point of SMGN as a point 1 cm anterior to the adductor tubercle. The needle is visualised. Asterix shows the adductor tubercle. Rt- right. Trans- Transverse view

SLGN landmark identification

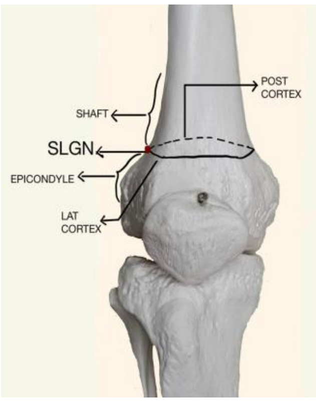


Figure 6 shows the schematic representation of the target point. The probe was placed in coronal plane, visualising the lateral joint line, and was translated superiorly, to identify the junction of shaft and condyle. Then the probe was rotated by 90 degrees, to transverse view, to visualise the crest between the lateral and posterior cortex (lateral most end of lateral cortex), and by in plane approach, needle was inserted from anterior to posterior, to target this point. (Figure 7)

Figure 6: Schematic representation of SLGN USG landmark. POST-Posterior, LAT- Lateral

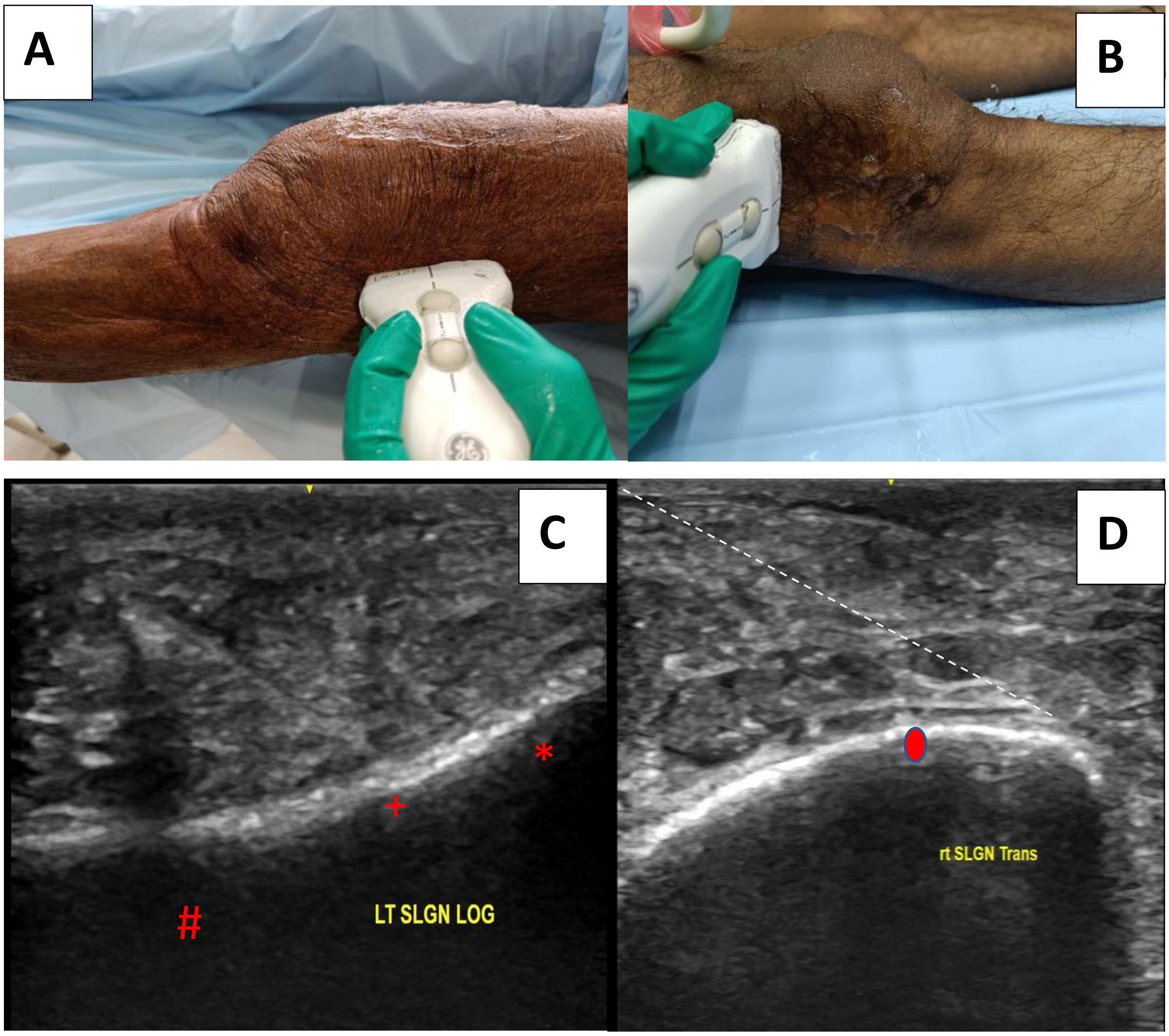


Figure:7 SLGN identification under USG guidance. A-probe position for longitudinal view. B- Probe position for transverse view. C- longitudinal view, lateral condyle of femur [Asterix], shaft of femur [hashtag], junction between two [plus]. D Transverse view, circle shows lateral cortex. At junction of lateral and posterior cortex (lateral most end of lateral cortex), targeted in transverse view. Needle track is visualised. log- longitudinal

IMGN landmark identification

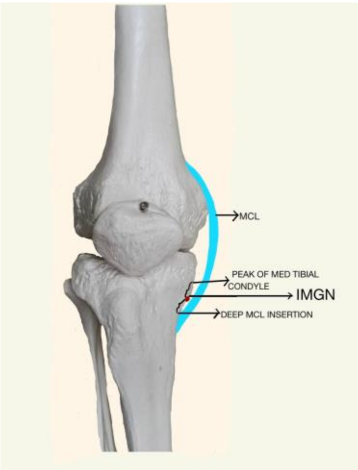


Figure 8: Schematic representation of IMGN USG landmark. MED-Medial, MCL- medial collateral ligament.

Figure 8 shows the schematic representation of the target point. The probe was placed in coronal plane, visualising the medial joint line, and it was translated inferiorly, to visualise the insertion of deep fibres of MCL. The midpoint between the peak of medial tibial condyle and insertion of medial collateral ligament, was identified, and marked on the skin, and the orientation of probe was rotated by 90 degrees, to transverse view, and needle was inserted in plane, to target the medial end of medial cortex. (Figure 10)

ILGN landmark identification

Figure 9 shows the schematic representation of the target point. The probe was placed in transverse plane over the antero-lateral tibia, and the insertion of the coronary ligament was identified, as an extension from the lateral collateral ligament to the lateral tibial condyle. The needle was inserted in in-plane approach, from lateral to medial. The target was just medial to the insertion of coronary ligament. Care was taken to remove the common peroneal nerve and biceps femoris out from the field, before needle insertion. (Figure 11)

Figure 9: Schematic representation of ILGN USG landmark. LCL-Lateral collateral ligament, LAT- Lateral

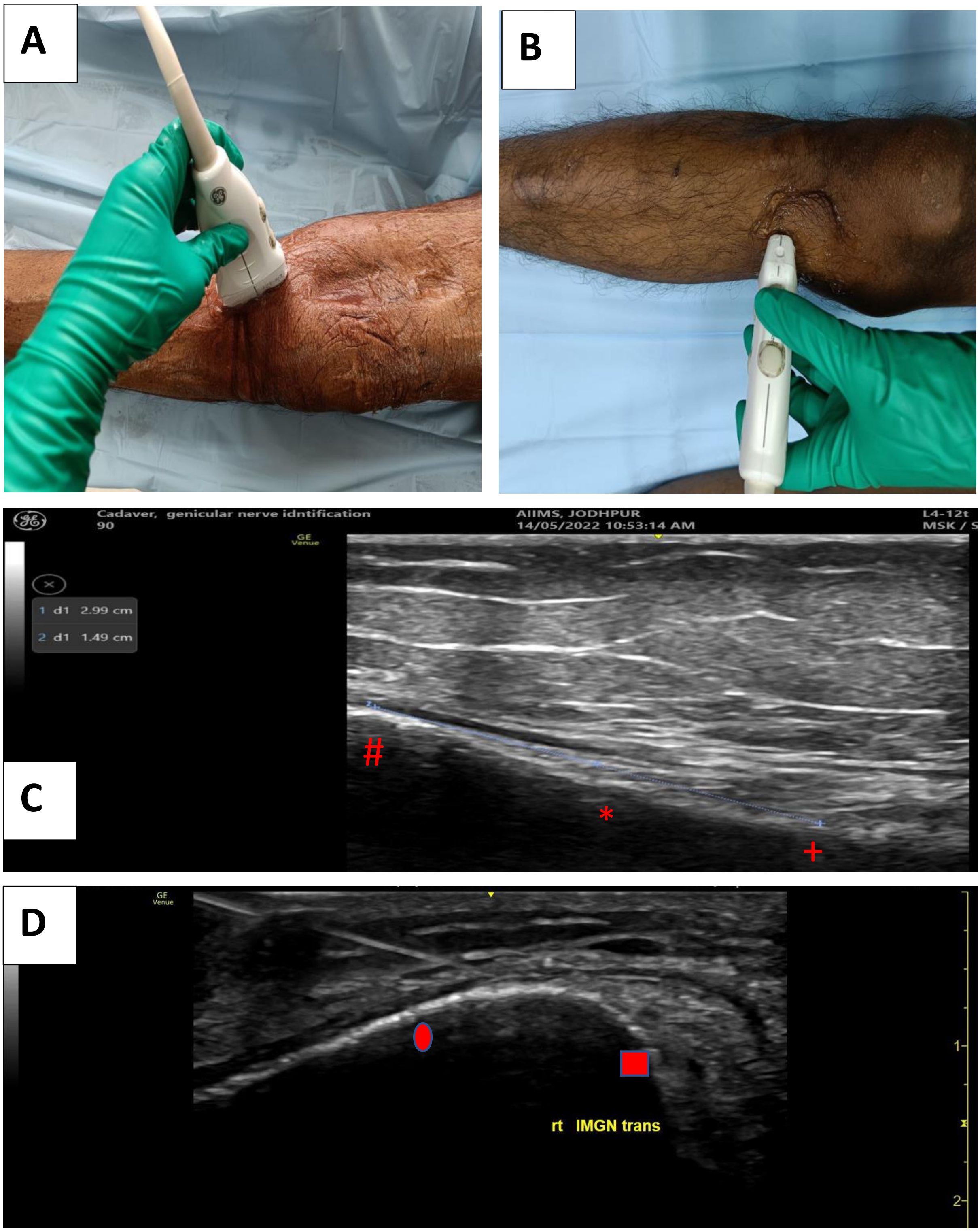


FIGURE:10 IMGN identification under USG guidance. A-Probe position for longitudinal view. B-Probe position for transverse view. C- Tibial medial condyle [Hashtag], deep fibre of MCL insertion [plus], and the midpoint between two [Asterix]. D- Transverse view, [circle] shows medial cortex, [square] shows posterior cortex. Targeted IMGN in transverse view between junction of medial and posterior cortex. Needle track is visualised.

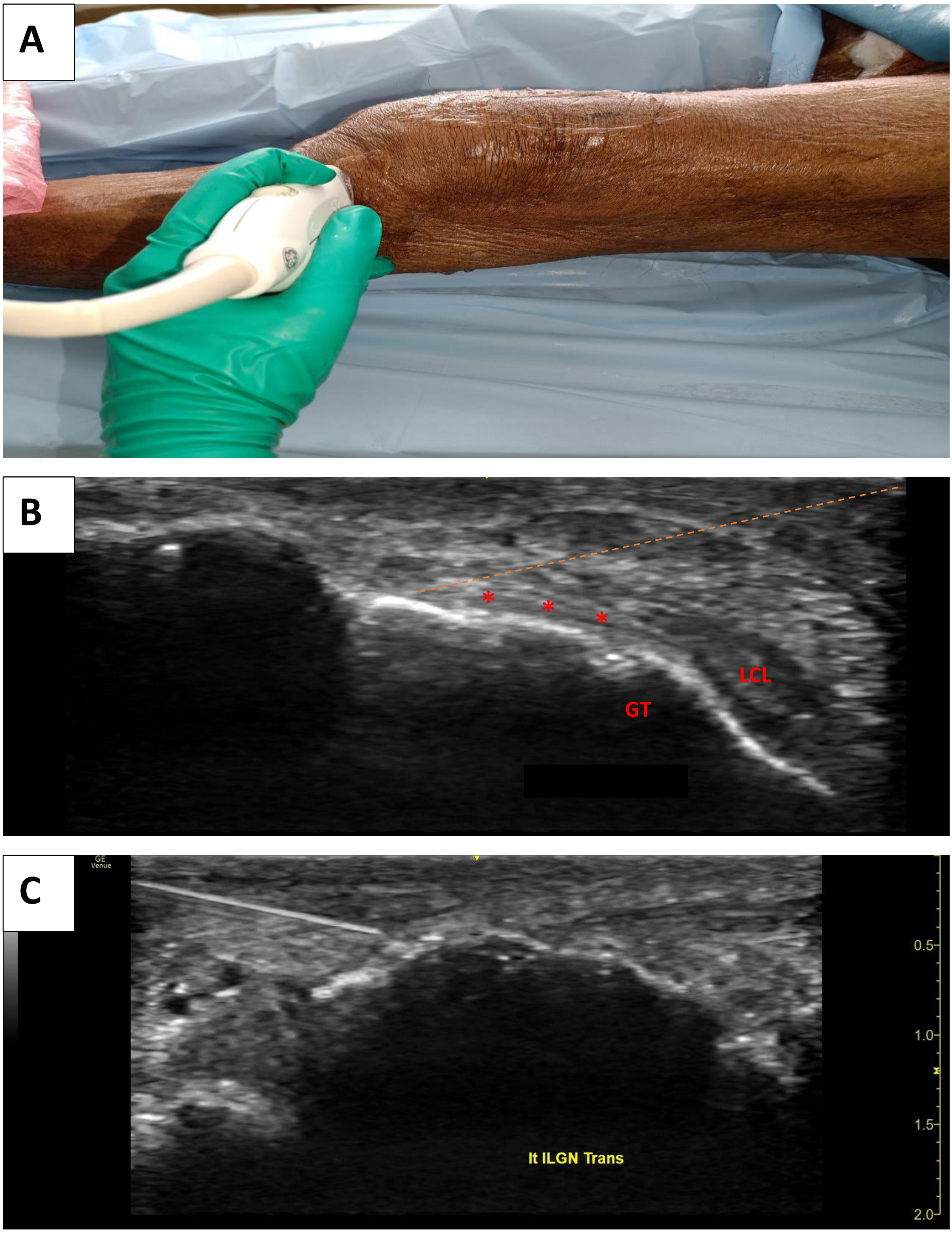


Figure 11: ILGN identification under USG guidance. A- Probe position Transverse view at the anterolateral tibia. B- Asterix shows the coronary ligament, attaching on the lateral tibial condyle, medial to Gerdy's tubercle, GT- Gerdy's tubercle, LCL- lateral collateral ligament. Target defined medial to insertion of coronary ligament. C- Needle track is visualised.

MGN landmark identification

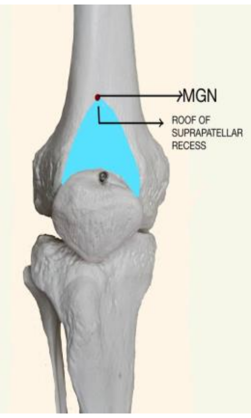


Figure 12 shows the schematic representation of target point. The probe is placed in sagittal orientation over the patella, and translated superiorly. The needle inserted, by in-plane approach, to target, just beneath the quadriceps tendon, over the roof of the suprapatellar bursa, 5 cm from the superior pole of patella. (Figure 13)

Figure 12: Schematic representation of MGN USG landmark.

Figure 13: MGN identification under USG guidance. A- Probe position for middle genicular nerve. B- longitudinal view at suprapatellar region. Asterix showing quadriceps tendon. Minimal fluid in suprapatellar recess (#). Middle genicular nerve is targeted at the roof of suprapatellar fossa [arrow]. Needle track is visualised. Arrow shows the roof of suprapatellar fossa.

SURFACE ANATOMY LANDMARKS FOR GENICULAR NERVE.

SMGN

Just proximal to medial femoral epicondyle. (Figure 14A)

IMGN

Just distal to tibial medial epicondyle. (Figure 14A)

SLGN

Just proximal to lateral femoral epicondyle. (Figure 14B)

ILGN

The intersection point of two lines, one longitudinal line through the Gerdy’s tubercle and one transverse line through the top of tibial tuberosity. (Figure 14B)

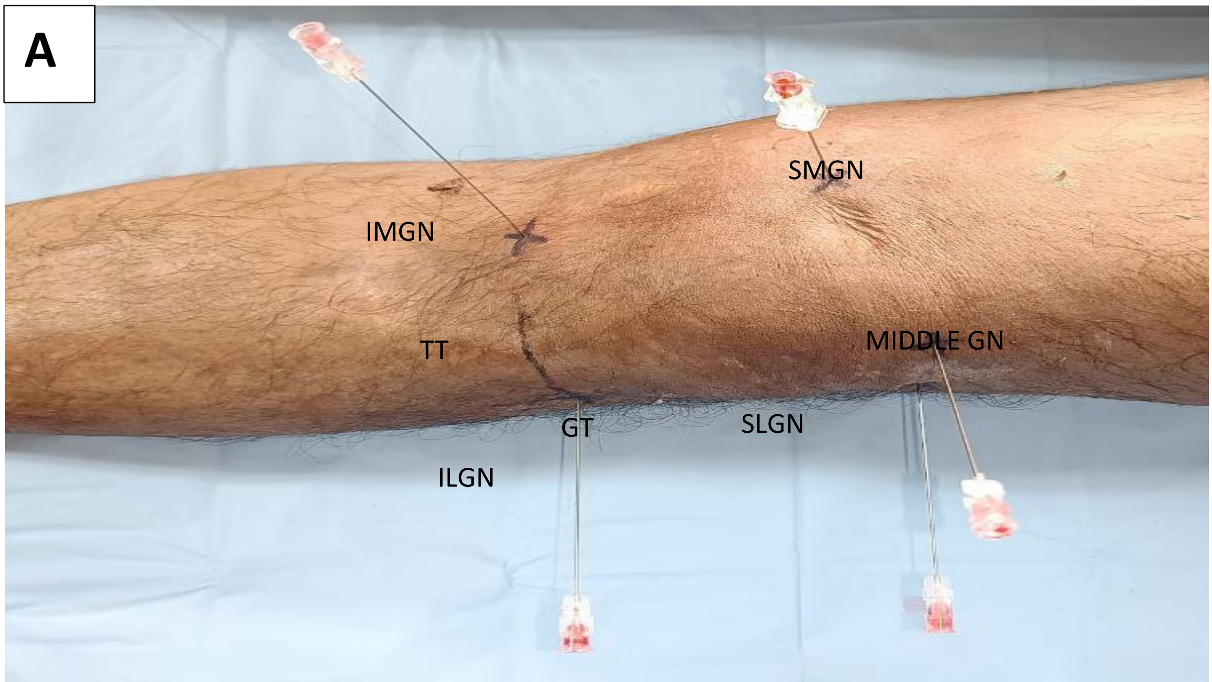
MGN

5 cm above the superior pole of the patella, in the midline. (Figure 14A)

The needle was directed perpendicular to the surface in all these points. One or two needle repositioning attempts were done during the procedure.

In all the needles (both groups) 0.1 ml of eosin 2% W/V, was injected, and dissection was done keeping needle in situ.

Photographs were taken at each point of dissection, using NIKON D5200 model DSLR (Digital Single lens reflex) camera.



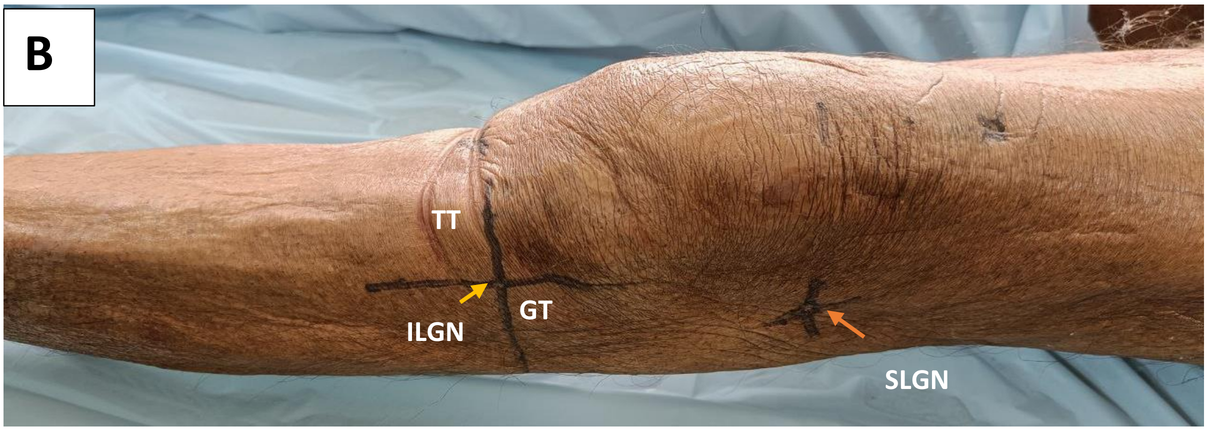


Figure 14: Surface anatomical landmarks of IMGN, SMGN, SLGN, ILGN and MGN. A- Anterior view, B- Lateral view showing landmark of ILGN [Junction of vertical line medial to GT, and horizontal line superior to TT] and SLGN. TT- Tibial tuberosity, GT- Gerdy's tubercle.

DISSECTION METHOD FOR GENICULAR NERVES

Under the guidance of an experienced anatomist careful dissection was done with needle in position, and visualising the nerves through, SurgiTel EVK450, loupes microscope, with 4.5 times magnification power. (Figure 15) The microdissection scissors and forceps were used. (Figure 16) The dissection method for each nerve is described below.

