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Annals of Orthopedics & Rheumatology

Research Article

Peri-Articular Regional Analgesia in Total Knee Arthroplasty. A Review of The Neuroanatomy And Injection Technique

George N. Guild III[1]*, Rubin P Galindo[1], Joseph Marino[3], Fred D. Cushner[2] and Giles R. Scuderi[2]

[1]Insall Scott Kelly Institute for Orthopedics and Sports Medicine, Lenox Hill Hospital - North shore LIJ Health System, USA

[2]Insall Scott Kelly Institute for Orthopedics and Sports Medicine, Lenox Hill Hospital - Northshore LIJ Health System, USA

[3]Department of Anesthesia, North shore LIJ Health System, USA

Abstract

Introduction: Preoperative pain control after total knee athroplasty may be insufficient resulting in insomnia, antalgic ambulation, and difficulty with rehabilitation. Current strategies, including the use of femoral nerve catheters, may control pain but have been associated with falls, motor blockade, and quadriceps inhibition. Periarticular infiltration (PAI) with the appropriate technique and knowledge of intrarticular knee anatomy may increase pain control and maximize rehabilitation.

Materials and methods: We reviewed current available literature using MEDLINE and other search engines regarding human knee innervation. Search terms included "knee innervation," "pain control," and other terms. Studies were excluded if they did not provide pertinent information on human knee innervation or studies that were not in English. We used this literature to summarize human knee innervation and relevant areas of increased mechanoreceptors with free nerve endings to systematically guide periarticular infiltration.

Results and discussion: Evidence from the literature supports the use of periarticular injections for the relief of pain following total knee arthroplasty. Effective use of PAI requires specific knowledge of the relevant neuroanatomy of the knee. Based upon a review of the literature we have identified eight areas around the knee that have an increased number of nerve endings and should be infiltrated with the anesthetic agents. Concentrating the PAI injection to these areas with a long acting liposomal bupivacaine can aid in improving postoperative pain following total knee arthroplasty.

Conclusion: Perioperative pain management with PAI and liposomal bupivacaine is a safe and effective method of controlling pain after total knee arthroplasty. The use of a systematic approach to periarticular injection with knowledge of intrarticular knee innervation may improve perioperative pain control after total knee arthroplasty, and decrease complications associated with femoral nerve blockade.

Special Issue on

Modern Anesthesia Techniques for Total Joint Arthroplasty: from Blood Preservation to Modern Pain Control

*Corresponding author

George N. Guild III, Insall Scott Kelly Institute for Orthopedics and Sports Medicine, Lenox Hill Hospital - North shore LIJ Health System, 1513 Bates Court NE, Atlanta, GA 30319, Tel: 404-916-5303; Email: georgeguild@yahoo.com

Submitted: 05 April 2014

Accepted: 28 May 2014

Published: 30 May 2014

Keywords

- Periarticular
- Injection
- Total knee arthroplasty

ABBREVIATIONS

PAI: Periarticular Injection

INTRODUCTION

Total knee arthroplasty is a frequently performed procedure and the incidence is expected to increase 673% to 3.48 million procedures annually by 2030 [1]. Current literature confirms that total knee arthroplasty is an effective treatment for osteoarthritis with excellent outcomes [2]. Despite these results, postoperative pain management may be insufficient and prevent patients from sleeping, ambulating, and participating with physical therapy [3,4]. Numerous strategies have been devised to control postoperative pain and reduce opioid consumption including neuraxial anesthesia and peripheral nerve blocks. Continuous femoral nerve blockade in particular, is associated with a 1%-

2.5% incidence of muscle weakness, nerve damage, and local infection with 57% of catheters colonized at 48 hours [5-9].

In addition to peripheral nerve blocks, parenteral narcotics continue to be a mainstay of perioperative pain management despite its significant side effects [10-12]. Oderda et al, demonstrated that opioid-related adverse drug events following surgery were associated with significantly increased length of stay and hospitalization costs [13]. With the goal of decreasing these adverse drug events, multimodal pain pathways have been developed to block pain at its source. Furthermore, a successful multimodal pathway should control pain, but also maximize muscle control, promote rehabilitation, and decrease venous stasis. Peri-articular injection (PAI), as an adjunct to multimodal pain management pathways, accomplishes both of these goals [14].

