

Partial Knee Joint Denervation for Knee Pain: A Review

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Abstract

Knee pain is transmitted via peripheral nerves. Once a medical or orthopedic surgical musculoskeletal approach has failed to relieve this chronic problem, then a partial knee denervation should be considered. In 1994 the medial and lateral retinacular nerves were described, and these are the main source for knee joint pain. A nerve block of each of these nerves followed by observation of increased stair climbing and kneeling with a decrease in the visual analog scale of >5 predicts a 90% success rate for partial knee denervation. This approach, pioneered by Dellon, is applicable to patients with persistent pain after partial or total knee arthroplasty, and to those with sports injuries and pain after ligament reconstruction, and for those too young for joint replacement. This review includes description of the neuroanatomy, the nerve block technique, the surgical approach and the results of Dellon's partial knee denervation over the past twenty years.

Keywords: Knee Pain; Musculoskeletal; Partial knee denervation; Total knee arthroplasty

Introduction

This is a review that highlights a fact which Orthopedic Surgery continues to underappreciate: *Joint Pain Can Be of Neural Origin!*

All perception of knee pain must be mediated via the nervous system. Yet the Orthopedic approach to knee pain is traditionally, and universally, and almost exclusively, *musculoskeletal*. While the musculoskeletal system is the natural starting point for the evaluation of knee pain, once *musculoskeletal* etiologies have been eliminated or treated, persistent knee pain should then be considered of neural origin. Once a neural etiology is being considered, the Orthopedic Surgeon may wish to proceed with diagnostic nerve blocks, or refer the patient to Pain Management for peripheral nerve blocks, in addition to management of anxiety and chronic pain with neuropathic pain medications. Appropriate nerve blocks will diagnose which nerves are transmitting the pain, permitting a plan for interruption of this painful transmission.

The approach described is to consider knee pain that exists after musculoskeletal or patellofemoral treatment of the knee to be of neural origin. The physician caring for these patients must consider whether the pain is coming from direct damage to the cutaneous nerves about the knee, such as a neuroma of the infrapatellar branch of the saphenous nerve, or whether the pain is coming from an injury to one of the nerves arising within the knee joint structures themselves. A further source of knee pain due to nerve injury is an injury to a nerve far away from the knee, like the lateral femoral cutaneous nerve. The concept of partial joint denervation will be presented as an approach where those joint afferents that transmit a pain message are interrupted, thereby stopping the pain, and preserving the musculoskeletal components of the joint.

At the outset, it must be clear that only sensory nerves are being divided, and that the knee joint is being partially denervated. A Charcot-type joint is not created because the deafferentation of this weight-bearing joint is partial instead of total. It must be stated clearly that a partial knee denervation should only be done for a patient in whom traditional Orthopedic approaches have provided a stable knee, with strong ligamentous support and normal patellofemoral tracking.

It is the purpose of this review to describe the peripheral neuroanatomy related to perception of knee pain, the performance of nerve blocks required to diagnose this etiology, the surgical approach for partial knee denervation, and the results of partial knee denervation.

Peripheral neuroanatomy of the knee joint

While it is intuitively clear that a joint is innervated, the exact pathways of this innervation curiously are omitted from the classic and even the newer anatomy texts. For the human knee, the innervation pattern was not described until 1994 [1].

The innervation of the human knee joint is remarkably constant. On the medial aspect, the femoral nerve branch that innervates the vastus medialis continues past its motor point and exits deep and distal to the vastus medialis. At this point it lies deep to the medial retinaculum and becomes related to the medial recurrent geniculate artery and vein. This nerve was termed *the medial retinacular nerve*. These structures, nerve and vessels continue directly adjacent to the vastus medialis and superficial to the synovium to enter the ligamentous structures of the medial knee. These fibers also continue towards the midline of the knee to innervate the undersurface of the patella (Figure 1). On the lateral aspect, a branch of the sciatic nerve leaves the popliteal fossa, travels laterally and anteriorly, to emerge deep to the biceps tendon and enter the space beneath the lateral retinaculum. In this location the nerve is adjacent to the recurrent lateral recurrent geniculate artery and vein. This nerve was termed *the lateral retinacular nerve*. These structures, the nerve and vessels, are immediately distal to the vastus lateralis and superficial to the synovium. The nerve enters the ligamentous structures of the lateral knee, and travels to the midline to innervate the undersurface of the patella (Figure 2). Anteriorly, another source of innervation is derived from the femoral nerve innervation of the vastus intermedius. This nerve continues on the surface of the periosteum to innervate the tissues around the pre-patellar bursa. This nerve can be termed *the nerve to the prepatellar space* (Figure 1). Finally, posteriorly, branches from the sciatic nerve enter the posterior knee joint capsule to provide innervation (Table 1). These nerves can be termed *the popliteal plexus* (Figure 2).