Figure 15: SurgiTel loupes microscope EVK 450

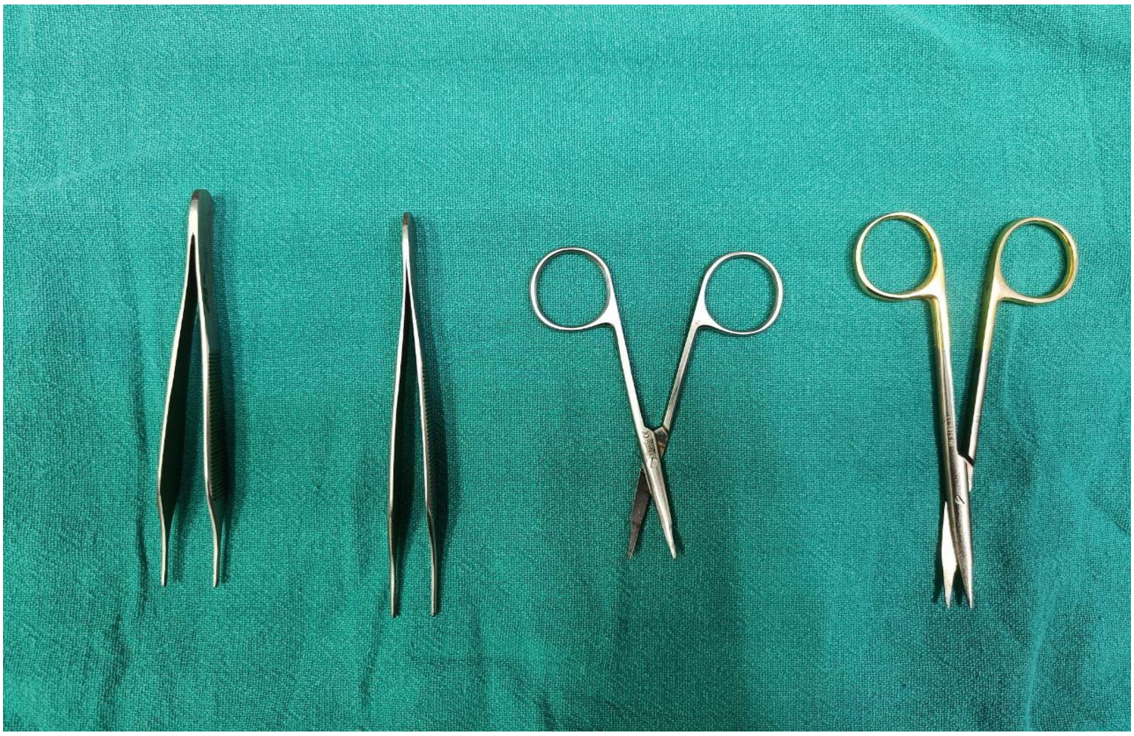


Figure 16: Forceps and scissors used for microdissection.

SMGN

The skin was cut through the needle. The subcutaneous tissue, and fat were removed with microdissection scissors, without altering the needle position. The vastus medialis muscle was cut longitudinally, in the middle of thigh. The fascial tunnel of vastus medialis, identified. The SMGN was identified inside this tunnel. The nerve was traced proximally to identify its branching from the nerve to vastus medialis. Then it was traced distally, carefully dissecting the rest of tissue, under loupes microscope visualisation. It was found to be descending with the adductor magnus tendon and joining superior medial genicular vessels near the adductor tubercle. (Figure 17A) The nerve to needle measurement was taken. (Figure 17B)

SLGN

The cadaver was positioned in side lying position. The skin was cut through the needle. The subcutaneous tissue, fat removed with microdissection scissors. The biceps femoris muscles, iliotibial tract, along with its fascia cut through the needle, and retracted away from needle. In this plane, the fatty tissue was removed carefully under visualisation through loupes microscope, keeping the soft tissue just around the needle, for anchorage. The common peroneal nerve was identified. The branches of the nerve dissected carefully the nerve tissues were identified with magnification and SLGN identified as making bony contact near the epicondyle shaft junction. Then it was dividing in to two branches. (Figure 18A) Then by forcing the needle in to the periosteum, and holding it, the trace of soft tissue released with microdissection scissors. Nerve to needle distance measured. (Figure 18B)

IMGN

The cadaver was positioned in supine. The skin was cut through the needle. The trace subcutaneous fat was removed. The deep fascia was cut through the needle. The MCL was visible. The MCL was cut transversely through the needle, and retracted proximally and distally. The fascia removed using microdissection forceps under loupes microscope visualisation. The needle was advanced to pierce the periosteum to maintain stability. The IMGN and vessels were found to be curling around the tibia, from posterior to anterior. (Figure 19A). Nerve to needle distance was measured. (Figure 19B).

ILGN

The cadaver was positioned in lateral decubitus position. The skin incision for SLGN was extended below and through the needle. The subcutaneous tissue was carefully dissected under loupes microscope using microdissection scissors. The visualisation of any nerve fibre was dealt very cautiously. The common peroneal branches were identified and traced. The anterior tibial muscles were cut and removed, fibre by fibre, to preserve the peroneal nerve division. Then the branch ascending between the Gerdy’s tubercle and tibial tuberosity, along with the vascular bundle was identified. The nerve was separated from the vessels and traced up. (Figure 20A) Nerve to needle distance was measured. (Figure 20B).

MGN

The cadaver was positioned in supine position, and the skin was cut through the needle. The soft tissue was removed. The quadriceps tendon cut transversely 4 cm proximal to patella. Then the proximal end was cut longitudinally and distracted the rectus femoris. The nerve was identified arising beneath the vastus intermedius and supplying the suprapatellar recess. (Figure 21A) Nerve to needle distance was measured. (Figure 21B).

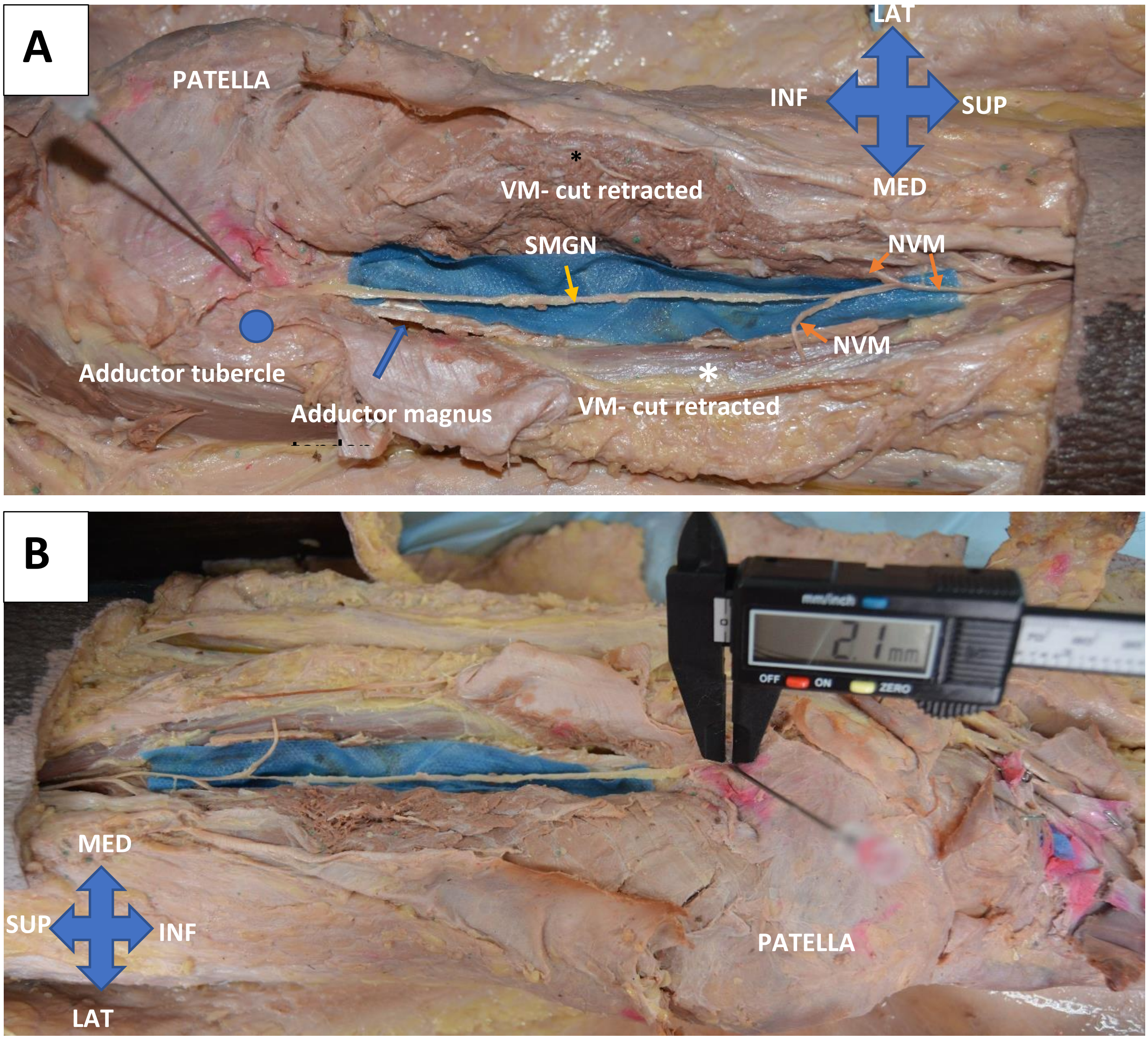


Figure: 17 Dissected SMGN. A: SMGN originating from the NVM. B- The distance from nerve to needle tip measured. VM- vastus medialis (Both are right knee specimens)

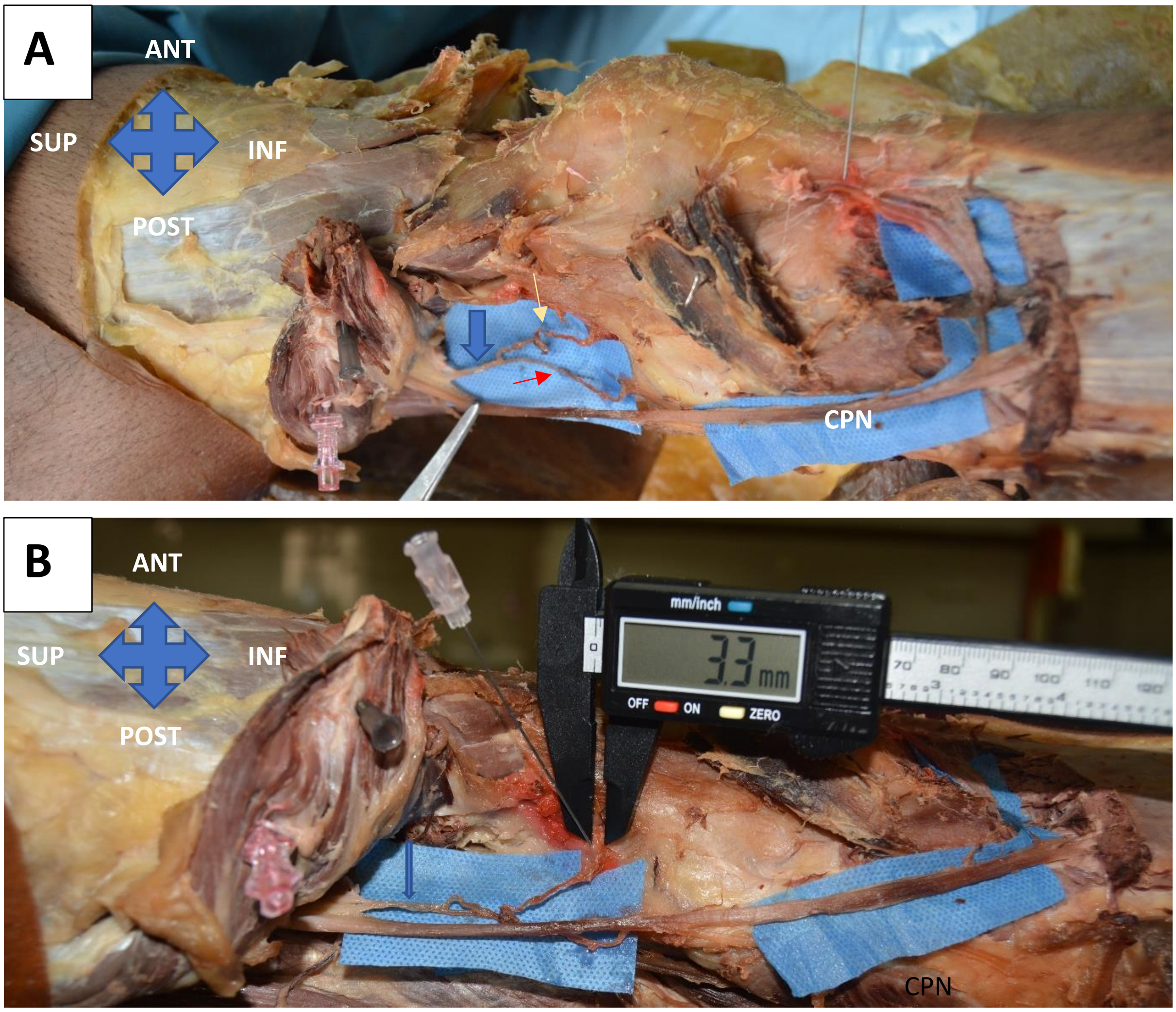


Figure 18: Dissected SLGN. A-SLGN [Thick blue arrow] dividing into transverse [yellow arrow] and descending [red arrow]. B- nerve to needle distance measured. (Both are right knee specimens)

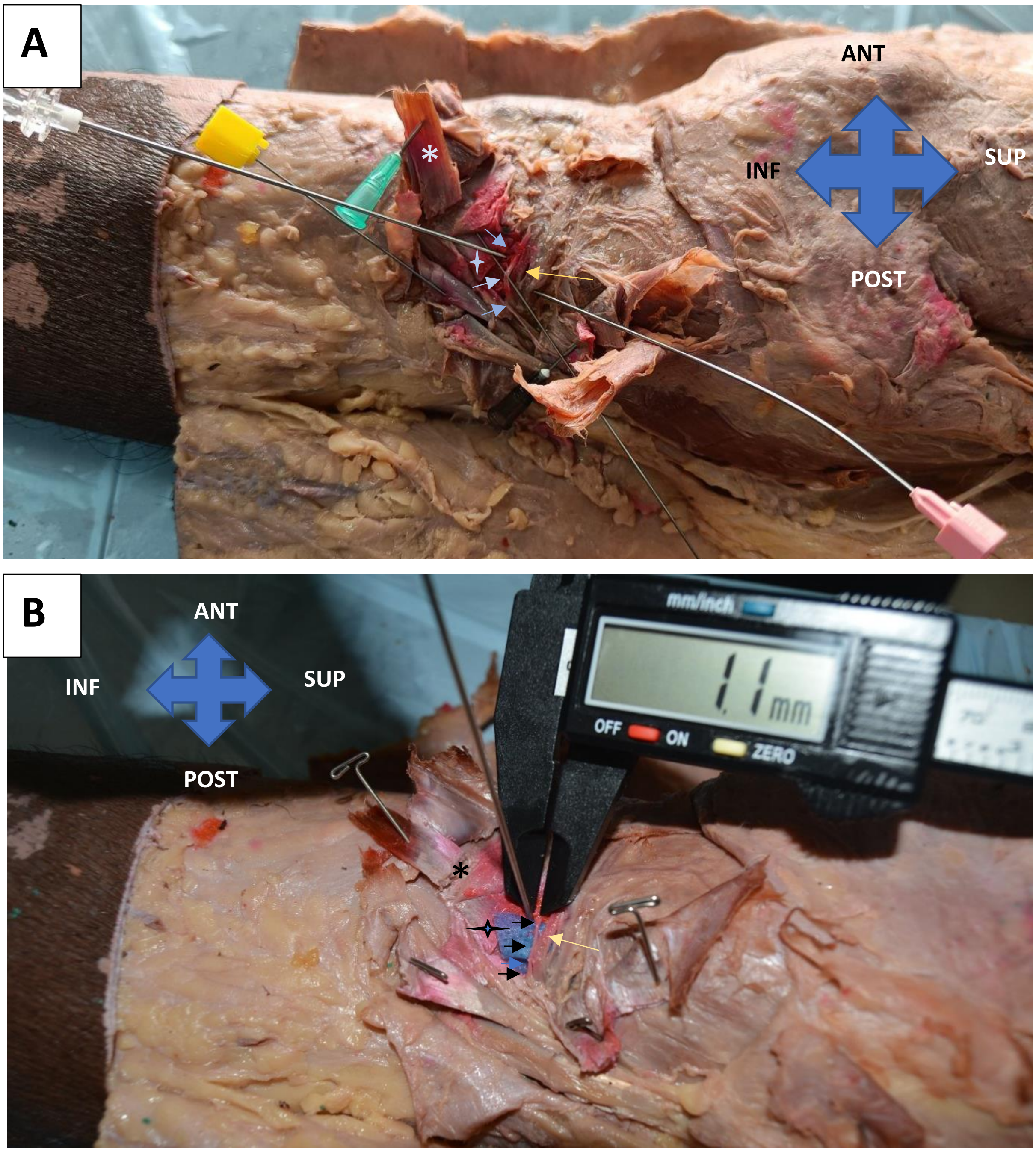


Figure 19: Dissected IMGN. ***.*** *A and B: IMGN marked with arrows, in left knee specimen. The Asterix shows the superficial MCL. The star shows deep MCL. Yellow arrow shows the inferomedial genicular vessels. B: measurement of IMGN to needle tip. (Both are right knee specimens)*

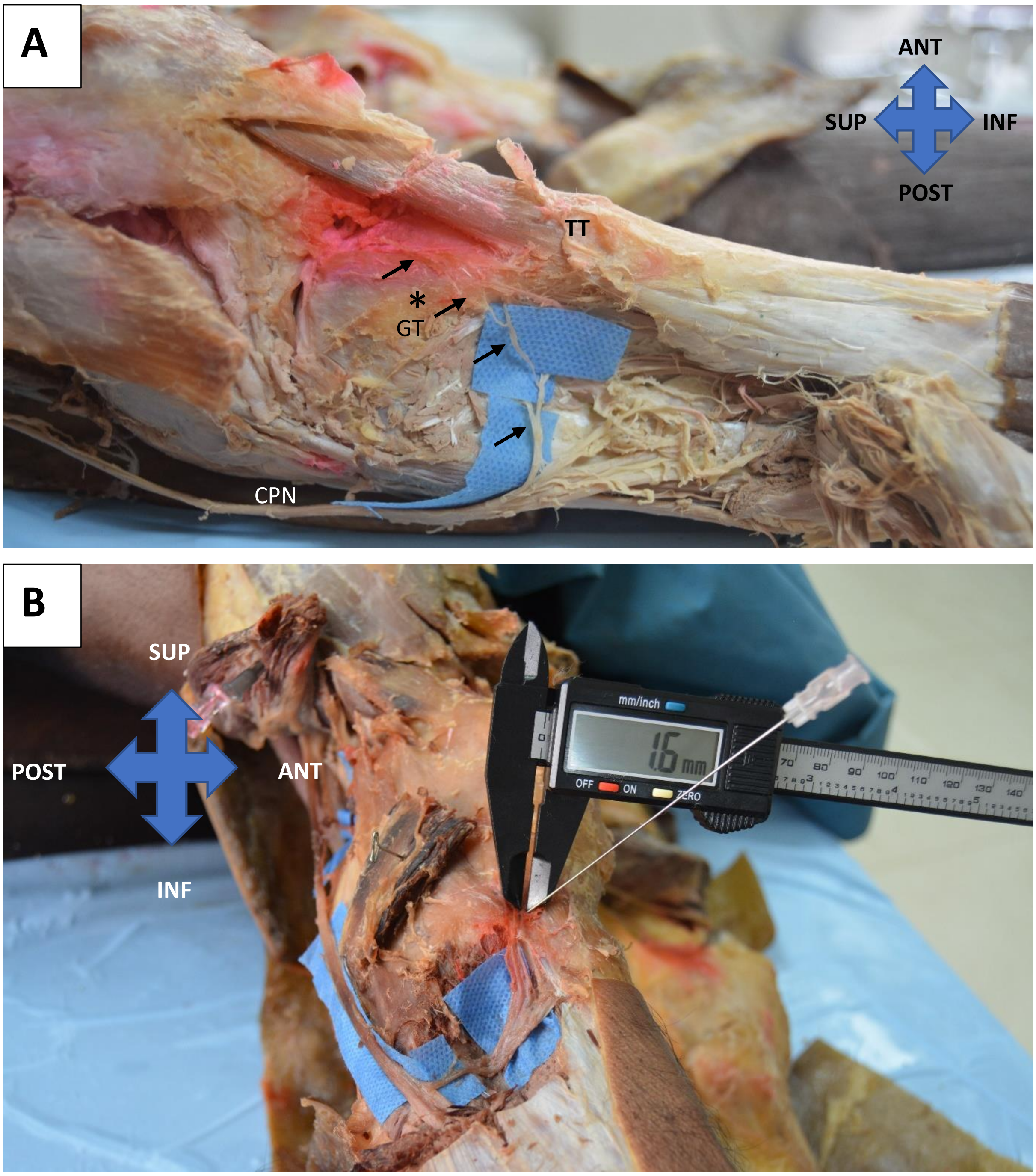


Figure 20: Dissected ILGN(RGN)- A- ILGN Emerging from common peroneal nerve. Finely separated from the vessels and visualised. The anterolateral compartment of leg is finely removed. Asterix represents the coronary ligament [cut during dissection] GT- Gerdy's tubercle. TT- tibial tuberosity, CPN- Common peroneal nerve. B- Nerve to needle distance measured. (Both are right knee specimens)

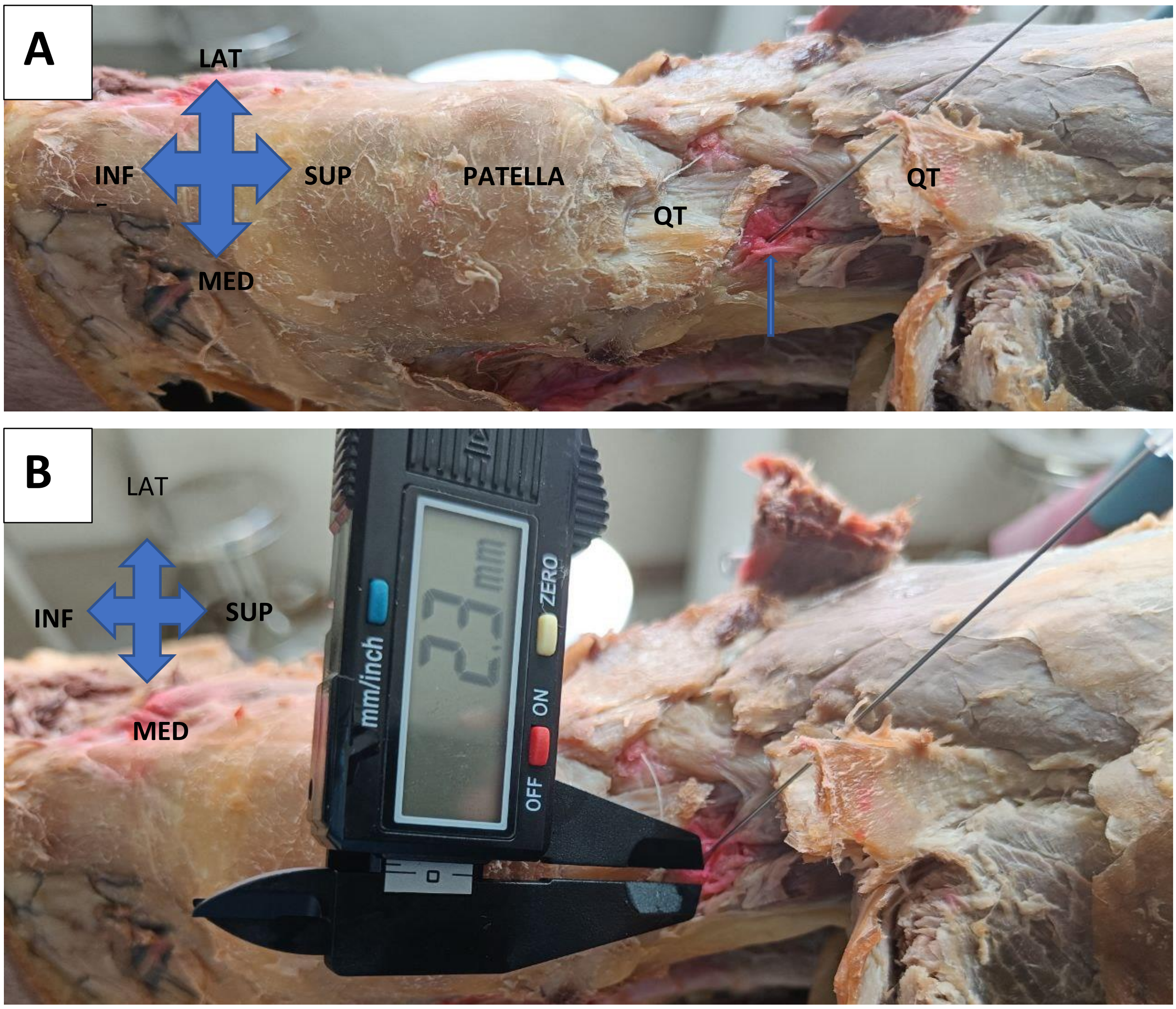


Figure 21: Dissected MGN. A-MGN Shown by the arrow. The quadriceps muscles have been cut and retracted. Quadriceps tendon is cut and retracted. QT- quadriceps tendon. B-Nerve to needle tip measured. (Both are right knee specimens)

While dissecting, the following distances were also measured and recorded.