Evidence from the literature supports the use of PAI. In a study by Venditolli, morphine consumption was lower in the PAI group compared to the control group for up to 40 hours postoperatively [14]. Other authors have compared different PAI protocols and reported lower narcotic consumption and lower pain scores compared to the femoral nerve block [15,16]. In a recent prospective randomized trial by Chaumeron, PAI provided equivalent pain control up to 120 hours without the 37% incidence of motor blockade experienced by the femoral nerve block group [17]. Patients with PAI had increased capacity to perform straight leg raise, active knee extension, and ambulate than the femoral nerve block group. In this article, we review the relevant neuroanatomy of knee with specific attention to the areas that are the most sensitive and should be infiltrated with an anesthetic.

Methods

The current available literature on knee neuroanatomy, pain generators, and concentrations of mechanoreceptors were reviewed. The databases searched include MEDLINE, MEDLINE In-Process, EMBASE, BIOSIS, Clinicaltrials.gov, and Cochrane Database of Systematic Reviews. Full text searching of key surgical journals was also performed. Searches were not restricted by study design, publication year, or language, and conference proceedings and abstracts were included in the search. Reference lists of all included studies were scanned to identify additional relevant studies. Search terms included "knee innervation," "pain control," "knee mechanoreceptor," "sartorial nerve," "saphenous nerve," "common peroneal nerve," and "tibial nerve." Studies were excluded if they did not provide pertinent information on human knee innervation or studies that were not in English. Our search produced 56 articles of which 15 met inclusion criteria. We summarize human knee innervation and relevant areas of increased mechanoreceptors below.

The Neuroanatomy

The degree to which the intrarticular components of the knee generate neurosensory signals that reach the spinal, cerebellar, and higher central nervous system levels is variable. These signals ultimately result in conscious perception [18]. In a study by Biedert et al, histologic examination of free nerve endings in the human knee was performed in an effort to describe which intrarticular areas contain increased nerve endings and mechanoreceptors [19]. They found that the retinacula, the patellar ligament, the pes anserinus, and in the ligaments of Wrisberg and Humphry had the greatest amount of free nerve endings, with the lowest amount was found in the anterior cruciate ligament. In a correlate study by Dye et al, conscious patients underwent knee arthroscopy without anesthesia, and were able to identify which areas of their knee were more painful to arthroscopic palpation [18]. There are 8 knee regions that have been identified as having increased neurosensory perception and elevated concentration of mechanoreceptors: (1) suprapatellar pouch and quadriceps tendon; (2) medial retinaculum; (3) patellar tendon and fat pad; (4) medial collateral ligament (MCL) and medial meniscus capsular attachment; (5) posterior cruciate ligament (PCL) tibial attachment; (6) anterior cruciate ligament (ACL) femoral attachment; (7) lateral collateral ligament (LCL) and lateral meniscus capsular attachment; and (8) lateral retinaculum. The nerve contributions to each zone are listed below.

Zone 1: Suprapatellar Pouch/Quadriceps Tendon

The saphenous nerve is the longest and the largest branch of the femoral nerve [20]. It is a pure sensory nerve that supplies innervation to the anteromedial aspect of the lower leg from the knee to the foot. During Its course in the thigh, the nerve runs in the adductor canal (Hunter´s canal) and migrates along with the sartorius muscle [21]. Within the adductor canal, *the saphenous nerve* lays anteromedial to the femoral artery and vein. In addition *to the saphenous nerve* and the femoral vessels, the canal also includes the *nerve to the vastus medialis*, and other motor branches of the femoral nerve. The minor branches of the femoral nerve including *the nerve to the vastus medialis* and *the nerve to the vastus lateralis*, supply innervation to the quadriceps tendon. These nerves are also distributed to the articular capsule, as well as the suprapatellar pouch (Figure 1) [22].

Zone 2 Medial Retinaculum

The medial retinacular nerve, the terminal branch of the *nerve to the vastus medialis*, provides innervation to the medial retinaculum. It usually travels in the substance of the muscle, and enters the joint capsule to innervate medial articular structures [23], sending a branch to the medial patella as well [24].