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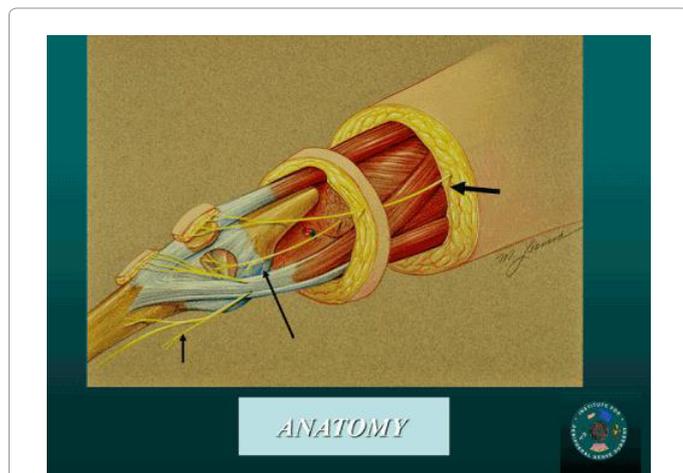


Figure 1: Medial view of the innervation of the knee. The skin overlying the patella is innervated by the medial cutaneous nerve of the thigh, a branch of the saphenous nerve (thick arrow). The medial joint structures are innervated by a branch of the femoral nerve, the medial retinacular nerve, which, after innervating the vastus medialis, continues distal and then anterior to this muscle, to enter the ligamentous structures of the knee joint (long thin arrow). This nerve lies superficial to the synovium and deep to the medial retinaculum. The saphenous nerve's infrapatellar and distal branches are shown in their most common variation (short thin arrow). The nerve to the patellar skin is from the medial cutaneous nerve of the thigh (short thick arrow) (With permission, Dellon.com).

TIBIOFEMORAL
CUTANEOUS: (from anterolateral to medial, then posterior)
lateral femoral cutaneous
anterior femoral cutaneous
medial cutaneous nerve of the thigh
infrapatellar branch of saphenous nerve
posterior femoral cutaneous nerve
JOINT: (from anterolateral to medial, then posterior)
lateral retinacular nerve
terminal branch of innervation of vastus intermedius
medial retinacular nerve
popliteal plexus from sciatic nerve
PATELLOFEMORAL
lateral retinacular nerve
terminal branch of innervation of vastus intermedius
medial retinacular nerve
PROXIMAL TIBIOFIBULAR
recurrent genicular branch of common peroneal nerve

Table 1: Innervation of & around the human knee joint.

While many patients complain of “knee pain”, they may be pointing or referring to the joint distal to the knee, laterally, which is the articulation between the fibular head and the tibia. This proximal tibiofibular joint space is likely to be injured by fractures of the fibular, lateral tibial plateau fractures, and surgery related to a high tibial osteotomy or a Marquet procedure. This space is innervated by the recurrent genicular branches of the common peroneal nerve (Figure 2). As the common peroneal nerve travels from the popliteal fossa to the fibular head, it gives off a small, about 1mm diameter, nerve that may enter this space posterior to the fibular head. The common peroneal nerve will give off a second branch to this space immediately as it curves anterior to the fibular head, at the junction with the fibular neck. This branch, too, is about 1 mm diameter. The next branch of the common peroneal nerve goes to the tibialis anterior, a critical motor branch. In the operating room, the only way to identify the branch to the joint is to

stimulate this little branch electrically. The branch to the joint will have no motor function elicited when stimulated. This is critical to do. This little branch often looks like epineurium.

Peripheral Neuroanatomy of the Skin around the Knee Joint

The saphenous nerve is a branch of the femoral nerve and arises from the femoral nerve in the proximal thigh. Its cutaneous branches to the skin below the knee are well described and lie in location to be injured directly either from a medial ankle endoscopy portal or the midline incisions used for many surgical approaches to the knee. These branches can be directly injured by blunt trauma as well (Figure 2). Less well-recognized is the nerve to the skin overlying the patellar itself. This is a branch of the femoral nerve, and may include sensory contribution from the obturator nerve joining within Hunter's canal, and is termed the medial cutaneous nerve of the thigh (Figure 2). It approaches from the medial aspect of the knee compared to the vertical approach taken by the anterior femoral cutaneous nerves [1]. Even less well-appreciated is that the saphenous nerve can be compressed in the distal thigh within Hunter's canal. This is called the adductor canal syndrome, and is rare in the absence of direct trauma to this region. Entrapment of the saphenous nerve in this location can present as medial knee pain [2,3]. The skin lateral to the patellar is innervated by the terminal branches of the lateral femoral cutaneous nerve [4,5]. Entrapment or injury to this nerve in the hip area, for example after anterior approaches to total hip arthroplasty or bone graft harvesting, may present as lateral knee pain, especially if the lateral femoral cutaneous nerve is within the inguinal next to the anterior superior iliac crest.