The distance of SMGN, from the medial femoral condyle distal end, medial tibial condyle proximal end, junction of shaft, superomedial pole of patella, midpoint of superior surface of patella, adductor tubercle and superior medial genicular artery.

The distance of IMGN, from insertion of medial collateral ligament, junction of shaft and medial epicondyle of tibia, medial tibial condyle proximal end, medial femoral condyle distal end, tibial tuberosity, inferior pole of patella, and inferior medial genicular artery.

The distance of SLGN, from the lateral femoral condyle distal end, lateral tibial condyle proximal end, junction of shaft and lateral epicondyle of femur, superolateral pole of patella, and superior lateral genicular artery.

The distance of ILGN(RGN), from lateral tibial condyle proximal end, lateral femoral condyle distal end, junction of shaft and lateral epicondyle of tibia, the fibular head- neck junction, tibial tuberosity proximal point, Gerdy's tubercle medial point, inferior pole of patella, common peroneal nerve division and inferior lateral genicular nerve.

The distance of middle genicular nerve, from the midpoint of patella, midpoint of superior border of patella, superolateral pole of patella, superomedial pole of patella, medial femoral condyle distal end, lateral femoral condyle distal end and middle genicular artery.

The procedure was repeated in three sets, with 10 cadaveric knee specimens in each set, over a duration of 1 year.

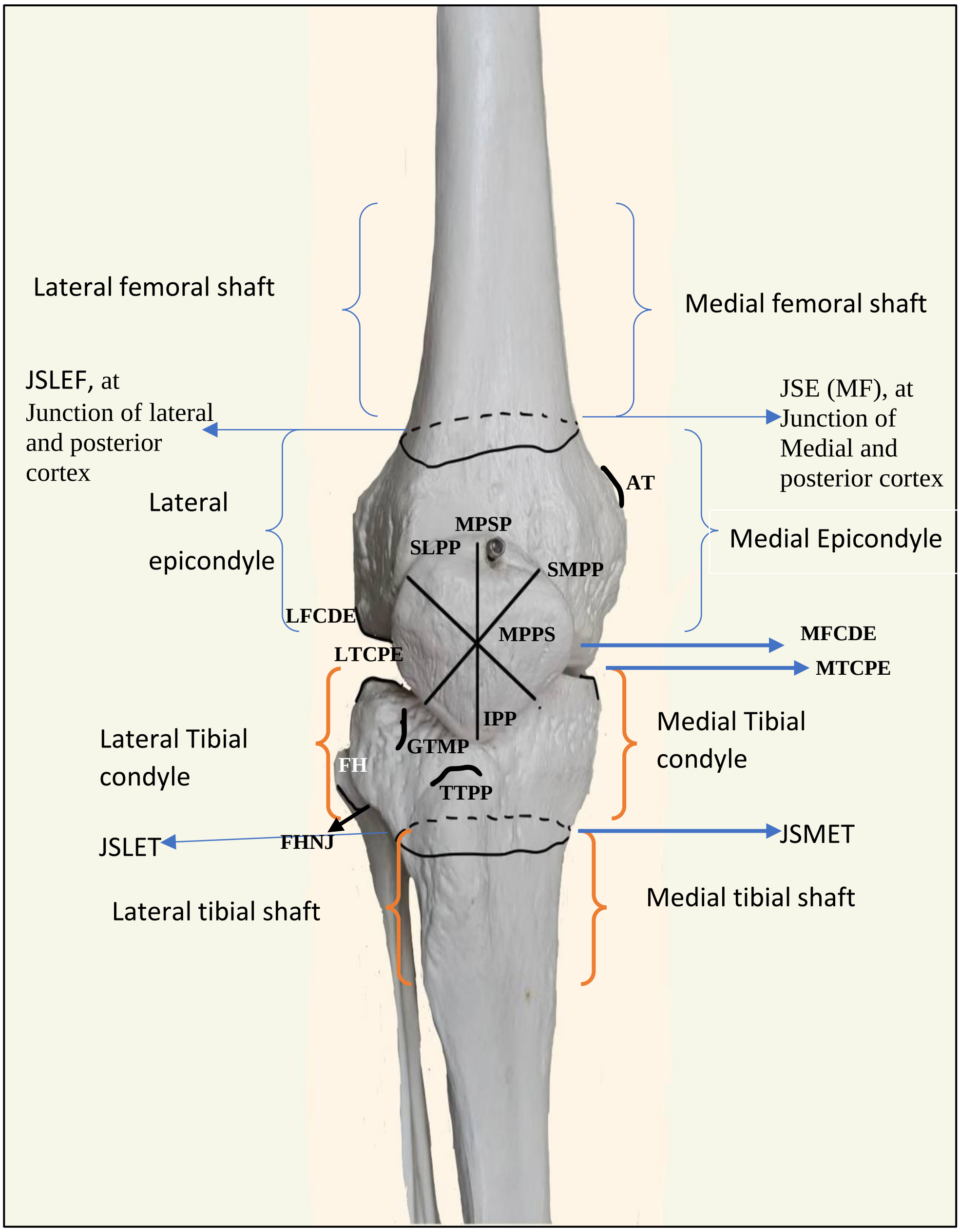


Figure 22: Schematic diagram of the bony landmarks used for secondary outcomes. Solid line shows the contour outline of the cortex visible from anterior view. The dotted lines shows the posterior cortex. MFCDE- Medial femoral condyle distal end, MTCPE- Medial tibial condyle

proximal end, AT- Adductor tubercle, JSC(MF)- Junction of shaft and condyle (medial femoral), SMPP- Superomedial pole of patella, MPSP- Midpoint of superior surface of patella, LFCDE- Lateral femoral condyle distal end, LTCPE- Lateral tibial condyle proximal end, JSLEF- Junction of shaft and lateral epicondyle of femur, SLPP- Superolateral pole of patella, IMCL- Insertion of medial collateral ligament, JSMET- Junction of shaft and medial epicondyle of tibia, IPP- Inferior pole of patella, . JSLET- Junction of shaft and lateral epicondyle of tibia, FH- fibular head, FHNJ- Fibular head- neck junction, TTPP -Tibial tuberosity proximal point, GTMP- Gerdy's tubercle medial point. MPPS- Midpoint of patellar surface.

STATISTICAL ANALYSIS:

The data was manually entered in Microsoft Excel (version - Office 365). The data was appropriately recoded for the Variables. The final sheet was imported into R version 4.2.2 using the "readxl" package and further analysis was done using packages like "tidyverse", "gtsummary", "flextable", "tidyr", "expss", "ggplot2" and their dependencies. Continuous variables such as height, distance was expressed in terms of median, interquartile range (IQR). The outcome variables which were nominal- sex of cadavers, and staining of nerves, are expressed in terms of frequencies and percentages. Wilcoxon rank sum test was used to find association between length of the cadavers in two groups. Chi- square test was used to find an association between sex of the cadavers in two groups. Fisher's test was used to find association between staining characteristics of two groups. Nerve to needle distance in the two groups were analysed using Wilcoxon rank sum test. The relationship between cadaver length and nerve distance to nearby landmarks was analysed using linear regression. P value <0.05 is taken as significant. Data is presented with the help of tables, and box and whisker plots.

RESULTS

RESULTS

A total number of 30 cadaveric knee specimens were studied, in lots of 10 at a time. Out of which 15 were in USG group, and 15 were in landmark group.

The available demographic data of the cadavers enrolled in this study is shown in Table 4. The descriptive analysis shows the median length of total study subjects as 160.0 cm, with interquartile range 156.0-168.0. The cadavers enrolled in USG group, was having median length as 162.0 cm, with interquartile range as 154.5-169.0 cm. In the landmark group, median length was 160.0 cm with interquartile range as 157.0-167.5 cm.

Of all the specimens studied, 40 % was female cadaveric specimens. In USG group, 33 % and in blind group 47 % were female cadaveric specimens.

Table 4: Demographic details of the cadavers

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value
LENGTH	160.0 (156.0, 168.0)	162.0 (154.5, 169.0)	160.0 (157.0, 167.5)	0.9 [2]
SEX				0.5 [3]
F	12 (40%)	5 (33%)	7 (47%)	
M	18 (60%)	10 (67%)	8 (53%)	

1: Median (IQR); n (% frequency), 2: Wilcoxon rank sum test, 3: Pearson's Chi-squared test

1. PRIMARY OUTCOMES

1.1 SMGN

The staining and nerve to needle distance of the SMGN is shown in Table 5.

93% of specimens targeted with USG guidance shows the nerve being stained, compared to 47% in surface landmark group. The median needle to nerve distance was 1.67 mm in the USG group, with the interquartile range of 1.49 to 1.84 mm. In group two, it was 8.65 mm, with interquartile range of 4.53 to 9.27. The data is shown as a box plot. (Figure 23)

Table 5: Staining and distance characteristics of SMGN

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value
Stained SMGN	21 (70%)	14 (93%)	7 (47%)	**0.014** [2]
Needle to SMGN distance	4.13 (1.67, 8.85)	1.67 (1.49, 1.84)	8.65 (4.53, 9.27)	**<0.001** [3]

1: n (% frequency); Median (IQR), 2: Fisher's exact test, 3: Wilcoxon rank sum test

1.2 SLGN

The staining and nerve to needle distance of SLGN is shown in Table 6.

100% of specimens targeted with USG guidance shows the nerve being stained, compared to 40 % in landmark group. The median needle to nerve distance was 3.20 mm in USG group, and 10 mm in the surface landmark group. Interquartile range is shown in the bracket. The data is shown as a box plot. (Figure 23)

Table 6: Staining and distance characteristics of SLGN

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value
Stained SLGN	21 (70%)	15 (100%)	6 (40%)	**<0.001** [2]
Needle to SLGN distance	4.6 (3.2, 10.0)	3.2 (3.1, 3.4)	10.1 (7.5, 12.0)	**<0.001** [3]

1: n (% frequency); Median (IQR), 2: Fisher's exact test, 3: Wilcoxon rank sum test

1.3 IMGN

The staining and nerve to needle distance of IMGN is shown in Table 7.

100% of specimens targeted with USG guidance shows the nerve being stained, compared to 67 % in landmark group. The median needle to nerve distance was 1.80 mm in USG group, and 4 mm in blind group. Interquartile range is shown in the bracket. The data is shown as a box plot. (Figure 23)

Table 7: Staining and distance characteristics of IMGN

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value
Stained IMGN	25 (83%)	15 (100%)	10 (67%)	**0.042** [2]
Needle to IMGN Distance	2.89 (1.82, 4.00)	1.80 (1.07, 2.04)	4.00 (3.82, 8.77)	**<0.001** [3]

1: n (% frequency); Median (IQR), 2: Fisher's exact test, 3: Wilcoxon rank sum test

1.4 ILGN

The staining and nerve to needle distance of ILGN is shown in Table 8.

100% of specimens targeted with both USG guidance and landmark group is stained. The median needle to nerve distance was 2.65 mm in USG group, and 5.03 mm in blind group. Interquartile range is shown in the bracket. The data is presented as a box plot. (Figure 23)

Table 8: Staining and distance characteristics of ILGN

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value[2]
Stained ILGN	30 (100%)	15 (100%)	15 (100%)	
Needle to ILGN distance	3.56 (2.66, 5.03)	2.65 (1.82, 3.01)	5.03 (4.62, 6.14)	**<0.001**

1: n (% frequency); Median (IQR), 2: Wilcoxon rank sum test

1.5 MGN

The staining and nerve to needle distance of MGN is shown in Table 9.

100% of specimens targeted with USG guidance shows the nerve being stained, compared to 13 % in landmark group. The median needle to nerve distance was 2.28 mm in USG group, and 6.48 mm in blind group. Interquartile range is shown in the bracket. The data is presented as a box plot. (Figure 23)

Table 9: Staining and distance characteristics of MGN

Characteristic	Overall, N = 30[1]	GROUP 1, N = 15[1]	GROUP 2, N = 15[1]	p-value
Stained MGN	17 (57%)	15 (100%)	2 (13%)	**<0.001** [2]
Needle to MGN distance	2.33 (2.09, 2.56)	2.28 (1.99, 2.40)	6.48 (6.23, 6.73)	**0.030** [3]

1: n (% frequency); Median (IQR), 2: Fisher's exact test, 3: Wilcoxon rank sum test

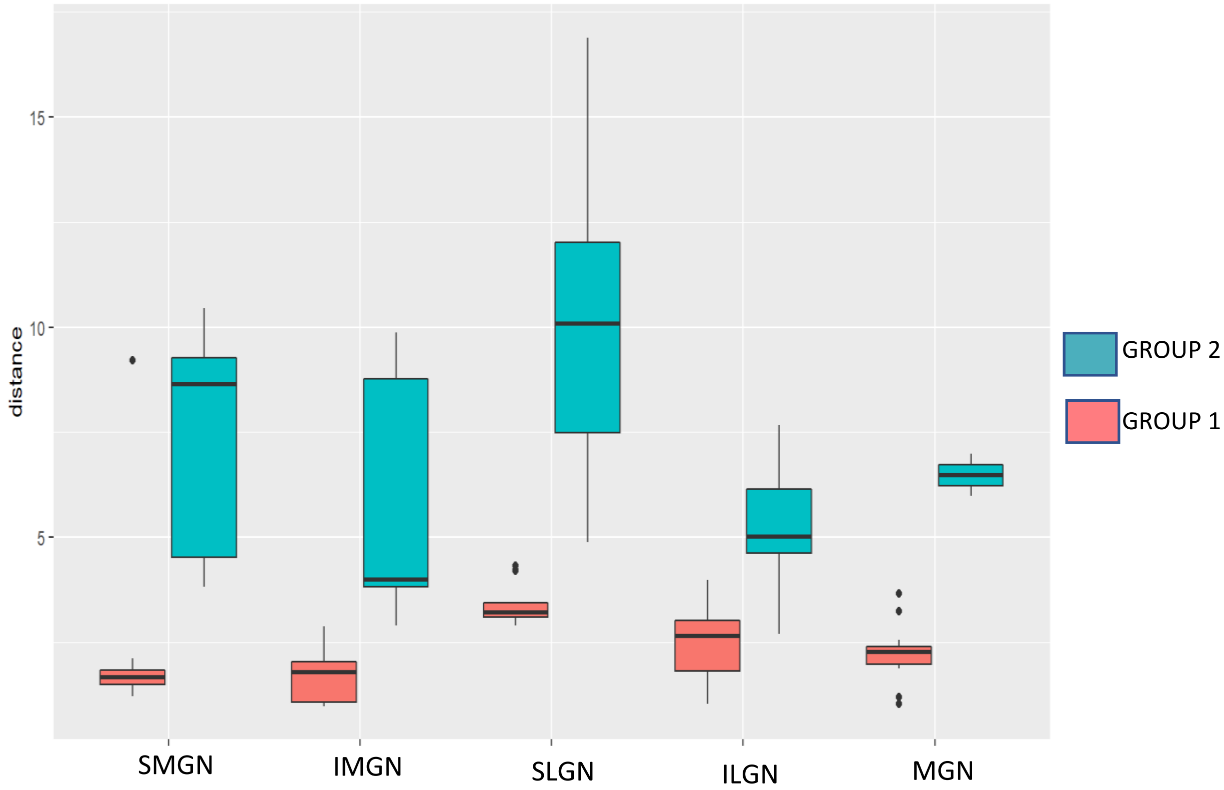


Figure 23: Nerve-to-needle distance expressed using box and whisker plots. Group 1(USG guided), and Group 2 (surface landmark guided). The nerve-to-needle distance of the respective nerves (Y axis, expressed in mm) are more in group 2, compared to group 1. The dispersion of the data is also more in group 1 compared to group 2. SMGN- superomedial genicular nerve, IMGN- Inferomedial genicular nerve, SLGN- superomedial genicular nerve, ILGN- Inferomedial genicular nerve, MGN- Middle genicular nerve.

2. SECONDARY OUTCOMES

These measurements were done in supine position, and knee in maximum extended position.

The data is expressed as median and standard deviation. The association of this data, with height of the cadaver was assessed with linear regression. The P value < 0.05 was taken as significant.

2.1 SMGN

The average distance measured for SMGN, from its bony contact to the nearby landmarks are shown in Table 10. The standard deviation is shown in the brackets. The data is presented with box and whisker plots. (Figure 24)

Table 10: The average distance measured of SMGN, from nearby landmarks.

Medial femoral condyle distal end	41.1 (6.5)
Medial tibial condyle proximal end	44.9 (6.4)
Adductor tubercle	10.15 (2.13)
Junction of shaft and medial condyle of femur and medial and posterior cortex junction.	16.84 (0.44)
Superior medial genicular artery	1.55 (0.58)
Superomedial pole of patella	40.61 (3.04)
Midpoint of superior surface of patella	60.18 (2.25)

The bracket shows standard deviation.

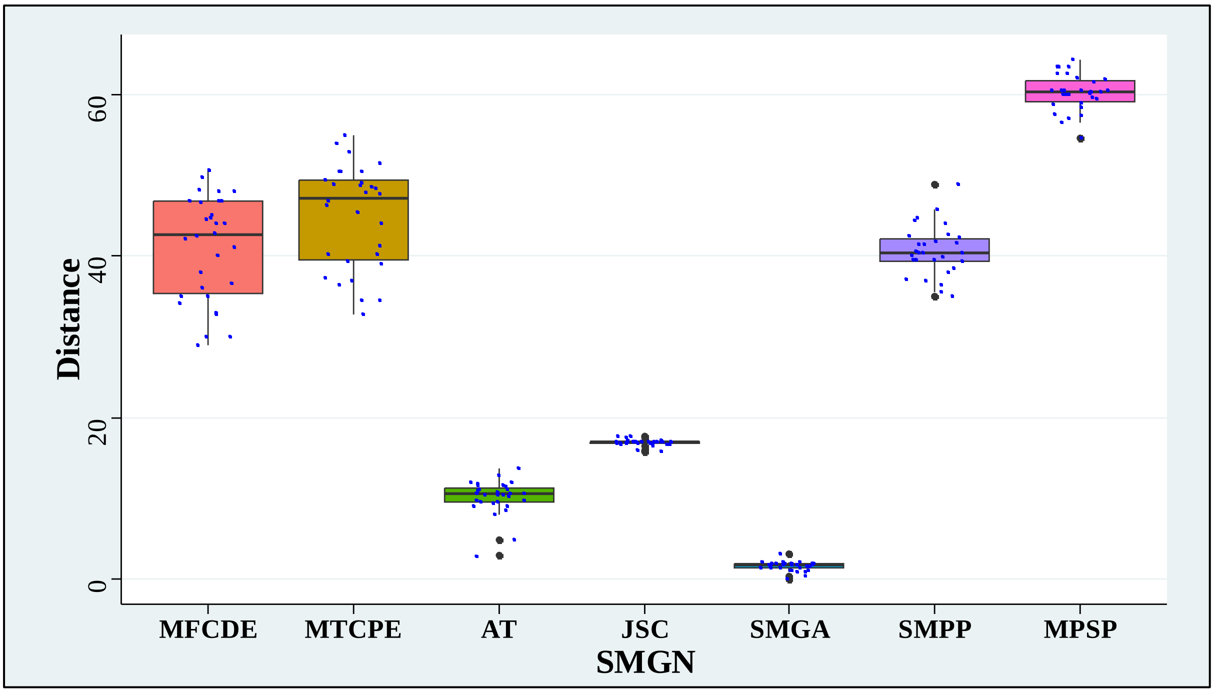


Figure 24: Distance of SMGN from nearby landmarks- expressed with box and whisker plots. MFCDE- Medial femoral condyle distal end, MTCPE- Medial tibial condyle proximal end, AT- Adductor tubercle, JSC- Junction of shaft and condyle (medial femoral), SMGA- Superior medial genicular artery, SMPP- Superomedial pole of patella, MPSP- Midpoint of superior surface of patella

The association of the distances, with the length of the cadaver was analysed, by linear regression. Table 11 shows these details for SMGN. It was found that, the parameters 1,2, and 4 shows significant relationship with length. Hence these distances are subjective to variation with height.