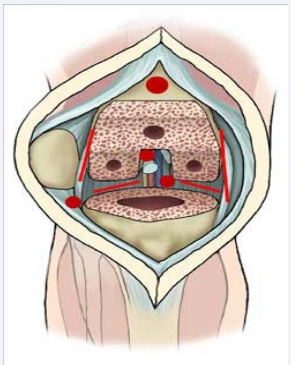

Figure 1 The eight regions of the knee having increased pain receptors (Reproduced with per mission of the Hip and Knee Best Infiltration Practice Working Group).

Zone 3: Patellar Tendon and Fat Pad

The infrapatellar fat pad is densely innervated structure, receiving nerve contribution from the *saphenous, tibial, and common peroneal nerves*. The *nerve to the vastus medialis* and the *saphenous nerve* provide medial sensory innervation to the fat pad [22]. The common peroneal nerve projects the *recurrent articular branch*, and the tibial nerve projects the *posterior articular branch* to provide the lateral sensory innervation [25, 26].

Zone 4: Medial Collateral Ligament and Medial Meniscus Capsular Attachment

The main branch of the *saphenous nerve,* as it runs down the anterolateral edge of the sartorius, supplies innervation to the medial and anteroinferior side of the knee. It also supplies a wide area covering the articular capsule, medial collateral ligament, and meniscal capsular attachment [22].

Zone 5: Posterior Cruciate Ligament Tibial Attachment and Zone 6: Anterior Cruciate Ligament Femoral Attachment

Formed by the L4-S3 nerve roots, the sciatic nerve is the largest nerve in the body [20,21]. The peroneal and tibial divisions of the sciatic nerve physically split at or above the popliteal fossa to form the common peroneal nerve and the tibial nerve [25]. The tibial nerve is the medial and the largest terminal branch of the sciatic nerve. The tibial nerve branches off from the sciatic nerve at the apex of the popliteal fossa, which appears like a diamond shaped fatty space bordered by the biceps femoris and the semimembranosus muscles superiorly and the two heads of the gastrocnemius muscle inferiorly. During Its vertical course in the popliteal fossa, the nerve is virtually median, typically just posterior to the popliteal vein whereas the popliteal artery is anterior to the vein. Collaterals of the tibial nerve in the knee region include the *posterior articular branch*, which supplies sensory innervation to the ACL and PCL [26, 27]

Zone 7: Lateral Collateral Ligament and Lateral Meniscus Capsular Attachment and Zone 8: Lateral Retinaculum

The *tibial nerve* projects articular branches at the popliteal fossa, innervating the posterolateral capsule [28]. The *common peroneal nerve* projects articular branches as it runs down medially along the long head of the biceps femoris. These branches run towards the deep part of the long head of the biceps femoris, and innervate the posterior and lateral side of the articular capsule. The *common peroneal nerve* also projects an articular branch as it runs down to the origin of the lateral head of the gastrocnemius and extends to the head of the fibula. This branch runs with the inferolateral popliteal vessels and innervates the anterolateral side of the lateral retinaculum, lateral cruciate ligament, and the lateral meniscus remnant [25]. There is also some contribution to the patellar tendon and infrapatellar fat pad.

Application of Neuroanatomy and Systematic Injection Technique

Our PAI cocktail is prepared by adding 266 mg (20 cc) Exparel® (Pacira Pharmaceuticals, Parsippany, NJ), 20 cc .25% bupivacaine, 20 cc normal saline, and epinephrine 1:200,000 for a volume of 60 cc in a single syringe. We only use 22 gage 1 ½ inch length needles for injections. The injection is technique dependent, and we only allow 2-3 cc of cocktail to disperse per pass. If more than 2-3 cc is injected per pass, the PAI cocktail will elute out of the soft tissues, and will be ineffective. Furthermore, the PAI is concentrated in the eight areas of the knee with the most abundant sensory innervations as detailed above.