Table:11 Association of distance of SMGN from nearby landmarks with length of the cadaver

SL no	Outcomes	N	Beta	95% CI	p-value[1]
1	Medial femoral condyle distal end	30	0.86	0.72, 1.0	**<0.001**
2	Medial tibial condyle proximal end	30	0.83	0.69, 1.0	**<0.001**
3	Adductor tubercle	30	0.04	-0.07, 0.16	0.46
4	Junction of shaft and condyle	30	0.05	0.03, 0.06	**<0.001**
5	Superior medial genicular artery	30	0.02	-0.01, 0.05	0.13
6	Superomedial pole of patella	30	0.00	-0.17, 0.17	>0.99
7	Midpoint of superior surface of patella	30	0.03	-0.10, 0.15	0.67

1: Linear regression

2.2 SLGN

Table:12 Shows the average distance of SLGN, from the nearby landmarks. The standard deviation is shown in bracket. This is presented with box and whisker plots (Figure 25)

Table 12: The average distance measured for SLGN, from nearby landmarks

Lateral femoral condyle distal end	43.10 (7.89)
Lateral tibial condyle proximal end	48.61 (7.82)
Junction of shaft and lateral epicondyle of femur	3.88 (1.59)
Superior lateral genicular artery	1.73 (0.60)
Superolateral pole of patella	60.03 (2.37)
Midpoint of superior surface of patella	80.09 (3.45)

The bracket shows standard deviation.

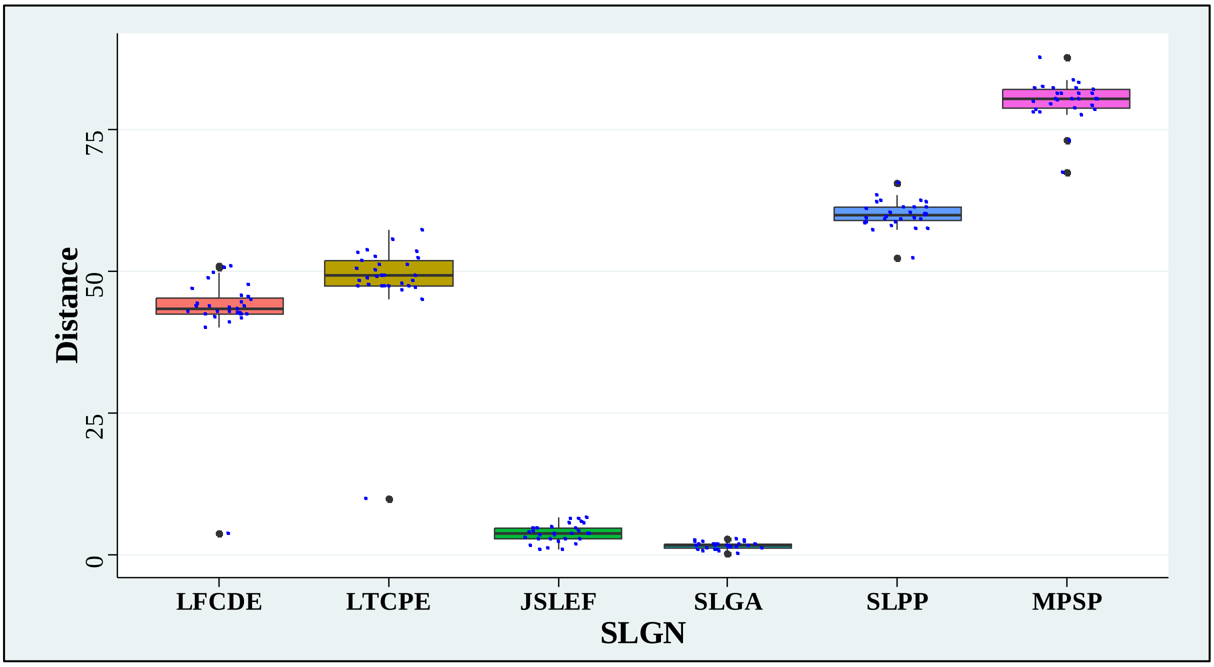


Figure 25: Distance of SLGN from nearby landmarks- expressed with box and whisker plot. LFCDE- Lateral femoral condyle distal end, LTCPE- Lateral tibial condyle proximal end, JSLEF- Junction of shaft and lateral epicondyle of femur, SLGA- Superior lateral genicular artery, SLPP- Superolateral pole of patella, MPSP -Midpoint of superior surface of patella.

Table 13: Association of distance of SLGN from nearby landmarks with length of the cadaver

	Outcome	N	Beta	95% CI	p-value[1]
1	Lateral femoral condyle distal end	30	0.52	0.13, 0.91	**0.010**
2	Lateral tibial condyle proximal end	30	0.40	-0.01, 0.81	0.053
3	Junction of shaft and lateral epicondyle of femur	30	0.04	-0.05, 0.12	0.40
4	Superior lateral genicular artery	30	0.00	-0.03, 0.04	0.84
5	Superolateral pole of patella	30	-0.07	-0.20, 0.06	0.28
6	Midpoint of superior surface of patella	30	-0.07	-0.26, 0.12	0.49

1: Linear regression

Table:13 Shows the relation of these distances of SLGN with length of the cadaver. By linear regression the parameter 1 shows significant relationship with length. Hence this distance is subjective to variation with height.

2.3 IMGN

Table:14 Shows the average distance of IMGN, from the nearby landmarks. The standard deviation is shown in bracket. This is presented with box and whisker plots (Figure 26)

Table:14 The average distance measured for IMGN, from nearby landmarks

Insertion of medial collateral ligament- deep fibers	8.86 (0.35)
Medial tibial condyle proximal end	9.30 (0.79)
Junction of shaft and medial epicondyle of tibia	2.99 (0.65)
Medial femoral condyle distal end	48.48 (1.21)
Inferior medial genicular artery	1.34 (0.58)
Tibial tuberosity inferomedial tip	39.18 (1.28)
Inferior pole of patella	65.10 (2.36)

The bracket shows standard deviation.

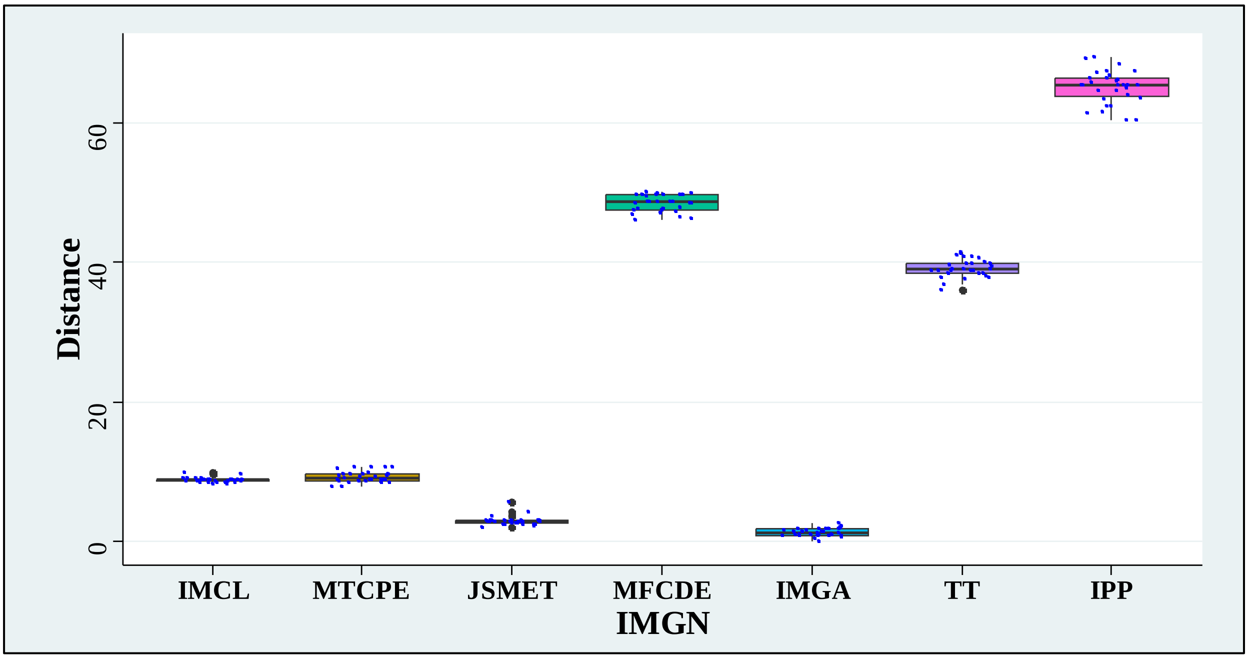


Figure 26: Distance of IMGN from nearby landmarks, expressed with box and whisker plots. IMCL- Insertion of medial collateral ligament, MTCPE- Medial tibial condyle proximal end, JSMET- Junction of shaft and medial epicondyle of tibia, MFCDE-Medial femoral condyle distal end, IMGA- Inferior medial genicular artery, TT -Tibial tuberosity, IPP- Inferior pole of patella

Table: 15 Shows the relation these distances of IMGN, with length of the cadaver. By linear regression the parameters 1 and 4 shows significant relationship with height. Hence these distances are subjective to variation with height.

Table 15: Association of distance the of IMGN from nearby landmarks with length of the cadaver

SL no	Outcome	N	Beta	95% CI	p-value[1]
1	Insertion of medial collateral ligament- deep fibers	30	0.03	0.01, 0.04	**0.003**
2	Medial tibial condyle proximal end	30	0.04	0.00, 0.08	0.054
3	Junction of shaft and medial epicondyle of tibia	30	0.02	-0.02, 0.05	0.35
4	Medial femoral condyle distal end	30	0.13	0.09, 0.18	<**0.001**
5	Inferior medial genicular artery	30	-0.01	-0.04, 0.02	0.60
6	Tibial tuberosity inferomedial tip	30	0.01	-0.06, 0.08	0.68
7	Inferior pole of patella	30	-0.03	-0.16, 0.10	0.66

1: Linear regression

2.4 ILGN(RGN)

Table 16 Shows the average distance of ILGN(RGN), from the nearby landmarks. The standard deviation is shown in bracket. This is presented with box and whisker plots. (Figure 27)

Table 16: The average distance measured for ILGN(RGN), from nearby landmarks

Junction of shaft and lateral epicondyle of tibia	29.48 (1.59)
Common peroneal nerve division	50.8 (3.5)
Lateral tibial condyle proximal end	13.91 (1.62)
Lateral femoral condyle distal end	16.62 (1.55)
Fibular head- neck junction	45.19 (3.34)
Inferior lateral genicular artery	1.07 (0.19)
Gerdy's tubercle medial point	6.01 (1.18)
Tibial tuberosity proximal point	8.70 (1.18)
Inferior pole of patella	46.47 (1.85)

The bracket shows standard deviation.

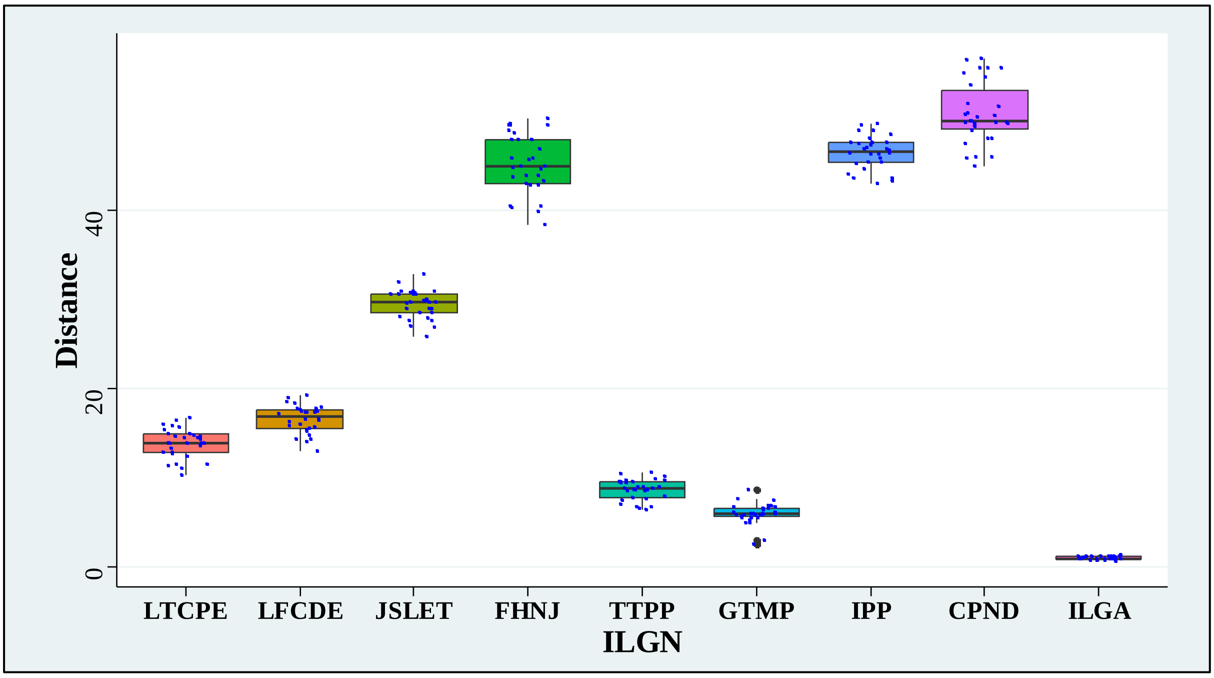


Figure 27: Distance of ILGN from nearby landmarks, expressed with box and whisker plots. LTCPE- Lateral tibial condyle proximal end, LFCDE- Lateral femoral condyle distal end, JSLET- Junction of shaft and lateral epicondyle of tibia, FHNJ- Fibular head- neck junction, TTPP -Tibial tuberosity proximal point, GTMP- Gerdy's tubercle medial point, IPP -Inferior pole of patella, CPND- Common peroneal nerve division, ILGA- Inferior lateral genicular artery.

Table 17: Association of the distance of ILGN(RGN) from nearby landmarks with length of the cadaver

Sl no	Outcome	N	Beta	95% CI	p-value[1]
1	Junction of shaft and lateral epicondyle of tibia	30	0.13	0.06, 0.20	**<0.001**
2	Common peroneal nerve division	30	0.10	-0.09, 0.29	0.30
3	Lateral tibial condyle proximal end	30	0.18	0.12, 0.24	**<0.001**
4	Lateral femoral condyle distal end	30	0.16	0.10, 0.22	**<0.001**
5	Fibular head- neck junction	30	0.07	-0.11, 0.26	0.43
6	Inferior lateral genicular artery	30	0.01	0.00, 0.02	0.18
7	Gerdy's tubercle medial point	30	0.07	0.00, 0.13	**0.036**
8	Tibial tuberosity proximal point	30	0.00	-0.06, 0.07	0.90
9	Inferior pole of patella	30	0.02	-0.08, 0.12	0.66

1: Linear regression

Table 17 shows the association of distance of ILGN(RGN) from nearby landmarks with length of the cadaver. By linear regression the parameters 1, 3, 4, and 7 shows significant relationship with height. Hence this distance is subjective to variation with height.

2.5 MGN

Table 18 shows the average distance of MGN, from the nearby landmarks. The standard deviation is shown in bracket. This is presented with box and whisker plots. (Figure 28)

Table 18: The average distance measured for MGN, from nearby landmarks

Midpoint of patellar surface	32.37 (3.68)
Midpoint of superior border of patella	12.59 (1.34)
Lateral femoral condyle distal end	54.7 (3.4)
Medial femoral condyle distal end	51.6 (6.8)
Middle genicular artery	1.65 (0.58)
Superomedial pole of patella	20.41 (2.35)
Superolateral pole of patella	31.79 (2.45)

The bracket shows standard deviation.

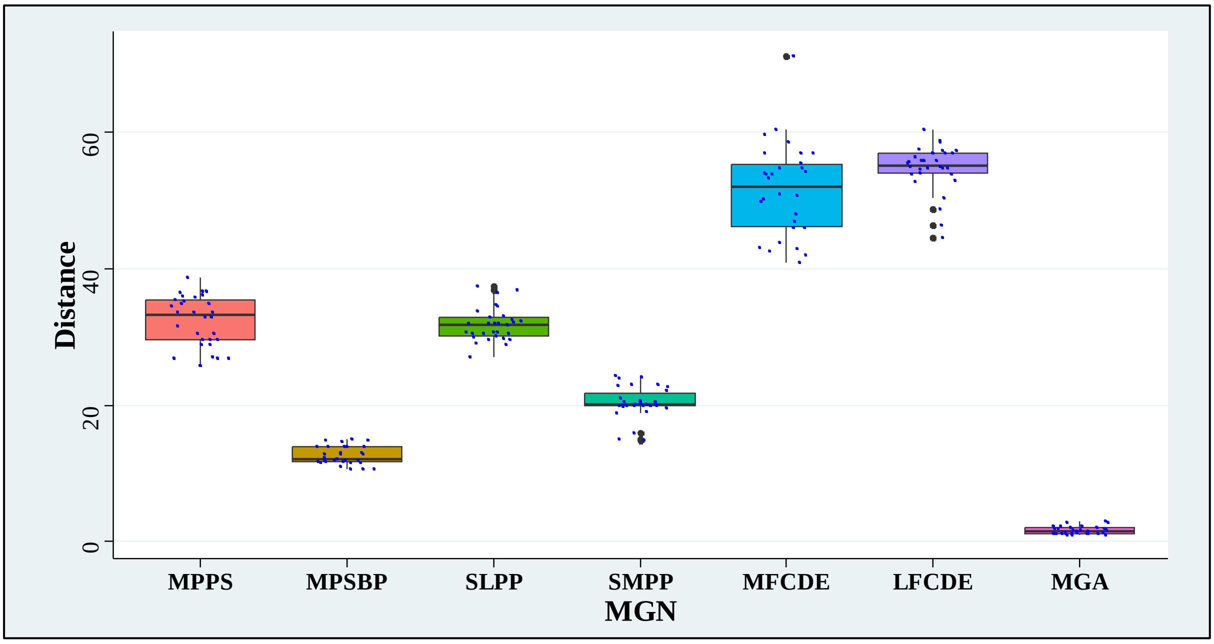


Figure 28: Distance of MGN from nearby landmarks, expressed with box and whisker plots. MPPS- Midpoint of patellar surface, MPSBP- Midpoint of superior border of patella, SLPP- Superolateral pole of patella, SMPP- Superomedial pole of patella, MFCDE-Medial femoral condyle distal end, LFCDE- Lateral femoral condyle distal end, MGA-Middle genicular artery.

Table 19: Association of the distance of MGN from nearby landmarks with length of the cadaver

Sl no	Outcome	N	Beta	95% CI	p-value[1]
1	Midpoint of patellar surface	30	0.05	-0.15, 0.26	0.60
2	Midpoint of superior border of patella	30	0.00	-0.07, 0.08	0.97
3	Lateral femoral condyle distal end	30	0.23	0.07, 0.40	**0.008**
4	Medial femoral condyle distal end	30	0.42	0.08, 0.75	**0.018**
5	Middle genicular artery	30	0.01	-0.02, 0.04	0.64
6	Superomedial pole of patella	30	0.09	-0.04, 0.21	0.17
7	Superolateral pole of patella	30	0.20	0.09, 0.31	**0.001**

1: Linear regression

Table- 19 shows the association of distance of MGN from nearby landmarks with length of the cadaver. By linear regression the parameters 3, 4 and 7 shows significant relationship with height. Hence this distance is subjective to variation with height.

DISCUSSION

DISCUSSION

In the previous studies comparing the USG guided and surface anatomy landmark guided genicular nerve block, even though both was found to be equally effective in controlling pain in patients with knee pain, (57,58) in our study we have found that there is considerable difference in the distance and the staining within the two groups. Both the parameters- staining and nerve to needle distance was statistically significant between two groups, for the defined landmarks of SMGN, SLGN, IMGN, and MGN. ($p<0.05$) The ILGN, was found to be stained in both groups, but the nerve to needle distance was significantly low in group 1. ($p<0.05$)

In those previous studies, the result may be due to placebo effect, or due to the usage of 2 ml of medication at a site as compared to 0.1 ml of dye in our study. Precise localisation of nerve, is necessary to carry out radiofrequency ablation, and we found that all these prescribed targets under ultrasound are accurate for this.

In this study the visualisation of the corresponding artery was not used, and is not possible in a cadaveric study, and in spite of this, the nerves were accurately targeted, which shows that it is not always necessary to visualise the artery pulsation, as it is being commonly done, in many of the previous studies.(16,28,30,52,56,58,59,61,68,70–72)

SMGN

The SMGN, was found to be the distal branch of the NVM, in 100% of the specimens, as was described in some previous anatomical studies. (44,75) The nerve at the middle of thigh entered a fascial tunnel and it took exit from the fascial tunnel near the distal third of the femur (Figure: 29 A) and then descended along with the adductor magnus tendon and it made a bony contact over the femur, on average, 10.15 mm anterior to the adductor tubercle, and the adductor magnus insertion. (Figure: 17) Hence the landmark 1 cm anterior to adductor tubercle, can be considered as accurate. Yasar et al described this landmark as 100 % accurate, in a cadaveric study.(53) In our study, the landmark was found to be 93% accurate. This can be attributed to a variation, in which the nerve was piercing the capsule, just medial and posterior to adductor magnus tendon, insertion. In that knee, the nerve was not stained and nerve to needle distance was 10 mm. (Figure: 30)

Kim et al., described the nerve to be dividing in to two branches after it makes bony contact.(46) In our dissection also we found this in 10 of the cadaveric knee specimens. (Figure: 29 B)

Many previous authors like, Yasar et al., Wong et al., Kesikburun et al., Ahmed and Arora, Cankurtaran et al., Gupta et al., Ghai et al., had targeted the nerve anterior to adductor tubercle.(52,53,55,57,58,61,62,70) In our study, the average nerve to needle distance, when targeted using adductor tubercle landmark, under ultrasound guidance was 1.67 mm, thus concluding that adductor tubercle is a well-established landmark for USG guided SMGN block.