We perform total knee arthroplasty through a standard medial parapatellar approach and use posterior stabilized implants. Once the tibial and femoral bone cuts are made, laminar spreaders are used to distract the joint in flexion for the removal of the medial meniscus, lateral meniscus, PCL and remnant of the ACL. With the laminar spreader placed in the lateral joint excellent visualization of the posteromedial structures and intercondylar region is achieved (Figure 2). Several cc's of the PAI cocktail is injected into the area of the ACL femoral attachment (Figure 3) and PCL tibial attachment, several cc's into the posteromedial capsule along the residual posterior meniscal rim and posterior capsule attachment, and several cc's into the residual middle and anterior residual rim of the medial meniscus (Figure 4). We then transfer the lateral laminar spreader into the medial joint, giving excellent visualization of the posterolateral capsule and lateral meniscus. Several cc's of the cocktail is injected into the posterolateral capsule along the residual posterior rim of the lateral meniscus and posterior capsule attachment (Figure 5), and several cc's into the residual rim of the middle and anterior portion of the lateral meniscus. While infiltrating the posterior areas of the knee, care should be taken not inject the political artery. Aspiration should be performed prior to any injection into the posterior region of the knee. Anatomic studies have confirmed that the popliteal artery location is variable, but about 2 cm from the posterior capsule in flexion, and is found just lateral to the midline in >95% of patients [29]. It can be found, on average, at a width of 40% of the lateral plateau. Posteromedial, poster lateral, and intercondylar injections may be performed safely, and the surgeon should always err on injecting superiorly juxtaposed to the femur. The knee is then balanced, and the tibial, femoral, and patellar components are cemented. While the cement is curing, several cc's of the PAI cocktail is injected into the quadriceps tendon and suprapatellar pouch (Figure 6), several cc's into the fat pad (Figure 7), and the residual several

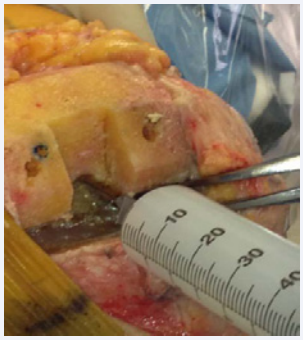

Figure 2 Exposure of posterior medial capsule, injection into intercondylar region.

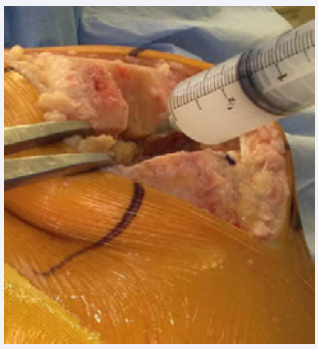

Figure 3 Injection in the posterior lateral capsule in the region of the ACL origin.

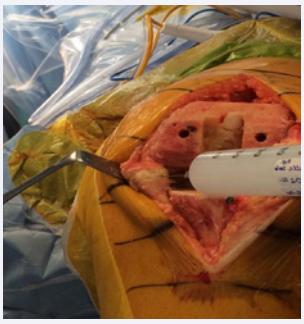

Figure 4 Injection in the residual medial meniscal rim.

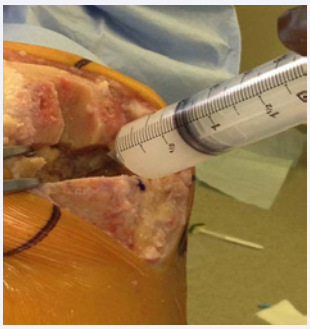

Figure 5 Injection along the posterior lateral meniscus rim.

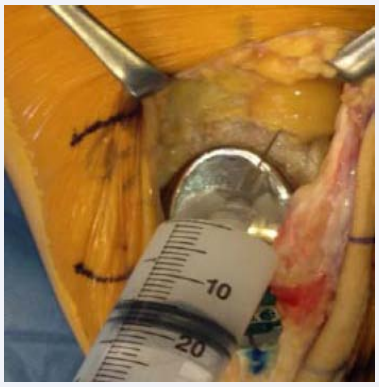

Figure 6 Injection within the lateral suprapatellar region.

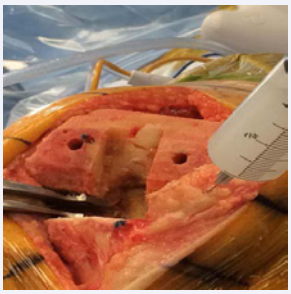

Figure 7 Injection into the infrapatellar fat pad.

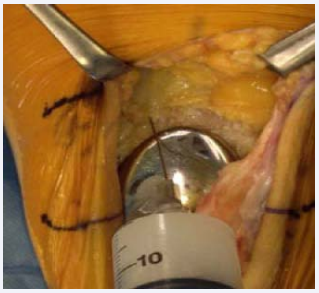

Figure 8 Injection within the medial suprapatellar region in the direction of Hunter's canal.

cc's into the region of the medial femoral condyle in the region of Hunter's canal (Figure 8). Once again, injections are dispersed in 2-3 cc passes in each location with strict attention to the soft tissue absorbing the periarticular cocktail. The knee is closed in a normal fashion and a dressing is applied.

DISCUSSION

Femoral nerve blocks are commonly used to decrease preoperative pain from total knee arthroplasty [30], despite the 1-2.5% incidence of femoral motor blockade with quadriceps weakness, nerve damage, and infection [5-9]. Furthermore, 15% of femoral nerve blocks are unsuccessful [31] and do not provide any analgesia to the posterior portion of the knee supplied by the sciatic nerve. This posterior knee knee pain requires analgesic intervention with either parenteral opiates or a single injection sciatic block which further impairs ambulation.

PAI allows for pain control at the source, maximizes muscle control, facilitates rehabilitation, and prevents venous stasis. In a randomized trial of 64 patients, Busch et al [32] found that patients who received a periarticular injection containing ropivacaine, ketorolac, epimorphine, and epinephrine used less patient-controlled analgesia at 6, 12, and 24 hours after surgery, and had lower pain scores in the post-anesthetic care unit and at 4 hours after the operation. An alternative to this cocktail is Exparel^{R} (Pacira Pharmaceuticals, Parsippany, NJ), a novel liposomal formulation of bupivacaine containing microscopic, spherical, lipid particles with the encapsulated drug. It is designed to provide prolonged postsurgical analgesia through diffusion [33]. In a double blind study, liposomal bupivacaine showed a favorable dose response and statistically significantly greater analgesia with lower NRS-A scores compared to a bupivacaine

injection alone [33]. When a periarticular injection of liposomal bupivacaine is used in conjunction with a multimodal pain pathway, rapid recovery is possible, and selected patients are able to undergo outpatient total knee arthroplasty [34]. A recent prospective study of 1,000 total joint arthroplasties utilizing the long acting liposomal bupivacaine, as part of a multimodal analgesic protocol, compared to a 1,000 patient control group demonstrated improved patient reported pain scores, increased 'pain free" patients, decreased length of stay, decreased falls, and decreased overall costs with the long acting analgesic [35].

Some concern exists regarding the maximum dose of bupivacaine and its side effects including cardiotoxicity and acute CNS side effects. The recommended maximum daily dose of bupivacaine is 400 mg. The typical total knee arthroplasty patient will undergo spinal anesthesia which requires 10-14 mg of bupivacaine. Our cocktail contains 40cc of .25% bupivacaine or 100 mg. The long acting liposomal bupivacaine Exparel[R] contains 266 mg, which elutes over 72 hours. When administering bupivacaine before EXPAREL, it is important to use no more than 50% of the total EXPAREL dose (266 mg) (e.g., 50 mL of 0.25% and 25 mL of 0.5% bupivacaine HCl) both equate to a total dose of 125 mg. Adherence to this dosing regimen will ensure that the maximum recommended dose is not exceeded. Exparel[R] has also been shown to be efficacious and safe at higher doses. In a phase I clinical trial Exparel[R] given subcutaneously in doses of up to 750mg did not prolong the QT interval and raised no cardiac concerns [36].

Since many PAIs involve mixing various drugs and preparing a "cocktail", a review of the compatibility of liposomal bupivacaine with other drugs was undertaken. As per package labeling, liposomal bupivacaine should not be mixed with other substances or drugs other than normal saline prior to injection into surgical sites. It was reported that liposomal bupivacaine may be safely administered with some commonly used drugs; interactions between liposomal bupivacaine and epinephrine, corticosteroids, antibiotics, non-steroidal anti-inflammatory drugs, transexamic acid and opiod analgesics were not clinically meaningful. No adverse synergistic effects on liposomal bupivacaine were observed in evaluations involving multiple medications compared with each drug's individual effects [37].