In the landmark guided group, we have targeted the nerve just above the medial femoral condyle. In terms of staining, this was having only 47% accuracy, and with a nerve to needle distance of 8.65 mm. There was statistically significant difference between two groups, considering both staining and distance. (P value - 0.014, P value < 0.001)

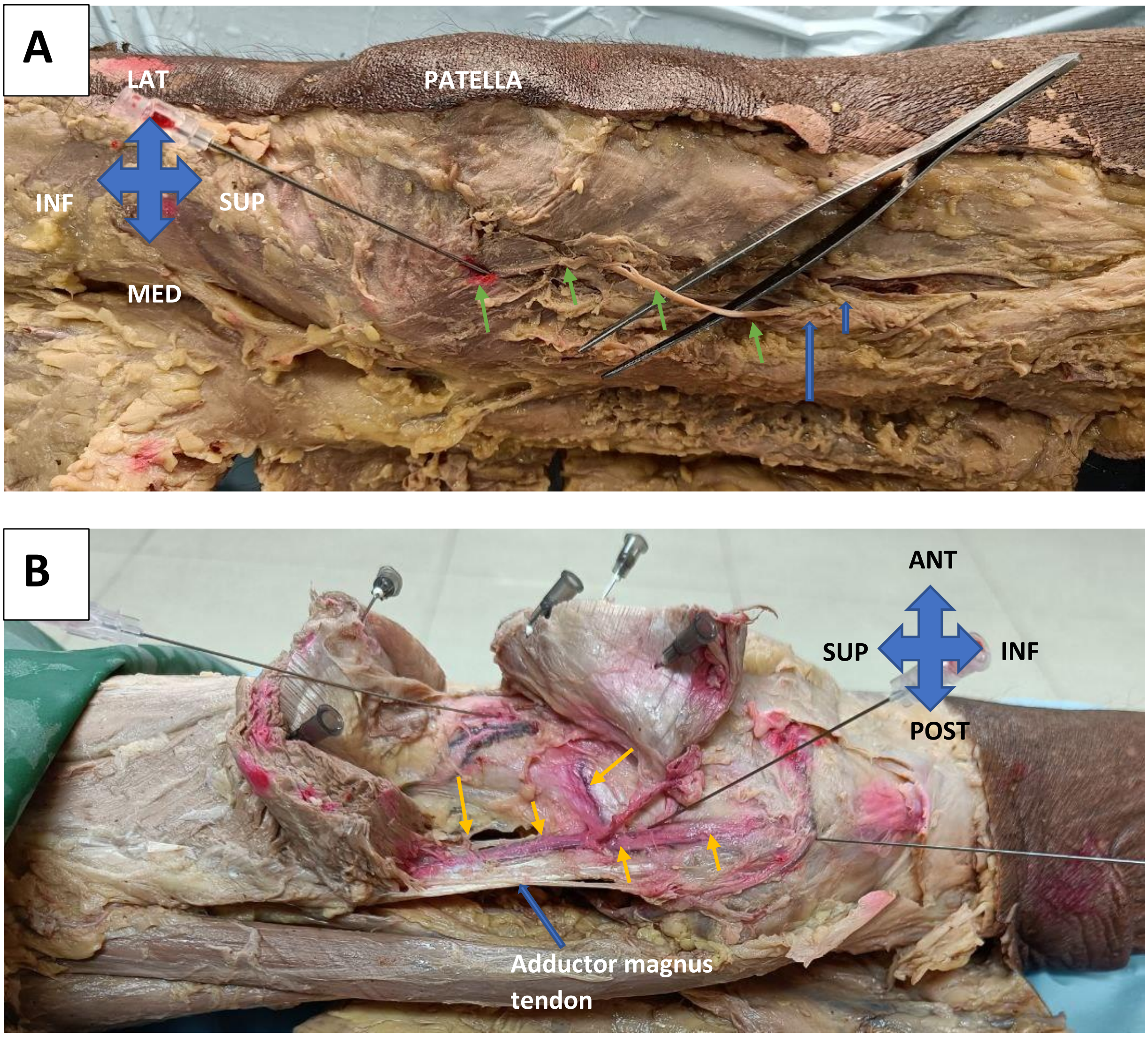


Figure 29: Course of SMGN. A- The SMGN partially dissected out to show its passage through the fascial tunnel. SMGN- Green arrow, blue arrow shows the nerve dissected out from the fascial tunnel. B- SMGN Branching (yellow arrows), accompanied by the SMG vessels. Note the dye has entered the vessel, and hence marking its trajectory, along with the nerve.

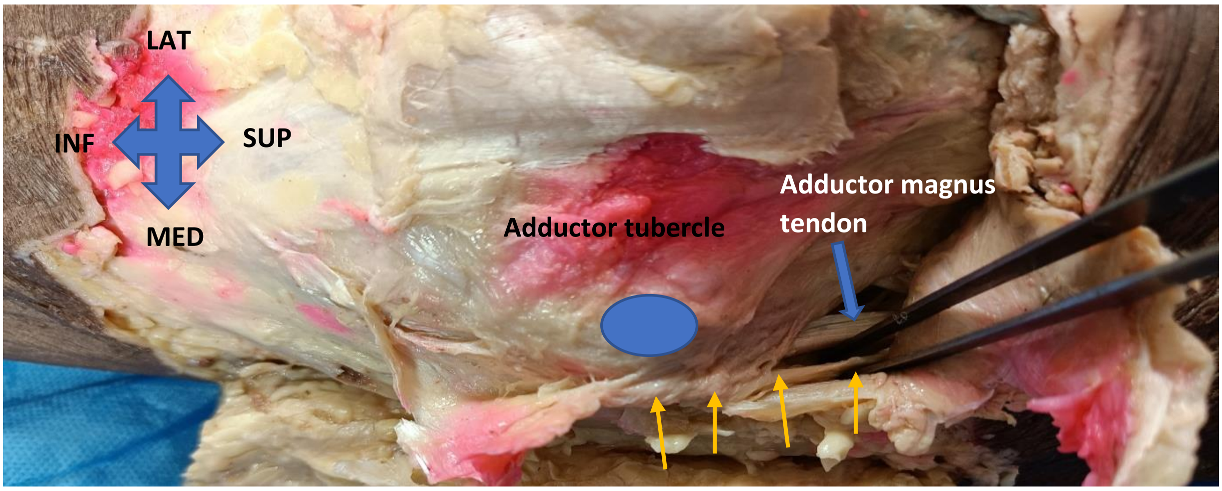


Figure 30: SMGN Variation. The SMGN descending posterior to adductor tendon, and piercing the capsule at the adductor tubercle. Right cadaveric knee specimen

Other landmarks for localisation of SMGN

The nerve was identified to be on an average, 16.84 mm away from the point of junction of shaft and medial femoral condyle, at junction of medial and posterior cortex.(Figure 22) This point is used in USG guided genicular nerve block. (59,60) Vanneste et al., Elsaman et al., Guler et al., Chang et al., Kose et al., have used the junction of medial femoral epicondyle and shaft as landmark for SMGN block, with steroid and RFA. (28,30,54,71,72)The pain relief was also adequate. The average distance between this point and SMGN, in our study suggests that, this landmark can be used for USG guided nerve injection with steroid, as the 2 ml volume can easily cover this distance, and RFA, preferably using larger gauge needles.(43)

The distance of nerve to superior medial genicular artery was found to be 1.22 mm. Hence it is clear that the nerve can be targeted by locating the corresponding artery, as was done in many previous studies.(16,28,30,52,56,58,60,68,70–72) Even RFA, is justifiable, after visualising artery pulsation and targeting the bony cortex, near the pulsation and 1 mm away from periosteum after aspirating for blood. In the studies, conducted by Sari et al., in both 2017, and 2018, the nerve was targeted as 1-1.5 cm from the upper lateral edge of patella.(16,51) So we calculated the average of this distance and it was 40.61 mm. This may not be an ideal target for both ultrasound and RFA.

The nerve was 60.18 mm medial to mid-point of superior surface of patella. This was measured in order to increase the accuracy of localisation. The nerve was found to be 41.1 mm superior to medial femoral condyle distal end, and 44.9 mm medial tibial condyle proximal end. And as expected the variables that are associated with height, are distance from medial femoral condyle, medial tibial condyle, junction of shaft and medial femoral condyle. (Table- 11) Hence these distances measured can change proportionately with height.

SLGN

SLGN was found to have two different origin, as was described by Fonkoue et al., and Kim et al., (44,46) It was found to be branching from the posterior articular nerve, a branch from the sciatic nerve, or common peroneal nerve, in 60 % of the specimens,(Figure: 32) and as a direct branch from common peroneal nerve, in 40% of the specimens.(Figure: 31) After making bony contact at the shaft condyle junction, it was found to be diving in to two branches. (Figure: 31) We noticed that, in some specimens, it’s the transverse branch that was getting stained, during this method of targeting at the junction, as the descending branch has already been descended and going towards the lateral femorotibial space. (Figure: 31) The nerve was having highly tortuous course. (Figure: 31) Tran et al described a nerve, that branches from common articular nerve, and supplies the superior part of the inferolateral capsule. He named it as ILGN.(47) In our study, we were unable to locate a nerve like that. In our observation the descending branch of the SLGN was supplying the superior part of the inferolateral joint capsule. Further exact definition and universalisation of the terminologies of the nerves are highly required in order to remove the confusion.

In group 1, the nerve was targeted, by locating the junction of shaft and epicondyle of lateral femur in coronal plane, and injecting at the lateral most end of lateral cortex in axial view, at the same level.(Figure: 6) Fonkoue et al., has targeted the nerve at the junction of lateral shaft and epicondyle, at the crest between lateral cortex and posterior cortex. (69) Vanneste et al., and Mittal et al., have targeted the nerve at lateral shaft-condyle junction of femur, and half the girth of the femur, in axial view. (54,59) Since the lateral most end of the lateral cortex, is almost half the girth of the femur, and its same as the crest between lateral and posterior cortex, we can conclude that, all these authors have targeted the nerve at the same landmark, but with different descriptions. Our study landmark was also, 100 % accurate. The nerve to needle distance was on an average 3.2 mm. While measuring the secondary objectives of our study, it was found that, the nerve was 3.88 mm from the junction of shaft and lateral condyle, from the crest between lateral and posterior cortex, or in other words, half the depth of femur. Hence at this point, SLGN can be targeted with high accuracy for both steroid injection and RFA.

The surface landmark guided method adopted in group 2 was found to be only 40 % accurate, with an average, nerve to needle distance of 10.1 mm. Both staining and nerve to needle distance is having statistically significant difference between two groups. (P value<0.001)

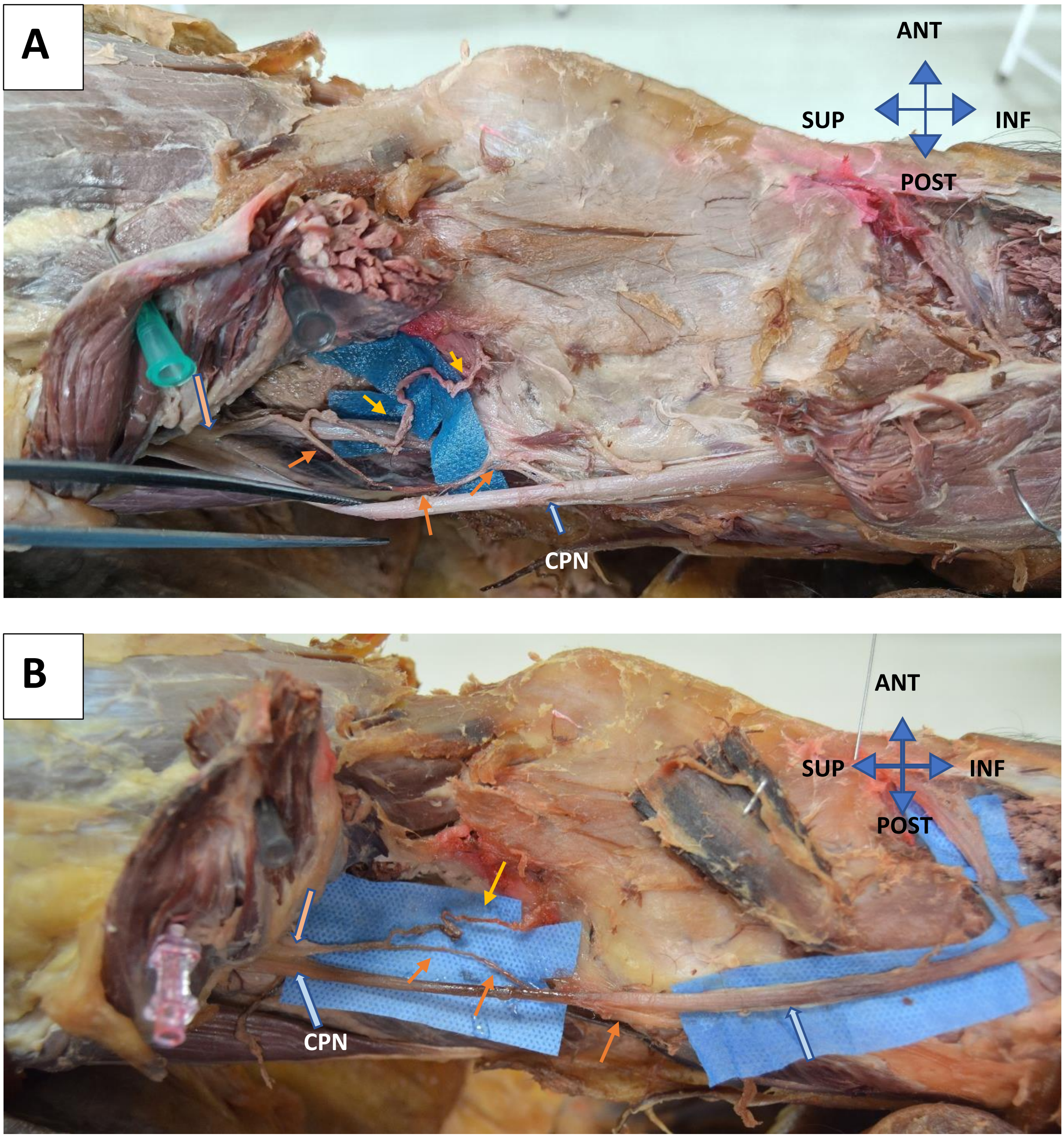


Figure 31: Course of SLGN. A, B- SLGN branching from the common peroneal nerve (orange thick arrow), and dividing into 2 branches. Yellow arrow- transverse branch. Orange arrow- descending branch. CPN- Common peroneal nerve (thick white arrow). Both are right knee specimens.

Other landmarks for localisation of SLGN

We observed that, the nerve is 1.73 mm distant from the corresponding artery, when it is making bony contact at the shaft epicondyle region. Hence visualising the arterial pulsation, and confirming it with colour doppler can be used for targeting SLGN, at the lateral femoral shaft-epicondyle region. This was done in many previous studies.(28,30,52,56,58,60,68,71,72) Adopting this technique is justifiable for both steroid injection and RFA.

As Sari et al., targeted the nerve at lower end of femur approximately 1-1.5 cm from lateral upper edge of patella, we measured this distance.(16,51) The average distance we got was 60.03mm, which is far beyond both steroid and RFA coverage. Hence this may not be a justifiable target point. We also measured the distance from the mid-point of the superior surface of patella, and the average came out to be 80.09. This was done to increase the accuracy if at all the above-mentioned technique is being used.

The ultrasound screening of knee preferably starts from the joint lines. Kim el at., described the distance of nerve's branching point to the lateral joint line as approximately 5.5 cm.(46) In our study, the distance of the nerves bony contact location, from lateral femoral condyle distal end was measured as average of 43.10mm, and from lateral tibial condyle proximal end was measured as 48.61 mm. As expected, this parameter, has significant association with length of cadaver. (Table 13) This indicates that the measurement from lateral joint line, as described by Kim et al., (46) as 5.5cm, is subjective to proportionately change with height of the person.

IMGN

IMGN was found to be arising from the tibial nerve in popliteal fossa, in 40 % of the knee specimens, as was described by Tran et al. and Robert et al. (47,49) (Figure: 32) In 60 % of the knee specimens it was found to be branching from the long articular branch from sciatic or tibial nerve, as was described by Kim et al. (46) (Figure: 33) Invariable of its origin, it traversed deep to the medial gastrocnemius, curving around the tibia, from posterior to anterior as a neurovascular bundle, beneath the medial collateral ligament.(Figure: 19) In group 1, we have targeted the nerve midway between the tibial condyle proximal end and the insertion of the deep fibres of MCL, as was done by Yasar et al., Wong et al., Kesikburun et al., and Ghai et al. (53,55,63,70) During dissection; we found that the nerve was coursing 8.86 mm above the insertion of deep MCL, and 9.30 mm below the proximal end of the medial tibia. Hence midway between these two points should be logically accurate, and in our study, we found this as 100% accurate, in terms of staining. The nerve to needle distance was 1.8mm, and this can be used for both steroid blocks, and RFA.

In group 2, we have targeted the nerve just distal to the medial tibial epicondyle, and was found to be 67% accurate. There was statistically significant difference between two groups, in terms of staining of the nerve, and nerve to needle distance. (p value= 0.042, p value < 0.001).

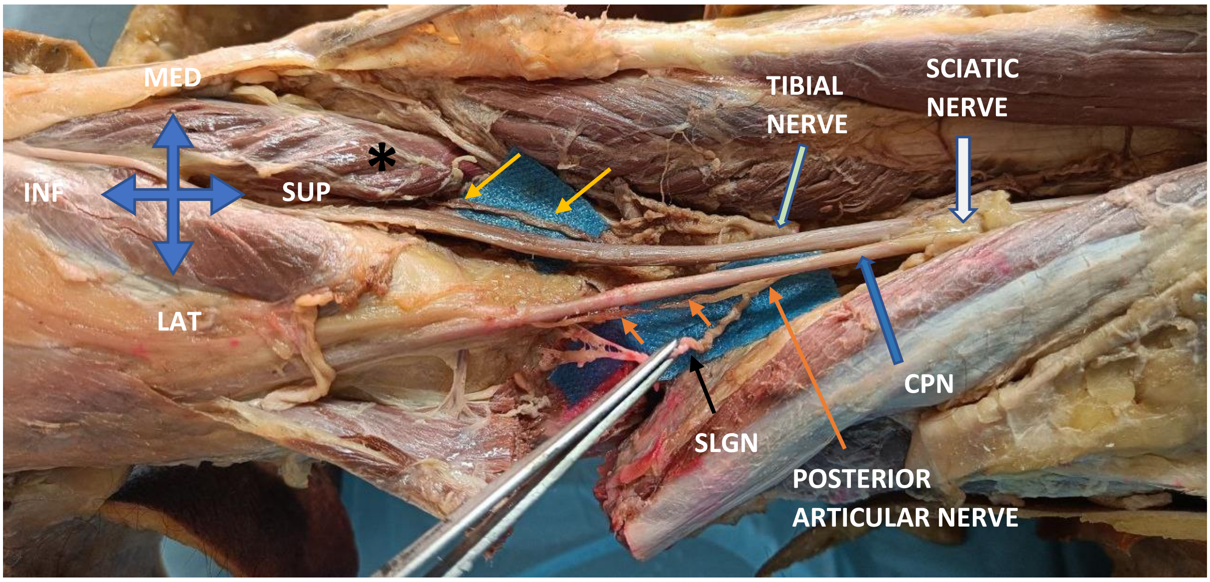


Figure 32: Popliteal fossa dissection- IMGN, and SLGN origin- The IMGN (Yellow arrow) arising from the tibial nerve and passing deep to the medial gastrocnemius (*). The SLGN branching from the posterior articular nerve, which in turn branches from the sciatic nerve. CPN- common peroneal nerve. SLGN- superolateral genicular nerve. Right knee specimen.

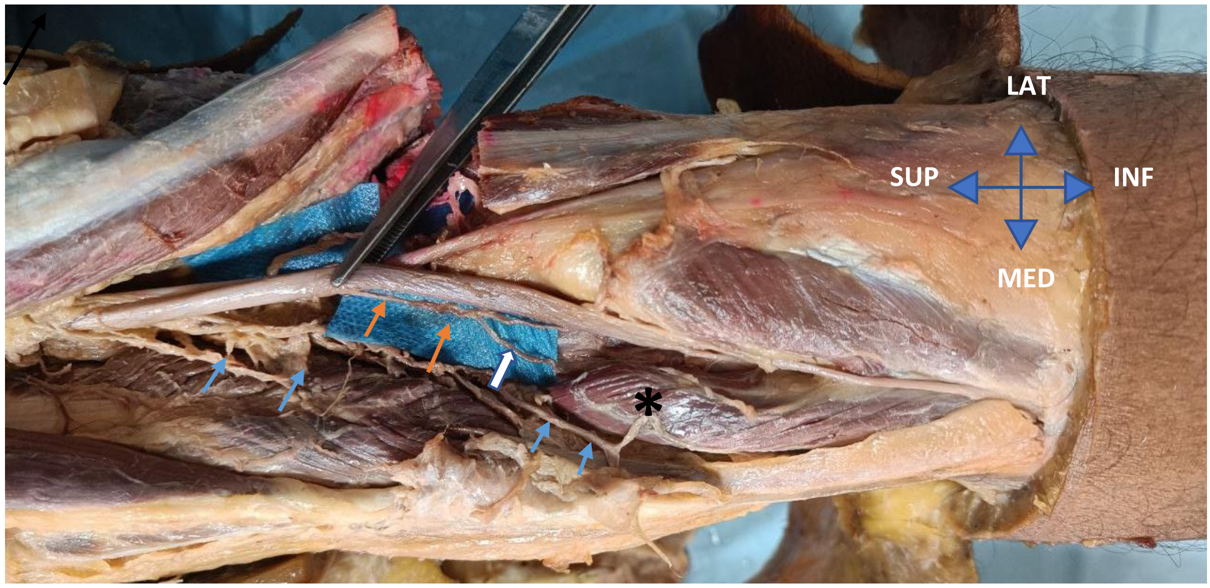


Figure 33: Popliteal fossa dissection- IMGN origin from articular nerve. Shows the articular nerve (orange arrow) supplying the posterior capsule, and giving branch as IMGN (white arrow), which traverses deep to medial gastrocnemius (*). Other muscular branches are shown in blue arrow. Right knee specimen.

Localisation of IMGN by other landmarks

In our study, the point of junction of shaft and medial condyle of tibia, was found to be 2.99 mm distant from the nerve. The distance of 2.99 mm comes within the average ablation diameter of RFA, and of course with steroid blocks. Hence this method, of using the junction of shaft and condyle, can be used, and this is justifiable. Kim et al., Ahmed and Arora, Vanneste et al., and Kose et al., have used this landmark and was found to be effective, for reduction of pain and stiffness in OA knee patients.(54,61,62,68,72)

The nerve was found to be 1.34 mm distant from the corresponding artery. Hence visualising the pulsation to target the nerve is justifiable, as was done in many previous studies, conducted by Yilmaz et al., Gular et al., Mittal et al., Elsaman et al., Gupta et al., Kim et al., and Kose et al.(28,30,56,58,59,68,72)

Fonkoue et al., and Lash et al., have targeted the nerve at the junction of the shaft and condyle, in longitudinal view, and to inject in the axial view, up to the 50 % girth of the tibia. (60,77)In our dissection we found that the nerve was following a horizontal course, along with the vessels, hence our observation is that, the girth of tibia, at which we target will not make any significant difference, for IMGN.