CONCLUSION

Periarticular infiltration with long acting liposomal bupivacaine is an effective method of controlling preoperative pain after total knee arthroplasty while decreasing the amount of opioid consumption and its related side effects. It has the potential benefit of increased muscle control with rehabilitation, while eliminating complications associated with opiates and peripheral nerve blockade. Careful attention to the infiltration method is necessary to prevent leaching from the soft tissues, and care should be taken to avoid intravascular injection. Concentrating the PAI in the areas of the knee with increased innervation is necessary to maximize benefits from periarticular injection, and can aid in improving post-operative pain control in total knee arthroplasty.

REFERENCES

1. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am. 2007; 89: 780-785.

2. Lavernia CJ, Guzman JF, Gachupin-Garcia A. Cost effectiveness and quality of life in knee arthroplasty. Clin Orthop Relat Res. 1997; 345: 134-139.

3. Forst J, Wolff S, Thamm P, Forst R. Pain therapy following joint replacement.A randomized study of patient-controlled analgesia versus conventional pain therapy. Arch Orthop Trauma Surg. 1999; 119: 267-270.

4. Strassels SA, Chen C, Carr DB. Postoperative analgesia: economics, resource use, and patient satisfaction in an urban teaching hospital. Anesth Analg. 2002; 94: 130-137.

5. Capdevila X, Barthelet Y, Biboulet P, Ryckwaert Y, Rubenovitch J, d'Athis F. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. Anesthesiology. 1999; 91: 8-15.

6. Horlocker TT, Cabanela ME, Wedel DJ. Does postoperative epidural analgesia increase the risk of peroneal nerve palsy after total knee arthroplasty? Anesth Analg. 1994; 79: 495-500.

7. Horlocker TT, Hebl JR, Kinney MA, Cabanela ME. Opioid-free analgesia following total knee arthroplasty--a multimodal approach using continuous lumbar plexus (psoas compartment) block, acetaminophen, and ketorolac. Reg Anesth Pain Med. 2002; 27: 105-108.

8. Strassels SA, Chen C, Carr DB . Postoperative analgesia: economics, resource use, and patient satisfaction in an urban teaching hospital. Anesth Analg. 2002; 94: 130-137, table of contents.

9. Cuvillon P, Ripart J, Lalourcey L, Veyrat E, L'Hermite J, Boisson C, Thouabtia E. The continuous femoral nerve block catheter for postoperative analgesia: bacterial colonization, infectious rate and adverse effects. Anesth Analg. 2001; 93: 1045-1049.

10. Albert TJ, Cohn JC, Rothman JS, Springstead J, Rothman RH, Booth RE Jr. Patient-controlled analgesia in a postoperative total joint arthroplasty population. J Arthroplasty. 1991; 6 Suppl: S23-28.

11. DeWeese FT, Akbari Z, Carline E. Pain control after knee arthroplasty: intraarticular versus epidural anesthesia. Clin Orthop Relat Res. 2001; : 226-231.

12. Singelyn FJ, Deyaert M, Joris D, Pendeville E, Gouverneur JM. Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. Anesth Analg. 1998; 87: 88-92.

13. Oderda GM, Evans RS, Lloyd J, Lipman A, Chen C, Ashburn M, Burke J. Cost of opioid-related adverse drug events in surgical patients. J Pain Symptom Manage. 2003; 25: 276-283.

14. Vendittoli PA, Makinen P, Drolet P, Lavigne M, Fallaha M, Guertin MC, Varin F. A multimodal analgesia protocol for total knee arthroplasty. A randomized, controlled study. J Bone Joint Surg Am. 2006; 88: 282-289.

15. Mullaji A, Kanna R, Shetty GM, Chavda V, Singh DP. Efficacy of periarticular injection of bupivacaine, fentanyl, and methylprednisolone in total knee arthroplasty:a prospective, randomized trial. J Arthroplasty. 2010; 25: 851-857.

16. Toftdahl K, Nikolajsen L, Haraldsted V, Madsen F, Tønnesen EK, Søballe K, Comparison of peri- and intraarticular analgesia with femoral nerve block after total knee arthroplasty: a randomized clinical trial. Acta Orthop. 2007; 78: 172-179.

17. Chaumeron A, Audy D, Drolet P, Lavigne M, Vendittoli PA . Periarticular

injection in knee arthroplasty improves quadriceps function. Clin Orthop Relat Res. 2013; 471: 2284-2295.

18. Dye SF, Vaupel GL, Dye CC. Conscious neurosensory mapping of the internal structures of the human knee without intraarticular anesthesia. Am J Sports Med. 1998; 26: 773-777.

19. Biedert RM, Stauffer E, Friederich NF. Occurrence of free nerve endings in the soft tissue of the knee joint. A histologic investigation. Am J Sports Med. 1992; 20: 430-433.

20. Testut L, Latarjet A. Traité D'anatomie Humaine.

21. Stoller DW, editor. Magnetic Resonance Imaging in Orthopaedics and Sports Medicine. 3rd ed. Lippincott Williams & Wilkins. 2007.

22. Kalenak A. Saphenous Nerve Entrapment. Oper Tech Sports Med 1996; 4: 40-5.

23. Horner G, Dellon AL . Innervation of the human knee joint and implications for surgery. Clin Orthop Relat Res. 1994; : 221-226.

24. Maralcan G, Kuru I, Issi S, Esmer AF, Tekdemir I, Evcik D, . The innervation of patella: anatomical and clinical study. Surg Radiol Anat. 2005; 27: 331-335.

25. Donovan A, Rosenberg ZS, Cavalcanti CF. MR imaging of entrapment neuropathies of the lower extremity. Part 2. The knee, leg, ankle, and foot. Radiographics. 2010; 30: 1001-1019.

26. Bianchi S, Martinoli C, Demondion X. Ultrasound of the nerves of the knee region: Technique of examination and normal US appearance. J Ultrasound. 2007; 10: 68-75.

27. Kennedy JC, Weinberg HW, Wilson AS. The anatomy and function of the anterior cruciate ligament. As determined by clinical and morphological studies. J Bone Joint Surg Am. 1974; 56: 223-235.

28. Hirasawa Y, Okajima S, Ohta M, Tokioka T. Nerve distribution to the human knee joint: anatomical and immunohistochemical study. Int Orthop. 2000; 24: 1-4.

29. Ninomiya JT, Dean JC, Goldberg VM. Injury to the popliteal artery and its anatomic location in total knee arthroplasty. J Arthroplasty. 1999; 14: 803-809.

30. Wang H, Boctor B, Verner J. The effect of single-injection femoral nerve block on rehabilitation and length of hospital stay after total knee replacement. Reg Anesth Pain Med. 2002; 27: 139-144.

31. McNamee DA, Parks L, Milligan KR. Post-operative analgesia following total knee replacement: an evaluation of the addition of an obturator nerve block to combined femoral and sciatic nerve block. Acta Anaesthesiol Scand. 2002; 46: 95-99.

32. Busch CA, Shore BJ, Bhandari R, Ganapathy S, MacDonald SJ, Bourne RB, Rorabeck CH . Efficacy of periarticular multimodal drug injection in total knee arthroplasty. A randomized trial. J Bone Joint Surg Am. 2006; 88: 959-963.

33. Bramlett K, Onel E, Viscusi ER, Jones K. A randomized, double-blind, dose-ranging study comparing wound infiltration of DepoFoam bupivacaine, an extended-release liposomal bupivacaine, to bupivacaine HCl for postsurgical analgesia in total knee arthroplasty. Knee. 2012; 19: 530-560.

34. Berger RA, Kusuma SK, Sanders SA, Thill ES, Sporer SM. The feasibility and perioperative complications of outpatient knee arthroplasty. Clin Orthop Relat Res. 2009; 467: 1443-1449.

35. Barrington JW, Emerson RH: Liposomal Bupivacaine: a case control study of the first, 000 cases in a new total knee arthroplasty era. Presented at the Annual AAOS Meeting, New Orleans, LA, March 2014

36. Naseem A, Harada T, Wang D, Arezina R, Lorch U, Onel E, Camm AJ. Bupivacaine extended release liposome injection does not prolong QTc interval in a thorough QT/QTc study in healthy volunteers. J Clin Pharmacol. 2012; 52: 1441-1447.

37. Kharitonov V . A review of the compatibility of liposome bupivacaine with other drug products and commonly used implant materials. Postgrad Med. 2014; 126: 129-138.

Cite this article

Guild GN III, Galindo RP, Marino J, Cushner FD, Scuderi GR (2014) Peri-Articular Regional Analgesia in Total Knee Arthroplasty. A Review of The Neuroanatomy And Injection Technique. Ann Orthop Rheumatol 2(3): 1025.