The nerve was on an average 48.48 mm inferior to medial femoral condyle distal end, which was significantly related to the height. The medial tibial condyle proximal end was 9.30 mm superior to the nerve. This in a combined way gives idea about the distance from medial joint line, as we start screening for this nerve from the medial joint line.

The nerve was found to be 65.10mm inferomedial to the inferior pole of patella. Sari et al used a target as 1-1.5 mm from lower medial end of patella.(16,51) But in our study, the distance are not correlating.

ILGN

In our dissection, we were able to identify only one consistent nerve supply to knee capsule in the inferolateral part of anterior knee capsule. Even though the targets described by USG and landmark guidance's, according to Ahmed et al., Cankurtaran et al., and Gupta et al., were for ILGN, (57,58,61,62) but the nerve that was in close proximity to the needle was identified as recurrent fibular nerve. The course was similar to the ILGN described by Fonkoue et al., in their anatomic study describing the joint capsule sensory in 2019 (44), whose terminology was changed to recurrent fibular nerve in subsequent studies. (75) In our dissection also, this nerve was present in 100% of the specimens. It emerged from the deep peroneal nerve, as its first branch and went deep to the anterior compartment muscles and then gave many muscular branches. It was joined by the anterior tibial recurrent genicular vessels and then ascended up between the Gerdy's tuberosity and tibial tuberosity to supply the lateral femorotibial space. (Figure: 34) The course was also in consistent with the recent literatures, and is called the recurrent fibular nerve. (46,64,69,75)

Kim et al., and Tran et al., have identified the ILGN, in recent literatures. Tran et al described the ILGN as a continuation of the long articular branch of the common peroneal nerve, running deep to the LCL to join the ILGN vessels and coming anteriorly just below the lateral femoral condyle. This innervates the upper part of the inferolateral quadrant. (50) Kim et al., described the ILGN as originating from common peroneal nerve in the popliteal fossa, and traversing deep to biceps femoris and iliotibial band, toward the lateral joint line. It was then joined by the inferolateral genicular vessels to innervate the lateral capsule.(46) But in our study, we were unable to identify such a nerve, consistently. In one of the cadaveric knee specimens we identified a nerve originating from the common peroneal nerve and was traversing deep to the biceps femoris and the ITB, and was piercing the lateral joint capsule at the lateral joint line.

(Figure: 35) In another, we found a nerve arising from CPN and traversing in the lateral femorotibial space, along with an artery, and giving descending branches to supply, between the Gerdy's tubercle and tibial tuberosity, and the proximal fibula-tibial space. (Figure: 36) We would like to consider this as some variations in the course of ILGN, and RGN respectively.

In our study we found that, both methods were 100 % accurate regarding staining of the nerve. The average nerve to needle distance was 2.65 mm in USG group (group 1), and 5.03 mm in surface landmark group (group 2). The nerve is ascending between the Gerdy's tubercle and the tibial tuberosity, so if we are targeting between the two, we are targeting the nerve near its main trunk. We also found that the nerve to the anterior group of muscles were also stained. But this is not an alarming concern as we will be using only the specified concentration, so as to cause sensory block, and for RFA, the motor block will be ruled out, by stimulating. In the USG group, we were targeting its more distal branches, near the joint space. The nerve was found just medial to the attachment of the coronary ligament, and we have inserted the needle under direct visualisation, to this point, hence the nerve to needle distance was significantly less, in group 1. But this cannot be considered more effective, as only few of its terminal branches are being targeted. As a result, we believe that the new USG validation by Fonkoue et al. to block this nerve 2 cm below the Gerdy's tubercle after visualisation of the anterior tibial recurrent artery is a viable method. (69) Moreover, we have seen the nerve being joined by an artery around this place in 100 % of the cadaveric knee specimens, with a nerve to artery distance of 1.07 mm (Figure: 37) We also found that the distance of Gerdy's tubercle from the nerve vertically is 6.01mm, on average. This was measured when the nerve was travelling the closest to Gerdy's tubercle. This distance is found to have a statistically significant association with the length of the cadavers. Hence there is no need of targeting 2 cm below Gerdy's tubercle, at least in Indian population.

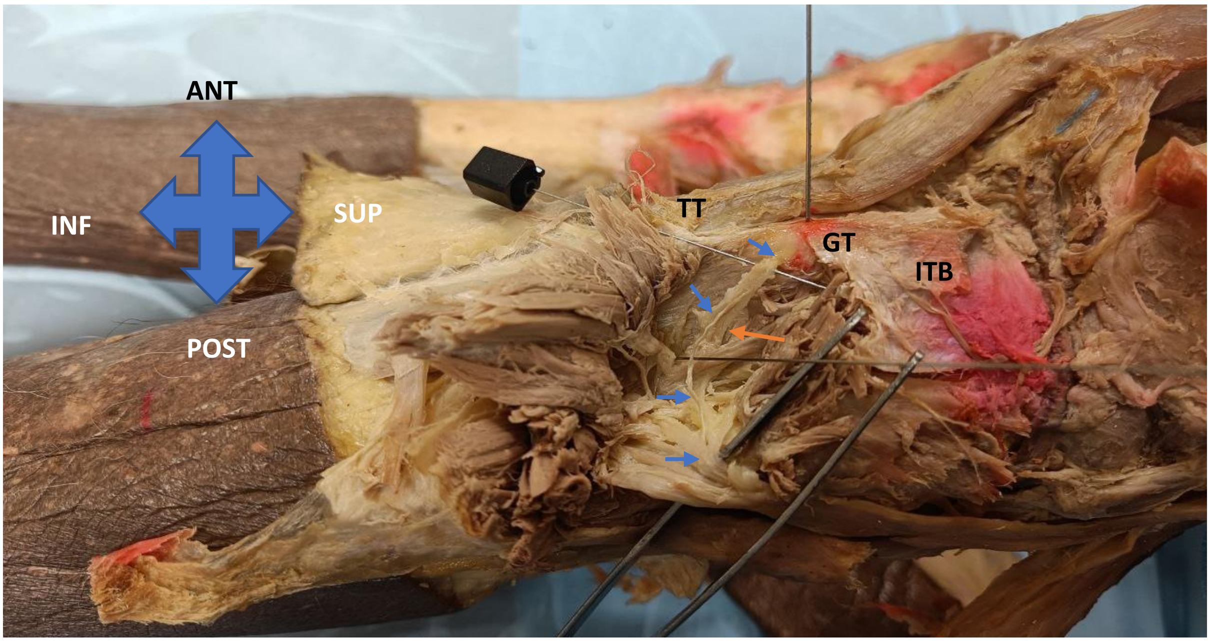


Figure 34: Course of ILGN: ILGN(RGN) represented by blue arrow, joined by the recurrent fibular vessels [red arrow] and traversing between the GT and tibial tuberosity. ITB- Iliotibial band. Left knee specimen.

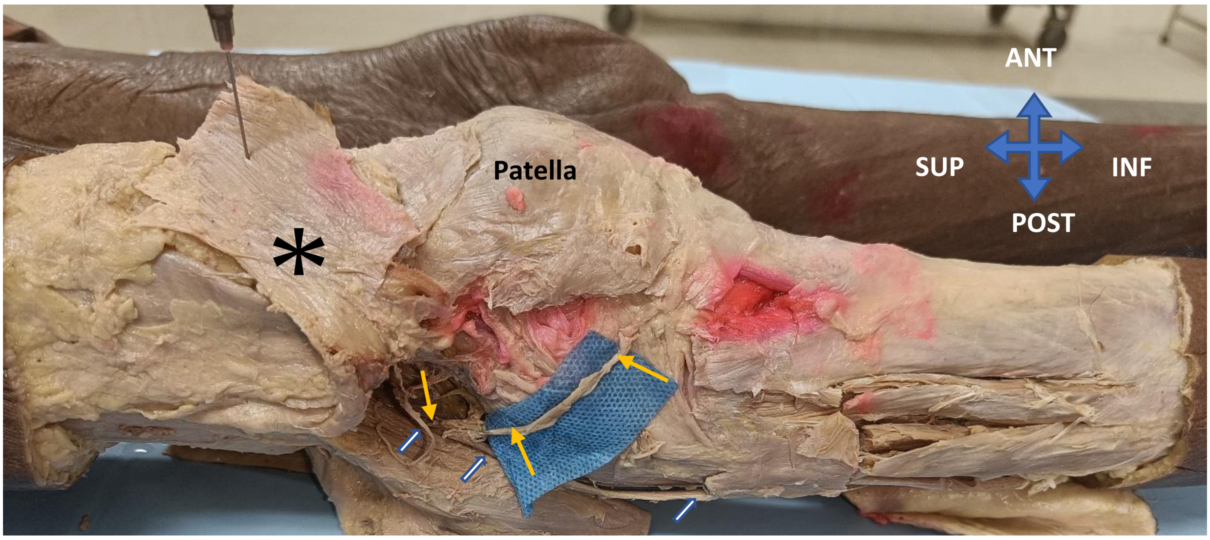


Figure 35: ILGN identified as described by Tran et al: A nerve arising from the Common peroneal nerve (White arrow), travelling deep to the biceps femoris and ITB (cut and retracted). Right knee specimen.*

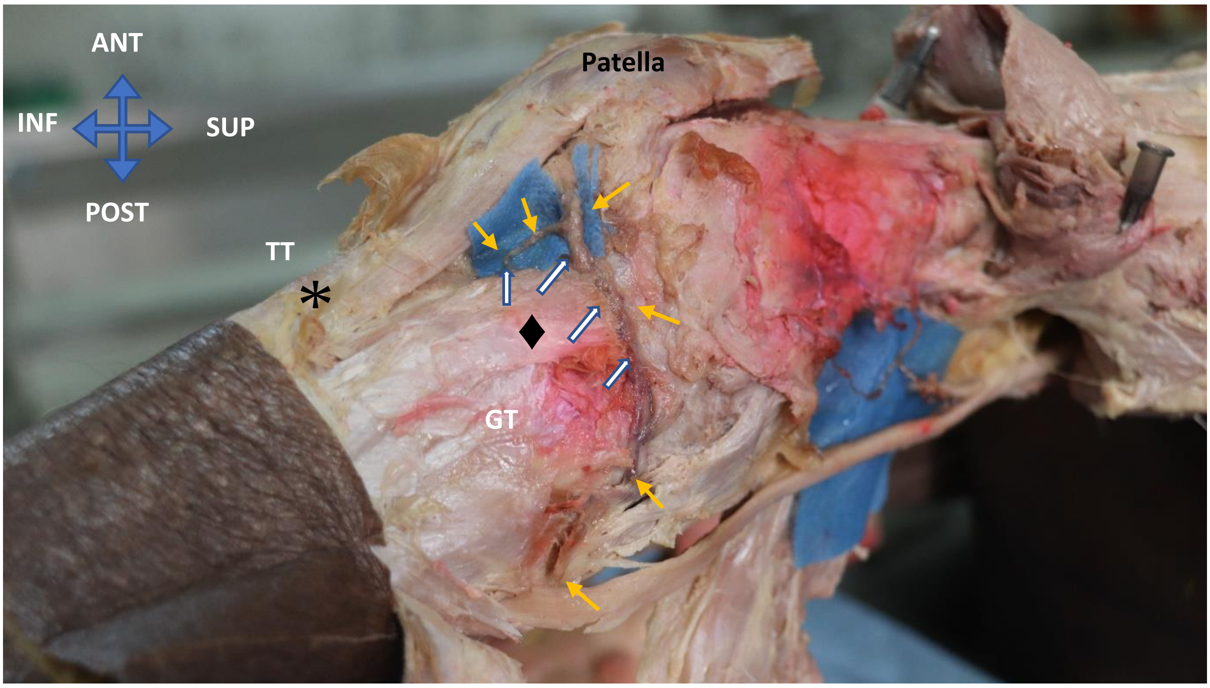


Figure 36: Variation in the course of ILGN: A genicular nerve (yellow arrow) arising from the common fibular nerve and joining an artery (white thick arrow) and running in the femorotibial space, and giving a descending branch to the area between tibial tuberosity (TT) and Gerdy's tubercle. (GT ♦) Left knee specimen.*

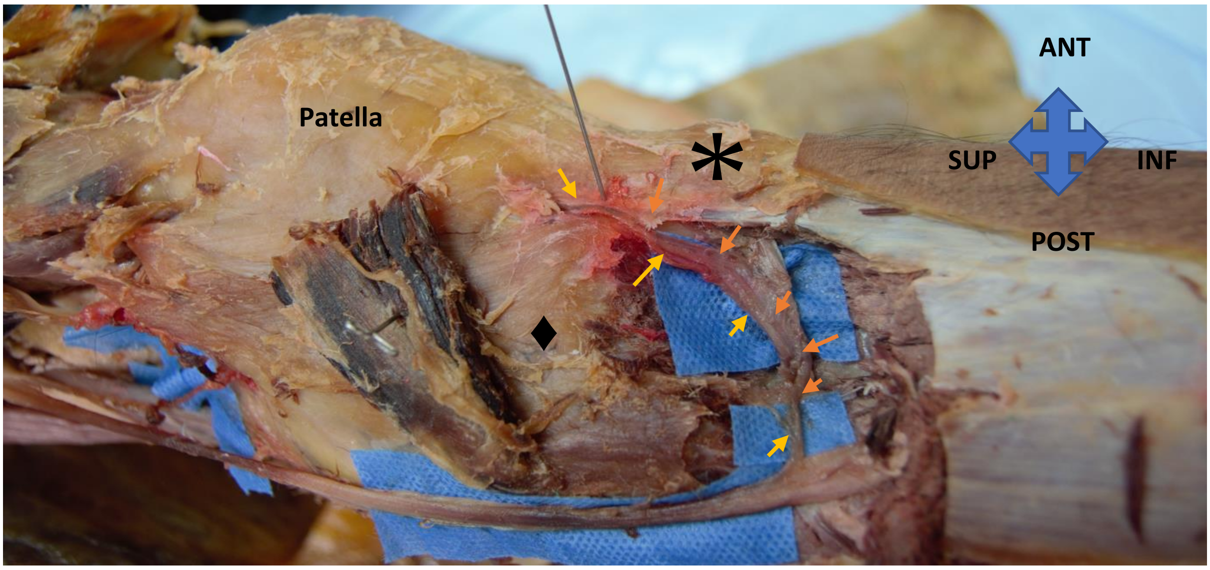


*Figure 37: ILGN(RGN) joined by the anterior tibial recurrent artery. RGN (Yellow arrow) Anterior tibial recurrent vessels(orange arrow), ♦Gerdy's tubercle, * Tibial tuberosity. Right knee specimen.*

Localisation of ILGN by other landmarks

As the studies targeting this nerve were limited, we have chosen some easily identifiable landmarks, and some vital structures from which the distances were measured. The nerve was found to be coursing 6.01 mm inferior to the Gerdy's tubercle prominence, the closest. The tibial tuberosity was around 8.70 mm medial to the nerve at the closest. From the inferior pole of patella, the nerve was 46.47 mm lateral, at the closest. From the lateral femoral condyle distal end, and lateral tibial condyle proximal end, the nerve main trunk was, 16.62mm and 13.91 mm, respectively, at the closest. These parameters were associated with length of the cadaver. Hence the distance from lateral joint line is subjective to change with height. The fibular head neck junction was 45.19 mm away, and common peroneal nerve from the target point of RGN (When joined by vessels, and after giving all motor branches) was 50.8 mm away. Hence the fear of having a foot drop, which was the major reason for not targeting genicular nerve on inferolateral knee, is not relevant with this technique, and RGN can be safely targeted with steroid injection, and RFA. Caution should be taken to use the most required amount of solution, in right concentration, as the motor branches are also present in the same fascial compartment.

MGN

For middle genicular nerve, we found that the nerve was consistently present in the roof of suprapatellar recess, with middle genicular vessels, in 100% of the specimens. After which it divided in to multiple branches and supplied the capsule. Ahmed and Arora has targeted the nerve at the roof of the suprapatellar recess. (61,62) In our study, in USG Group we have targeted at the roof of the suprapatellar fossa level, and it was found to be 100 % accurate, in terms of staining. (Figure 38) The nerve to needle distance was 2.28 mm. It can be concluded that both steroid block and RFA of MGN can be done with this landmark.

In the surface landmark group, we have targeted 5 cm proximal from superior border of patella, in the midline, as was described by Lash et al., (60) In our dissection, we found that, MGN was not always in the midline, it was having variable mediolateral shift. The accuracy was only 13 %, in terms of staining, and nerve to needle distance was 6.48, in this group. The staining and nerve to needle distance was having statistically significant difference between two groups. (p value<0.001, p value - 0.03) Hence it is advisable to target MGN at the roof of the suprapatellar recess, under ultrasound guidance.

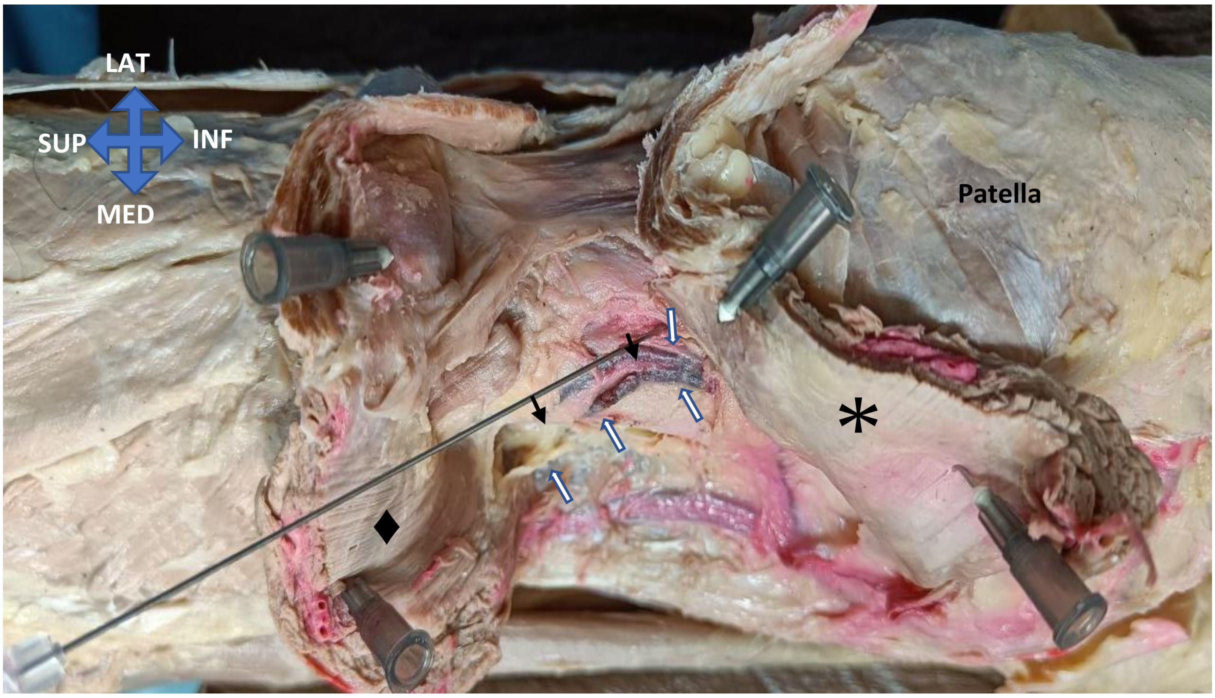


*Figure 38: Course of MGN. MGN (Black arrow), in the roof of the suprapatellar recess, along with the corresponding vascular bundle (White thick arrow). * Quadriceps tendon, ♦ Quadriceps muscle cut and retracted. Right knee specimen.*

Localisation of MGN by other landmarks

There are very few studies targeting MGN. Hence, we have chosen some easily identifiable landmarks, and some vital structures, to measure the distances in secondary objective. We have tried to define the nerve in terms of measurements from patella. (Figure:39) The nerve, before branching, was 32.37 mm superior to the midpoint of the anterior patellar surface, with 12.59 mm superior to the midpoint of the upper patellar border. Considering the mediolateral shift, the nerve was more towards the medial side. As is evident from the distance of the nerve from the superomedial pole of patella- 20.41, as compared to the distance from the superolateral pole of patella- 31.79. Also, the distance from medial femoral condyle distal end – 51.6 mm is less than that from the lateral femoral condyle distal end- 54.7. Hence, the MGN lies in the roof of the suprapatellar recess, and slightly towards the medial side.

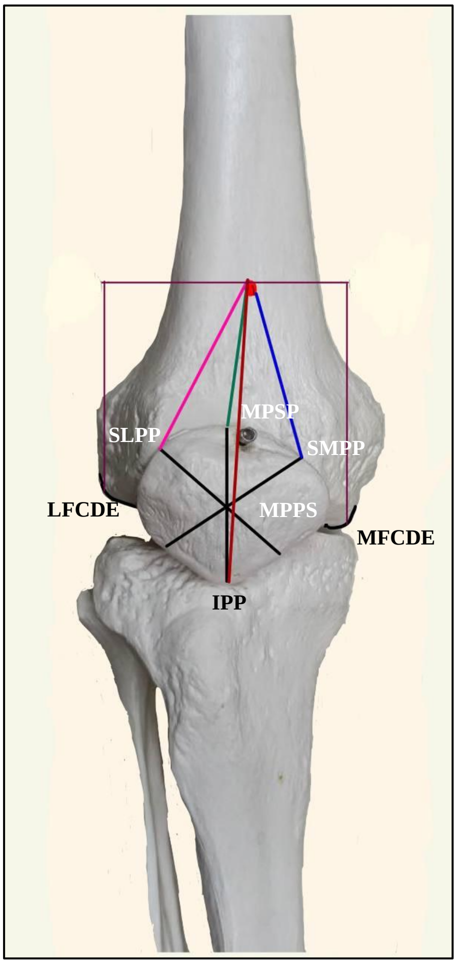


Figure 39: Schematic diagram showing the landmarks from which the distance of MGN was measured. MFCDE- Medial femoral condyle distal end, SMPP- Superomedial pole of patella, MPSP- Midpoint of superior surface of patella, LFCDE- Lateral femoral condyle distal end, SLPP- Superolateral pole of patella, IPP- Inferior pole of patella, MPPS- Midpoint of patellar surface.

IPBSN

Though not included in this study, we were able to appreciate this nerve consistently in all cadaveric knee specimens. The nerve was arising from the saphenous nerve, and was running in the subcutaneous plane, above the MCL, and piercing the inferomedial part of the joint capsule. (Figure: 40) we found that it is almost 4 cm medial to the patellar lateral surface, and the tibial tuberosity, as was described by Ikeuchi et al. (79)

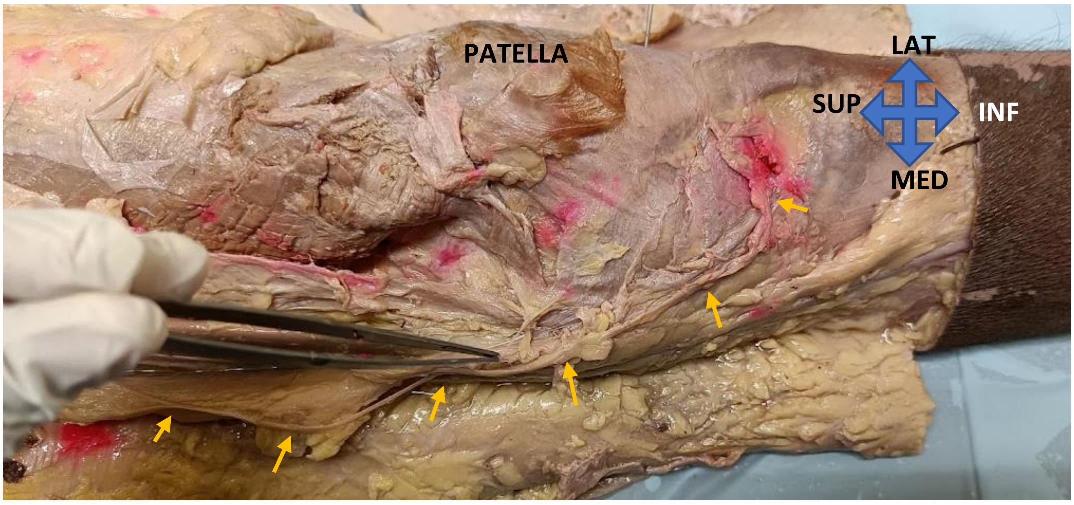


Figure 40: IPBSN Course. IPBSN dissected out from the subcutaneous plane, supplying the inferomedial part of the joint capsule. (Yellow arrow) Left knee specimen.

CONCLUSION

CONCLUSION

- The ultrasound guided genicular nerve block is more accurate than surface landmark guided techniques, for SMGN, SLGN, IMGN, and MGN, when targeted at the specified landmarks used in this study.
- Visualising the defined bony landmarks under USG guidance, makes the genicular nerve block more accurate.
- SMGN can be accurately targeted in relation to adductor tubercle. (1 cm anterior to AT) For increased accuracy, SMG artery pulsation can be looked around this region.
- SLGN can be accurately targeted at the level of shaft- epicondyle junction of lateral femur, over the crest between the posterior and lateral cortex in axial view. Also locating SLG artery pulsation, around this region, can increase the accuracy.
- The ILGN landmarks used in this study was found to be targeting recurrent fibular nerve.
- The recurrent fibular nerve can be targeted between Gerdy's tubercle and tibial tuberosity. It can also be targeted below Gerdy's tubercle, visualising the anterior tibial recurrent artery pulsation. With this RFA can be given, safely, but not preferably nerve block, as the muscular branches were also found to be stained. There may be chance of developing foot drop.
- The IMGN can also be targeted in relation to corresponding artery, and shaft medial condyle junction of tibia.

STRENGHTS

- Five genicular nerves were studied.
- The landmarks were confirmed in both coronal and axial view, prior to injection
- The needle was firmly fixed to periosteum to decrease the movement, further an assistant was holding in position, throughout dissection.
- The cadavers were relatively fresh, with very less length variation.
- The microdissection was done, under magnification through a loupes microscope.

LIMITATION OF STUDY

- The landmarks used in the study for ILGN, was found to be targeting a nerve with recurrent course, and on latest literature, this nerve has been termed as the recurrent genicular nerve/ recurrent fibular nerve.
- The IPBSN was not included in the study.

FURTHER STUDY RECOMMENDATIONS

- Accuracy of the infrapatellar branch of the saphenous nerve, can be studied.
- As we found that, targeting the genicular nerves by visualising bony landmarks, under ultrasound guidance is accurate, a comparative study, with C-arm guided technique can be proposed.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Bunt CW, Jonas CE, Chang JG. Knee pain in adults and adolescents: the initial evaluation. American family physician. 2018 Nov 1;98(9):576-85.

2. Farrell ME, Gutierrez G, Desai MJ. Demonstration of lesions produced by cooled radiofrequency neurotomy for chronic osteoarthritic knee pain: a case presentation. Pm&r. 2017 Mar 1;9(3):314-7.

3. Safiri S, Kolahi AA, Smith E, Hill C, Bettampadi D, Mansournia MA, Hoy D, Ashrafi-Asgarabad A, Sepidarkish M, Almasi-Hashiani A, Collins G. Global, regional and national burden of osteoarthritis 1990-2017: a systematic analysis of the Global Burden of Disease Study 2017. Annals of the rheumatic diseases. 2020 Jun 1;79(6):819-28.

4. Xie J, Wang Y, Lu L, Liu L, Yu X, Pei F. Cellular senescence in knee osteoarthritis: molecular mechanisms and therapeutic implications. Ageing Research Reviews. 2021 Sep 1;70:101413.

5. Hunter DJ, Bierma-Zeinstra S. Osteoarthritis. Lancet Lond Engl. 2019 Apr 27;393(10182):1745–59.

6. Kolasinski SL, Neogi T, Hochberg MC, Oatis C, Guyatt G, Block J, Callahan L, Copenhaver C, Dodge C, Felson D, Gellar K. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis & Rheumatology. 2020 Feb;72(2):220-33.

7. Overview | Osteoarthritis: care and management | Guidance | NICE [Internet]. NICE; [cited 2022 May 8]. Available from: https://www.nice.org.uk/guidance/cg177

8. Migliore A, Gigliucci G, Alekseeva L, Avasthi S, Bannuru RR, Chevalier X, Conrozier T, Crimaldi S, Damjanov N, de Campos GC, Diracoglu D. Treat-to-target strategy for knee osteoarthritis. International technical expert panel consensus and good clinical practice statements. Therapeutic Advances in Musculoskeletal Disease. 2019 Dec;11:1759720X19893800.

9. Hauk L. Treatment of knee osteoarthritis: a clinical practice guideline from the AAOS. Am Fam Physician. 2014 Jun 1;89(11):918–20.

10. Sinusas K. Osteoarthritis: diagnosis and treatment. American family physician. 2012 Jan 1;85(1):49-56.

11. Podmore B, Hutchings A, van der Meulen J, Aggarwal A, Konan S. Impact of comorbid conditions on outcomes of hip and knee replacement surgery: a systematic review and meta-analysis. BMJ open. 2018 Jul 1;8(7):e021784.

12. Gonzalez FM. Cooled radiofrequency genicular neurotomy. Techniques in Vascular and Interventional Radiology. 2020 Dec 1;23(4):100706.

13. Lipnick S. Editorial Commentary: Radiofrequency Ablation for Patients With Osteoarthritis of the Knee Could Be Indicated for Patients Failing Conventional Nonoperative Treatment and Wishing to Avoid Total Knee Arthroplasty. Arthroscopy: The Journal of Arthroscopic & Related Surgery. 2022 Jul 1;38(7):2303-6.

14. Choi WJ, Hwang SJ, Song JG, Leem JG, Kang YU, Park PH, Shin JW. Radiofrequency treatment relieves chronic knee osteoarthritis pain: a double-blind randomized controlled trial. PAIN®. 2011 Mar 1;152(3):481-7..

15. Kirdemir P, Catav S, Solmaz FA. The genicular nerve: radiofrequency lesion application for chronic knee pain. Turkish journal of medical sciences. 2017;47(1):268-72.

16. Sarı S, Aydın ON, Turan Y, Özlülerden P, Efe U, Kurt Ömürlü İ. Which one is more effective for the clinical treatment of chronic pain in knee osteoarthritis: Radiofrequency neurotomy of the genicular nerves or intra-articular injection?. International journal of rheumatic diseases. 2018 Oct;21(10):1772-8.

17. Pineda MM, Vanlinthout LE, Martín AM, van Zundert J, Huertas FR, Ruiz JP. Analgesic effect and functional improvement caused by radiofrequency treatment of genicular nerves in patients with advanced osteoarthritis of the knee until 1 year following treatment. Regional Anesthesia & Pain Medicine. 2017 Jan 1;42(1):62-8.

18. Wylde V, Beswick A, Bruce J, Blom A, Howells N, Gooberman-Hill R. Chronic pain after total knee arthroplasty. EFORT open reviews. 2018 Aug 16;3(8):461-70.

19. Kukreja P, Venter A, Mason L, Kofskey AM, Northern T, Naranje S, Ghanem E, Lawson PA, Kalagara H. Comparison of genicular nerve block in combination with adductor canal block in both primary and revision total knee arthroplasty: a retrospective case series. Cureus. 2021 Jul 29;13(7).

20. Khan FM, Tran A, Wong PK, Aiyedipe S, Loya MF, Cristescu MM, Gonzalez FM. Management of uncomplicated total knee arthroplasty chronic pain and stiffness utilizing cooled radiofrequency ablation: a single institution pilot study. Skeletal Radiology. 2022 Jun;51(6):1215-23.

21. Rambhia M, Chen A, Kumar AH, Bullock WM, Bolognesi M, Gadsden J. Ultrasound-guided genicular nerve blocks following total knee arthroplasty: a randomized, double-blind, placebo-controlled trial. Regional Anesthesia & Pain Medicine. 2021 Oct 1;46(10):862-6.

22. Stake S, Agarwal AR, Coombs S, Cohen JS, Golladay GJ, Campbell JC, Thakkar SC. Total Knee Arthroplasty After Genicular Nerve Radiofrequency Ablation: Reduction in Prolonged Opioid Use Without Increased Postsurgical Complications. JAAOS Global Research & Reviews. 2022 Aug;6(8).

23. Qudsi-Sinclair S, Borrás-Rubio E, Abellan-Guillén JF, Padilla del Rey ML, Ruiz-Merino G. A comparison of genicular nerve treatment using either radiofrequency or analgesic block with corticosteroid for pain after a total knee arthroplasty: A double-blind, randomized clinical study. Pain Practice. 2017 Jun;17(5):578-88..

24. Ghai B, Kumar M, Makkar JK, Goni V. Comparison of ultrasound guided pulsed radiofrequency of genicular nerve with local anesthetic and steroid block for management of osteoarthritis knee pain. The Korean Journal of Pain. 2022 Apr 1;35(2):183-90.

25. McCormick ZL, Korn M, Reddy R, Marcolina A, Dayanim D, Mattie R, Cushman D, Bhave M, McCarthy RJ, Khan D, Nagpal G. Cooled radiofrequency ablation of the genicular nerves for chronic pain due to knee osteoarthritis: six-month outcomes. Pain Medicine. 2017 Sep 1;18(9):1631-41..

26. McCormick ZL, Reddy R, Korn M, Dayanim D, Syed RH, Bhave M, Zhukalin M, Choxi S, Ebrahimi A, Kendall MC, McCarthy RJ. A prospective randomized trial of prognostic genicular nerve blocks to determine the predictive value for the outcome of cooled radiofrequency ablation for chronic knee pain due to osteoarthritis. Pain Medicine. 2018 Aug 1;19(8):1628-38.

27. Davis T, Loudermilk E, DePalma M, Hunter C, Lindley D, Patel N, Choi D, Soloman M, Gupta A, Desai M, Buvanendran A. Prospective, multicenter, randomized, crossover clinical trial comparing the safety and effectiveness of cooled radiofrequency ablation with corticosteroid injection in the management of knee pain from osteoarthritis. Regional Anesthesia & Pain Medicine. 2018 Jan 1;43(1):84-91.

28. Güler T, Yurdakul FG, Önder ME, Erdoğan F, Yavuz K, Becenen E, Uçkun A, Bodur H. Ultrasound-guided genicular nerve block versus physical therapy for chronic knee osteoarthritis: a prospective randomised study. Rheumatology International. 2022 Apr;42(4):591-600.

29. Broida SE, Wong PK, Umpierrez E, Kakarala A, Reimer NB, Gonzalez FM. Alternate treatment approach to subchondral insufficiency fracture of the knee utilizing genicular nerve cooled radiofrequency ablation and adjunctive bisphosphonate supplementation: A case report. Radiology Case Reports. 2020 Jun 1;15(6):691-6.

30. Elsaman AM, Maaty A, Hamed A. Genicular nerve block in rheumatoid arthritis: a randomized clinical trial. Clinical Rheumatology. 2021 Nov;40(11):4501-9.

31. Deviandri R, Yuliana V, Irawan D, Rahman AN. Genicular nerve radiofrequency ablation for pain control following anterior cruciate ligament reconstruction - A case report. Trauma Case Rep. 2022 Aug;40:100661.

32. Radwan A, Ohrndorf S, Aly H, Hamed M, Khalifa A, Elsaman AM. Genicular nerve block in juvenile idiopathic arthritis: a randomized clinical trial. Clinical Rheumatology. 2022 Oct 5:1-0.

33. Bellini M, Barbieri M. Cooled radiofrequency system relieves chronic knee osteoarthritis pain: the first case-series. Anaesthesiology intensive therapy. 2015;47(1):30-3.

34. Iannaccone F, Dixon S, Kaufman A. A review of long-term pain relief after genicular nerve radiofrequency ablation in chronic knee osteoarthritis. Pain physician. 2017;20(3):E437.

35. Wu L, Li Y, Si H, Zeng Y, Li M, Liu Y, et al. Radiofrequency Ablation in Cooled Monopolar or Conventional Bipolar Modality Yields More Beneficial Short-Term Clinical Outcomes Versus Other Treatments for Knee Osteoarthritis: A Systematic Review and Network Meta-Analysis of Randomized Controlled Trials. Arthrosc - J Arthrosc Relat Surg. 2022;38(7):2287–302.

36. Chou SH, Shen PC, Lu CC, Liu ZM, Tien YC, Huang PJ, Chou CM, Shih CL. Comparison of efficacy among three radiofrequency ablation techniques for treating knee osteoarthritis: A systematic review and meta-analysis. International journal of environmental research and public health. 2021 Jul 12;18(14):7424.

37. Liu J, Wang T, Zhu ZH. Efficacy and safety of radiofrequency treatment for improving knee pain and function in knee osteoarthritis: a meta-analysis of randomized controlled trials. Journal of orthopaedic surgery and research. 2022 Dec;17(1):1-4.

38. Li G, Zhang Y, Tian L, Pan J. Radiofrequency ablation reduces pain for knee osteoarthritis: A meta-analysis of randomized controlled trials. International Journal of Surgery. 2021 Jul 1;91:105951.

39. Koshi E, Cheney CW, Sperry BP, Conger A, McCormick ZL. Genicular nerve radiofrequency ablation for chronic knee pain using a three-tined electrode: A technical description and case series. Pain Medicine. 2020 Dec;21(12):3344-9.

40. Kidd VD, Strum SR, Strum DS, Shah J. Genicular nerve radiofrequency ablation for painful knee arthritis: the why and the how. JBJS essential surgical techniques. 2019 Mar 26;9(1):e10..

41. Bogduk N, Macintosh J, Marsland A. Technical limitations to the efficacy of radiofrequency neurotomy for spinal pain. Neurosurgery. 1987 Apr 1;20(4):529-35..

42. Cosman Jr ER, Dolensky JR, Hoffman RA. Factors that affect radiofrequency heat lesion size. Pain Medicine. 2014 Dec 1;15(12):2020-36.

43. Schneider BJ, Doan L, Maes MK, Martinez KR, Gonzalez Cota A, Bogduk N, Standards Division of the Spine Intervention Society. Systematic review of the effectiveness of lumbar medial branch thermal radiofrequency neurotomy, stratified for diagnostic methods and procedural technique. Pain Medicine. 2020 Jun 1;21(6):1122-41.

44. Fonkoué L, Behets C, Kouassi JÉ, Coyette M, Detrembleur C, Thienpont E, Cornu O. Distribution of sensory nerves supplying the knee joint capsule and implications for genicular blockade and radiofrequency ablation: an anatomical study. Surgical and Radiologic Anatomy. 2019 Dec;41(12):1461-71.

45. Gardner E. The innervation of the knee joint. The Anatomical Record. 1948 May;101(1):109-30.

46. Kim JH, Shustorovich A, Arel AT, Downie SA, Cohen SP, Kim SY. Genicular nerve anatomy and its implication for new procedural approaches for knee joint denervation: A cadaveric study. Pain Medicine. 2022 Jan;23(1):144-51.

47. Tran J, Peng PW, Lam K, Baig E, Agur AM, Gofeld M. Anatomical study of the innervation of anterior knee joint capsule: implication for image-guided intervention. Regional Anesthesia & Pain Medicine. 2018 May 1;43(4):407-14.

48. Tran J, Peng PW, Chan VW, Agur AM. Overview of innervation of knee joint. Physical Medicine and Rehabilitation Clinics. 2021 Nov 1;32(4):767-78.

49. Roberts SL, Stout A, Dreyfuss P. Review of knee joint innervation: implications for diagnostic blocks and radiofrequency ablation. Pain Medicine. 2020 May 1;21(5):922-38.

50. Tran J, Agur A, Peng P. Revisiting the anatomical evidence supporting the classical landmark of genicular nerve ablation. Regional Anesthesia & Pain Medicine. 2019 Dec 4.

51. Sarı S, Aydın ON, Turan Y, Şen S, Özlülerden P, Ömürlü İK, Gulastı F. Which imaging method should be used for genicular nerve radio frequency thermocoagulation in chronic knee osteoarthritis?. Journal of clinical monitoring and computing. 2017 Aug;31(4):797-803.

52. Wong J, Bremer N, Weyker PD, Webb CA. Ultrasound-guided genicular nerve thermal radiofrequency ablation for chronic knee pain. Case reports in anesthesiology. 2016 Oct 16;2016.

53. Evren Yasar MD, Serdar Kesikburun MD, Cenk Kılıç MD, Ümüt Güzelküçük MD. Accuracy of ultrasound-guided genicular nerve block: a cadaveric study. Pain Physician. 2015 Sep;18:E899-904.

54. Vanneste B, Tomlinson J, Desmet M, Krol A. Feasibility of an ultrasound-guided approach to radiofrequency ablation of the superolateral, superomedial and inferomedial genicular nerves: a cadaveric study. Reg Anesth Pain Med. 2019 Aug 12;rapm-2019-100381.

55. Kesikburun S, Yasar E, Uran A, Adiguzel E, Yilmaz B. Ultrasound-guided genicular nerve pulsed radiofrequency treatment for painful knee osteoarthritis: a preliminary report. Pain Physician. 2016;19(5):E751.

56. Yilmaz V, Umay E, Gundogdu I, Aras B. The comparison of efficacy of single intraarticular steroid injection versus the combination of genicular nerve block and intraarticular steroid injection in patients with knee osteoarthritis: a randomised study. Musculoskeletal surgery. 2021 Apr;105(1):89-96.

57. Cankurtaran D, Karaahmet OZ, Yildiz SY, Eksioglu E, Dulgeroglu D, Unlu E. Comparing the effectiveness of ultrasound guided versus blind genicular nerve block on pain, muscle strength with isokinetic device, physical function and quality of life in chronic knee osteoarthritis: a prospective randomized controlled study. The Korean Journal of Pain. 2020 Jul 1;33(3):258-66.

58. Gupta N, Begum SA, Biswas A, Saha D, Ghosal V, Haldar RN, et al. A randomized open label comparative study on efficacy of ultrasonography guided vis a vis anatomical landmark guided genicular nerve block in knee osteoarthritis in a tertiary care hospital in Eastern India. Int J Health Clin Res. 2020 Nov 1;3(8):148–53.

59. Mittal N, Catapano M, Peng PW. Knee Ablation Approaches. Physical Medicine and Rehabilitation Clinics. 2021 Nov 1;32(4):779-90.

60. Lash D, Frantz E, Hurdle MF. Ultrasound-guided cooled radiofrequency ablation of the genicular nerves: a technique paper. Pain Management. 2020 May;10(3):147-57.

61. Ahmed A, Arora D. Ultrasound-guided radiofrequency ablation of genicular nerves of knee for relief of intractable pain from knee osteoarthritis: a case series. British journal of pain. 2018 Aug;12(3):145-54.

62. Ahmed A, Arora D. Ultrasound-Guided Neurolysis of Six Genicular Nerves for Intractable Pain from Knee Osteoarthritis: A Case Series. Pain practice. 2019 Jan;19(1):16-26.

63. Wong PK, Kokabi N, Guo Y, Reiter D, Reimer NB, Oskouei S, Gonzalez FM. Safety and efficacy comparison of three-vs four-needle technique in the management of moderate to

severe osteoarthritis of the knee using cooled radiofrequency ablation. Skeletal Radiology. 2021 Apr;50(4):739-50.

64. Fonkoue L, Steyaert A, Kouame JE, Bandolo E, Lebleu J, Fossoh H, Behets C, Detrembleur C, Cornu O. A comparison of genicular nerve blockade with corticosteroids using either classical anatomical targets vs revised targets for pain and function in knee osteoarthritis: a double-blind, randomized controlled trial. Pain Medicine. 2021 May;22(5):1116-26.

65. Sperry BP, Conger A, Kohan L, Walega DR, Cohen SP, McCormick ZL. A proposed protocol for safe radiofrequency ablation of the recurrent fibular nerve for the treatment of chronic anterior Inferolateral knee pain. Pain Medicine. 2021 May;22(5):1237-41.

66. Gonzalez FM. Cooled radiofrequency genicular neurotomy. Techniques in Vascular and Interventional Radiology. 2020 Dec 1;23(4):100706.

67. Park MR, Kim D, Yu JH, Hong J, Yoon S, Lee D, Koh JC. An anatomical neurovascular study for procedures targeting peri-articular nerves in patients with anterior knee pain. The Knee. 2020 Oct 1;27(5):1577-84.

68. Kim DH, Choi SS, Yoon SH, So-Hee L, Seo DK, Lee IG, Woo-Jong C, Jin-Woo S. Ultrasound-guided genicular nerve block for knee osteoarthritis: a double-blind, randomized controlled trial of local anesthetic alone or in combination with corticosteroid. Pain Physician. 2018;21(1):41.

69. Fonkoue L, Stoenoiu MS, Behets CW, Steyaert A, Kouassi JE, Detrembleur C, Cornu O. Validation of a new protocol for ultrasound-guided genicular nerve radiofrequency ablation with accurate anatomical targets: cadaveric study. Regional Anesthesia & Pain Medicine. 2021 Mar 1;46(3):210-6.

70. Ghai B, Kumar M, Makkar JK, Goni V. Comparison of ultrasound guided pulsed radiofrequency of genicular nerve with local anesthetic and steroid block for management of osteoarthritis knee pain. The Korean Journal of Pain. 2022 Apr 1;35(2):183-90.

71. Chang YW, Tzeng IS, Lee KC, Kao MC. Functional Outcomes and Physical Performance of Knee Osteoarthritis Patients After Ultrasound-Guided Genicular Nerve Radiofrequency Ablation. Pain Medicine. 2022 Feb;23(2):352-61.

72. Kose SG, Kose HC, Celikel F, Akkaya OT. Predictive factors associated with successful response to utrasound guided genicular radiofrequency ablation. The Korean Journal of Pain. 2022 Oct 1;35(4):447-57.

73. Franco CD, Buvanendran A, Petersohn JD, Menzies RD, Menzies LP. Innervation of the anterior capsule of the human knee: implications for radiofrequency ablation. Regional Anesthesia & Pain Medicine. 2015 Jul 1;40(4):363-8.

74. Valls JM, Vallejo R, Pais PL, Soto E, Rodríguez DT, Cedeño DL, Tornero CT, Rodríguez MQ, González AB, Escudero JÁ. Anatomic and ultrasonographic evaluation of the knee sensory innervation: a cadaveric study to determine anatomic targets in the treatment of chronic knee pain. Regional Anesthesia & Pain Medicine. 2017 Jan 1;42(1):90-8.

75. Fonkoue L, Behets CW, Steyaert A, Kouassi JE, Detrembleur C, De Waroux BL, Cornu O. Accuracy of fluoroscopic-guided genicular nerve blockade: a need for revisiting anatomical landmarks. Regional Anesthesia & Pain Medicine. 2019 Oct 1;44(10):950-8.

76. Fonkoue L, Behets CW, Steyaert A, Kouassi JE, Detrembleur C, De Waroux BL, Cornu O. Current versus revised anatomical targets for genicular nerve blockade and radiofrequency ablation: evidence from a cadaveric model. Regional Anesthesia & Pain Medicine. 2020 Aug 1;45(8):603-9.

77. Fonkoue L, Behets C, Steyaert A, Kouassi JE, Detrembleur C, Cornu O. Anatomical study of the descending genicular artery and implications for image-guided interventions for knee pain. Clinical Anatomy. 2021 May;34(4):634-43.

78. Ikeuchi M, Ushida T, Izumi M, Tani T. Percutaneous radiofrequency treatment for refractory anteromedial pain of osteoarthritic knees. Pain Medicine. 2011 Apr 1;12(4):546-51.

ANNEXURES

ANNEXURE- 1

अखिल भारतीय आयुर्विज्ञान संस्थान, जोधपुर

All India Institute of Medical Sciences, Jodhpur

संस्थागत नैतिकता समिति

Institutional Ethics Committee

No. AIIMS/IEC/2021/ 3564 **Date: 12/03/2021**

ETHICAL CLEARANCE CERTIFICATE

Certificate Reference Number: **AIIMS/IEC/2021/3399**

Project title: **"Accuracy of Genicular nerve block by ultrasound guided versus landmark guided techniques - A Cadaveric study"**

Nature of Project:	**Research Project Submitted for Expedited Review**
Submitted as:	**M.D. Dissertation**
Student Name:	**Dr. Chinchu K**
Guide:	**Dr. Nitesh Manohar Gonnade**
Co-Guide:	**Dr. Ravi Gaur, Dr. Ashish Kumar Nayyar & Dr. Pawan Kumar Garg**

Institutional Ethics Committee after thorough consideration accorded its approval on above project.

The investigator may therefore commence the research from the date of this certificate, using the reference number indicated above.

Please note that the AIIMS IEC must be informed immediately of:

- Any material change in the conditions or undertakings mentioned in the document.
- Any material breaches of ethical undertakings or events that impact upon the ethical conduct of the research.

The Principal Investigator must report to the AIIMS IEC in the prescribed format, where applicable, bi-annually, and at the end of the project, in respect of ethical compliance.

AIIMS IEC retains the right to withdraw or amend this if:

- Any unethical principle or practices are revealed or suspected
- Relevant information has been withheld or misrepresented

AIIMS IEC shall have an access to any information or data at any time during the course or after completion of the project.

Please Note that this approval will be rectified whenever it is possible to hold a meeting in person of the Institutional Ethics Committee. It is possible that the PI may be asked to give more clarifications or the Institutional Ethics Committee may withhold the project. The Institutional Ethics Committee is adopting this procedure due to COVID-19 (Corona Virus) situation.

If the Institutional Ethics Committee does not get back to you, this means your project has been cleared by the IEC.

On behalf of Ethics Committee, I wish you success in your research.

Dr. Praveen Sharma
Member Secretary

Member secretary
Institutional Ethics Committee
AIIMS,Jodhpur

Basni Phase-2, Jodhpur, Rajasthan-342005; **Website:** www.aiimsjodhpur.edu.in; **Phone:** 0291-2740741 Extn. 3109
E-mail : ethicscommittee@aiimsjodhpur.edu.in; ethicscommitteeaiimsjdh@gmail.com

ANNEXURE- 2

Data collection form

Cadaveric knee specimen number –

Type of intervention (ultrasound guided / blind technique)-

Length of Cadaver-

Sex of Cadaver-

Serial no:	Nerve	Staining of the nerve (yes or no)	Nerve to needle distance (mm)
1	SMGN		
2	IMGN		
3	SLGN		
4	ILGN		
5	MGN		

Distance of SMGN from-

I. Medial femoral condyle distal end (MFCDE) -
II. Medial tibial condyle proximal end (MTCPE) -
III. Junction of shaft and condyle (JSC) -
IV. Superomedial pole of patella (SMPP) -
V. Midpoint of superior surface of patella (MPSP)-
VI. Adductor tubercle (AT)-
VII. Superior medial genicular artery (SMGA)-

Distance of the IMGN from

I. Insertion of medial collateral ligament (IMCL)-
II. Junction of shaft and medial epicondyle of tibia (JSMET)-
III. Medial tibial condyle proximal end (MTCPE)-
IV. Medial femoral condyle distal end (MFCDE)-
V. Tibial tuberosity (TT)-
VI. Inferior pole of patella (IPP)-
VII. Inferior medial genicular artery (IMGA)-

Distance of the SLGN from,

I. Insertion of medial collateral ligament (IMCL)-
II. Junction of shaft and medial epicondyle of tibia (JSMET) –
III. Medial tibial condyle proximal end (MTCPE)-
IV. Medial femoral condyle distal end (MFCDE)-
V. Tibial tuberosity (TT)-
VI. Inferior pole of patella (IPP)-
VII. Inferior medial genicular artery (IMGA)-

Distance of the ILGN from-

I. Lateral tibial condyle proximal end (LTEPE)-
II. Lateral femoral condyle distal end (LFCDE)-
III. Junction of shaft and lateral epicondyle of tibia (JSLET)-
IV. Fibular head- neck junction (FHNJ)-
V. Tibial tuberosity proximal point (TTPP)-
VI. Gerdy's tubercle medial point (GTMP)-
VII. Inferior pole of patella (IPP)-
VIII. Common peroneal nerve division (CPND)-
IX. Inferior lateral genicular artery (ILGA)-

Distance of the middle genicular nerve from-

I. Midpoint of patellar surface (MPPS)-
II. Midpoint of superior border of patella (MPSBP)-
III. Superolateral pole of patella (SLPP)-
IV. Superomedial pole of patella (SMPP)-
V. Medial femoral condyle distal end (MFCDE)-
VI. Lateral femoral condyle distal end (LFCDE)-
VII. Middle genicular artery (MGA)-

MASTER CHART

CADAVERIC KNEE SPECIMEN No.	HEIGHT	SEX	MODALITY	SMGN_STAINED	SMGN_NND	IMGN_STAINED	IMGN_NND	SLGN_STAINED	SLGN_NND	ILGN_STAINED	ILGN_NND	MGN_STAINED	MGN_NND	SMGN_MFCDE	SMGN_MTCPE	SMGN_AT	SMGN_JSC	SMGN_SMGA	SMGN_SMPP	SMGN_MPSP
1	162	M	USG	1	2.12	1	1.11	1	3.3	1	1.6	1	1.2	46.6	49.08	9.69	16.56	0.9	41.4	64.22
2	162	M	USG	1	2.01	1	1.01	1	3.1	1	1.4	1	1.04	44.78	48.84	10.62	16.84	0.28	41.76	63.44
3	159	M	S.LAND	1	4.86	0	8.89	0	10.1	1	5.02	0	6.2	37.92	40.22	4.83	16.89	0.08	39.8	58.76
4	159	M	USG	1	1.66	1	0.98	1	2.9	1	2.03	1	2.09	40.1	44.03	11.06	16.93	0.8	48.9	59.86
5	160	M	S.LAND	0	8.92	1	4.02	0	9.89	1	4.03	0	6.7	42.1	47.82	9.7	16.98	1.7	44.3	56.99
6	160	M	USG	1	1.34	1	1.03	1	3.21	1	1.04	1	2.33	44.6	48.75	11.4	16.9	1.7	35.56	54.56
7	156	F	USG	1	1.22	1	1	1	2.9	1	2.09	1	1.88	32.76	36.92	10.58	16.89	1.56	38.45	58.32
8	156	F	S.LAND	0	9.08	0	9.6	0	11.89	1	4.9	0	6.24	34.09	38.93	10.56	16.83	1.34	36.92	57.43
9	160	M	S.LAND	1	3.82	1	3.8	0	13.02	1	4.34	0	6.72	42.45	46.82	8.98	16.87	1.56	40.54	60.54
10	160	M	S.LAND	0	10.45	1	4.2	1	4.88	1	3.45	0	6.63	41.05	46.22	10.75	16.98	1.98	41.56	62.56
11	158	F	S.LAND	1	4.44	1	3.89	0	12.98	1	6.87	0	6.42	36.05	41.23	12.03	16.98	1.39	42.53	60.43
12	152	F	USG	0	9.22	1	2.4	1	3.01	1	2.65	1	2.34	34.98	37.23	2.87	16.45	1.03	44.62	61.83
13	174	M	USG	1	1.8	1	2.01	1	4.23	1	3.04	1	2.28	50.6	54.88	12.02	17.7	0.98	40.43	60.34
14	172	M	S.LAND	1	4.54	0	9.32	1	6.01	1	5.02	1	5.98	49.78	53.92	11.04	17.43	2.09	45.78	63.45
15	168	M	USG	1	1.53	1	2.08	1	3.42	1	3.98	1	2.22	45.08	48.43	10.42	16.93	1.78	40.43	59.45
16	168	M	S.LAND	0	9.98	1	3.98	1	8.22	1	6.01	0	6.52	46.78	49.45	9.59	16.78	1.94	36.44	57.33
17	170	M	USG	1	1.67	1	1.88	1	4.2	1	3.01	1	1.88	48.09	52.81	8.56	17.01	3.09	37.12	58.97
18	170	M	USG	1	1.56	1	2.88	1	3.26	1	2.98	1	2.22	47.98	50.34	9.62	17.2	2.01	34.93	56.45
19	154	F	S.LAND	0	9.08	0	8.65	0	16.89	1	5.24	1	6.98	35.06	39.33	10.3	15.98	1.09	39.56	59.89
20	154	F	S.LAND	0	10.45	0	9.88	0	12.02	1	7.67	0	6.97	36.54	40.23	11.6	15.79	1.89	40.34	60.45
21	152	F	S.LAND	0	8.65	1	2.98	1	7.09	1	5.03	0	6.24	29.98	34.43	12.87	15.73	1.94	41.45	61.98
22	152	F	USG	1	1.78	1	2	1	4.32	1	2.98	1	2.56	28.87	32.83	13.69	16.57	1.45	39.56	60.43
23	168	M	USG	1	1.88	1	2.7	1	3.45	1	3.02	1	2.45	47.9	50.34	11.59	16.98	1.38	43.99	62.56
24	168	M	S.LAND	1	4.52	1	2.9	0	11.7	1	6.02	0	6.33	46.85	51.44	10.43	16.95	1.78	42.45	61.53
25	153	F	USG	1	1.68	1	1.8	1	3.2	1	3.67	1	2.34	30.04	34.53	8.98	16.97	1.94	37.98	59.56
26	153	F	USG	1	1.43	1	1.5	1	3.08	1	2.22	1	3.24	32.98	36.45	7.98	16.59	1.56	39.29	60.12
27	170	M	USG	1	1.45	1	1.45	1	3.14	1	1.45	1	3.67	46.78	50.34	9.45	17.09	1.79	42.32	63.45
28	170	M	S.LAND	1	4.47	1	3.48	0	12.01	1	7.33	0	6.63	44.04	48.33	10.84	17.6	2.03	40.32	60.32
29	167	F	S.LAND	0	9.46	1	3.83	1	7.89	1	2.69	0	6.53	42.87	45.32	11.87	16.92	1.67	40.11	60.45
30	167	F	S.LAND	1	5.67	1	4	1	6.86	1	6.26	0	6.43	43.98	47.56	10.48	17.03	1.87	39.58	59.87

CADAVERIC KNEE SPECIMEN No.	IMGN_IMCL	IMGN_MTCPE	IMGN_JSMET	IMGN_MFCDE	IMGN_IMGA	IMGN_TT	IMGN_IPP	SLGN_LFCDE	SLGN_LTCPE	SLGN_JSLEF	SLGN_SLGA	SLGN_SLPP	SLGN_MPSP	ILGN_JSLET	ILGN_CPND	ILGN_LTEPE
1	8.69	8.88	2.98	46.98	1	36.08	65.44	42.48	47.35	1.08	0.9	59.22	77.98	29.53	46	12.35
2	8.86	8.96	3.02	47.66	0.09	40.01	62.43	40.26	45.16	3.83	0.44	59.66	78.74	32.84	48	14.53
3	8.67	8.56	5.66	49.79	2	41.22	64.92	42.46	47.36	1.28	1.01	57.45	77.98	26.82	46	11.59
4	8.56	8.99	3.75	48.79	0.92	37.81	66.32	43.58	48.88	1.06	0.92	65.55	87.67	30.54	48	13.36
5	8.3	7.98	4.32	48.78	0.84	38.43	65.35	42.54	47.34	3.2	1.2	59.34	80.12	28.08	49	13.98
6	9.2	8.67	3.02	48.67	2.3	39.61	65.45	43.83	47.81	2.98	2.54	58.85	67.45	30.04	50	14.8
7	8.88	7.98	2.95	47.45	0.89	38.94	67.43	44.41	10.11	3.76	2.35	62.46	83.21	29.82	49.4	13.98
8	8.67	9.86	2.09	47.9	1.01	41.54	65.36	42.45	48.35	1.89	1.98	60.43	80.47	29.78	49.83	12.89
9	8.97	8.56	3.06	48.65	1.04	40.78	65.32	42.67	50.17	3.82	1.78	61.42	81.34	30.73	50.43	13.98
10	9.01	8.67	2.98	48.52	0.93	39.88	67.23	45.49	50.42	2.56	1.65	60.44	80.42	30.58	51.56	14.39
11	8.98	8.89	2.67	47.34	0.97	38.98	67.46	42.89	47.22	3.7	1.04	61.39	81.45	29.78	49.74	12.92
12	8.4	8.53	2.56	47.01	0.67	39.08	64.09	41.09	47.43	4.85	1.74	63.54	82.34	28.94	51.93	11.56
13	9.2	10.7	3.09	50.2	1.22	39.6	69.24	45.12	51.32	5.93	1.38	57.53	78.45	30.89	55.4	15.76
14	9.06	10.76	3.04	50.01	1.03	40.67	61.65	49.72	53.44	6.82	1.09	62.32	81.35	30.94	55.98	16.43
15	8.98	9.78	2.98	49.44	1.56	39.56	66.03	43.03	49.45	4.39	3.01	57.99	77.51	30.67	56.83	14.67
16	8.74	8.75	2.88	49.74	1.45	40.87	60.45	47.71	52.33	4.14	1.93	58.67	79.21	29.83	49.78	14.56
17	9.04	9.08	2.98	49.8	1.87	40.98	68.45	44.67	51.22	3.88	2.69	59.53	80.43	28.59	50.56	15.94
18	8.99	10.66	3.01	49.78	0.38	38.79	69.43	45.84	51.99	1.67	2.4	52.33	73.12	28.93	49.82	15.84
19	8.56	9.34	2.45	47.62	0.98	36.9	66.42	43.93	52.54	4.29	1.59	57.57	78.45	27.93	50.88	13.92
20	8.44	8.95	2.76	46.56	2.7	38.79	65.43	42.76	49.34	3.87	1.93	59.96	80.45	26.97	55.98	11.09
21	8.67	9.44	2.35	46.32	1.89	38.99	64.53	42.09	47.65	5.69	1.49	60.42	82.19	25.83	54.83	10.4
22	8.66	9.69	2.56	46.01	1.45	39.87	63.45	3.98	46.77	6.39	1.73	61.45	82.21	27.56	49.95	11.43
23	9.88	10.6	2.98	48.56	0.98	38.95	66.26	43.91	49.34	2.98	1.59	62.21	83.78	28.89	45.87	14.93
24	9.76	9.77	2.86	48.66	1.78	38.56	65.89	42.89	47.35	6.39	1.83	61.21	81.35	29.78	44.89	13.56
25	8.55	10.72	2.47	47.56	1.98	37.95	66.74	43.5	49.22	4.99	1.96	58.53	79.45	28.56	50.65	12.73
26	8.98	9.36	2.45	49.67	1.845	39.78	64.53	41.78	48.36	2.84	2.67	59.12	80.43	27.56	47.41	14.73
27	9.01	8.93	3.02	49.99	1.65	37.99	60.43	47.05	53.53	4.82	1.39	62.43	82.45	30.84	49.62	16.74
28	8.99	9.42	2.99	49.82	1.38	38.79	63.67	50.82	57.44	5.67	1.78	60.21	80.43	31.98	56.98	15.34
29	8.56	9.63	2.87	48.52	1.79	38.49	62.31	50.98	55.78	2.95	1.93	60.11	82.31	30.73	55.93	14.93
30	8.64	8.99	2.76	48.69	1.58	37.65	61.42	48.95	53.77	4.76	2.09	59.42	79.89	30.56	53.98	13.88

CADAVERIC KNEE SPECIMEN No.	ILGN_LFCDE	ILGN_FHNJ	ILGN_ILGA	ILGN_GTMP	ILGN_TTPP	ILGN_IPP	MGN_MPPS	MGN_MPSBP	MGN_LFCDE	MGN_MFCDE	MGN_MGA	MGN_SMPP	MGN_SLPP
1	15.23	45.81	1.2	3.01	9.06	47.51	36.56	12.03	56.3	50.2	1.08	20.31	29.54
2	17.34	48.91	1.03	2.59	8.65	46.45	36.18	11.87	58.56	54.16	1.14	24.12	30.45
3	14.32	40.32	1.4	4.93	7.02	43.25	35.27	10.56	52.76	58.55	2.33	15.98	32.94
4	17.54	46.81	1.23	6.65	9.06	46.32	34.56	12.84	57.32	71.2	2.73	14.78	31.94
5	16.65	40.5	0.8	6.2	6.76	45.33	36.67	14.67	55.87	54.02	1.09	24.37	30.67
6	17.42	45.78	1.02	5.98	8.94	48.54	34.87	13.92	54.59	56.92	1.1	20.55	29.56
7	16.36	45.67	0.9	6.92	10.67	46.89	33.67	11.57	53.93	50.83	0.94	19.89	26.98
8	15.43	43.86	0.98	5.84	7.65	45.23	26.84	13.09	50.43	45.92	2.03	20.01	28.78
9	16.67	44.82	1.43	5.94	8.78	46.25	35.89	11.84	48.72	42.01	2.87	18.79	30.73
10	17.65	47.83	0.95	6.65	6.78	43.56	26.83	10.56	55.89	45.92	0.98	19.95	32.34
11	15.53	43.28	1.02	6.23	9.56	49.56	25.69	11.72	46.39	42.98	1.97	20.06	31.94
12	14.43	44.67	1.09	5.98	6.59	46.23	34.91	13.88	44.62	42.47	1.67	20.32	30.76
13	17.64	49.52	1.28	7.55	7.46	47.98	28.93	11.83	58.67	59.67	1.57	18.97	34.65
14	18.95	50.34	0.98	6.83	8.64	47.28	38.78	10.56	57.49	56.93	1.42	22.93	29.78
15	17.23	49.67	0.67	5.67	9.43	43.51	27.1	12.84	54.66	60.43	1.48	20.68	30.55
16	17.34	42.84	0.94	5.64	10.23	44.67	29.56	12.2	57.34	55.42	2.93	19.91	31.83
17	18.53	43.72	1.22	8.74	9.65	47.59	30.56	11.9	55.86	50.23	1.73	19.85	32.09
18	17.98	42.91	1.31	7.63	8.56	46.39	33.65	13.84	54.94	47.91	1.09	22.04	33.02
19	15.99	44.89	0.79	5.83	7.94	45.32	32.94	11.56	55.67	40.89	1.93	23.08	31.98
20	14.01	48.67	0.97	5.53	9.43	46.73	35.82	12.9	54.93	43.09	1.03	19.79	30.45
21	13.02	47.83	0.97	5.02	8.56	48.96	31.64	13.84	53.82	46.92	1.23	19.88	31.88
22	14.82	43.92	1.32	5.93	10.56	45.87	26.92	14.93	56.9	43.82	1.11	21.06	30.12
23	17.83	39.78	1.31	6.76	6.49	49.65	36.63	11.74	60.45	50.75	1.32	20.03	32.45
24	16.43	38.42	1.21	6.54	7.86	46.88	33.68	12.98	53.92	53.76	1.82	23.09	33.87
25	15.82	44.92	0.98	5.34	9.73	43.94	29.56	11.54	52.98	54.7	1.23	14.94	29.87
26	17.74	40.43	0.79	5.59	8.76	47.63	30.55	11.09	54.78	53.28	2.32	20.53	28.98
27	19.32	42.81	1.2	6.96	9.84	46.99	35.48	14.92	56.94	49.83	2.25	19.59	36.54
28	18.42	49.54	1.11	5.98	9.78	42.98	32.81	14.89	55.39	56.88	1.72	22.75	34.56
29	17.35	49.53	0.98	5.95	9.64	48.92	29.56	13.92	54.72	53.82	2.01	23.92	37.45
30	15.72	47.83	1.05	5.84	8.79	47.57	28.94	11.78	56.93	54.68	1.34	19.98	36.86