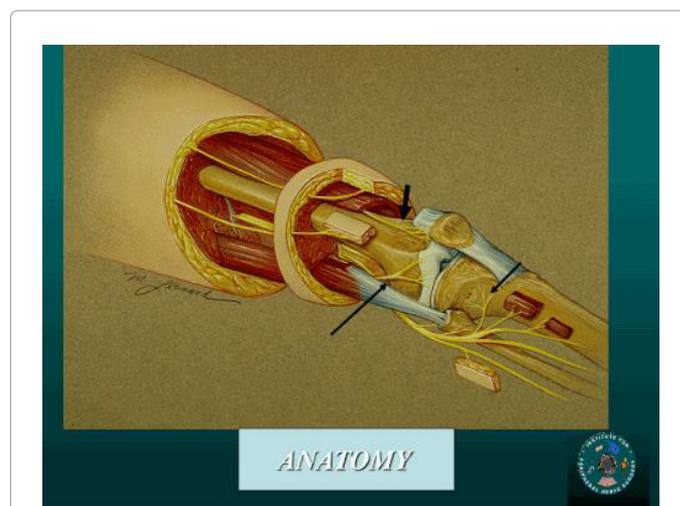


Figure 2: Lateral view of the innervation of the knee. The skin in this area represents the terminal branches of the lateral femoral cutaneous nerve. The lateral joint structures are innervated by a branch of the sciatic nerve that comes from the popliteal fossa, goes deep to the biceps tendon to enter the joint, the lateral retinacular nerve (long thin arrow). The nerve passes just distal to the vastus lateralis, and then lies superficial to the synovium and deep to the lateral retinaculum as it enters the joint. The branches of the sciatic nerve to the posterior knee joint capsule are shown next to the femur posteriorly. The branch to the pre-patellar bursa is shown on the anterior surface of the femur as it exists the vastus intermedius. The innervation of the proximal tibiofibular joint is shown as branches proximal and distal to the fibular head, arising from the common peroneal nerve (short arrow). The terminal branch of the nerve to the vastus intermedius innervates the prepatellar space (short thick arrow). (With permission, Dellon.com).

Clinical Evaluation of Knee Pain of Neural Origin

The history of knee pain is critical to obtain. Knee pain does not arise *de novo*.

Something happened. There will be a history of some type of sports event, over use activity, new activity, or actual direct injury to the knee (Table 2). The knee injury can be blunt or open. Knee surgery should be considered as an iatrogenic source of this trauma. Many patients with knee pain due to musculoskeletal problems awake from their reconstructive knee surgery to have a different pain or paralysis. These are known complications of knee surgery, and should be recognized as such, and referred for appropriate treatment in a timely manner. The history of whether the pain is made worse by certain positions of the body or leg, or is made worse by certain activities is important in arriving at a correct diagnosis. Certainly, most knee pain unrelated to structural impairment will be relieved by non-operative treatment. But when pain persists beyond a reasonable time frame of three to six months, then the history is most consistent with pain of neural origin.

The physical examination is directed to identifying one or more sources of neural origin for the pain. First try to distinguish if any skin territories are dysesthetic, i.e., painful when touched lightly. If so, outline them. The most common distribution is that of the infrapatellar branch of the saphenous nerve, and the second is the skin over the patella itself. These areas might be numb, indicating loss of sensation (Figure 3). Once the pattern is identified, the examination continues proximally, along the course of the given nerve, looking for a trigger spot, which is either a true end-bulb neuroma or an in-contiguity nerve lesion. The hypothesis is made that this nerve or these nerves are the source of the cutaneous pain, and a diagnostic nerve block will be required to confirm this hypothesis. A combination of 1% xylocaine and 0.5% Marcaine is mixed 50:50, without epinephrine, and 5 cc is injected into each site for the nerve block. These blocks are done along the course of the involved cutaneous nerve (Figure 4). Then the physical examination is directed to the joint afferents. Palpation is done deeply to the spot located just distal to the vastus medialis muscle, through the medial retinaculum to elicit pain from the medial retinacular nerve. Palpation is next done deeply to the spot located just distal to the vastus lateralis muscle, through the lateral retinaculum to elicit pain from the lateral retinacular nerve. The hypothesis is made the knee joint pain is due to an injury to one or both of the joint afferents, and a diagnostic nerve block will be required to confirm this hypothesis (Figure 4).

The medial cutaneous nerve to the thigh and the medial retinacular nerve can be blocked at the same spot

Ten minutes following the nerve blocks, the patient is instructed to walk in the hallway, climb and descend a few steps, and even to kneel on a padded chair (Figure 5). A reduction of 5 points on a

AGING:
osteoarthritis in patient not a candidate for total knee arthroplasty
osteoarthritis in patient not wanting a contralateral total knee arthroplasty
INJURY:
sports-related, with normal MRI, not responding to sports medicine Rx
work-related, with normal MRI, not responding to pain management
IATROGENIC:
sports-related, s/p operative approach to ligamentous/osseous reconstruction
sports-related, s/p operative approach to ligamentous/osseous reconstruction
sports-related, s/p operative approach to ligamentous/osseous reconstruction
work-related, s/p operative approach to ligamentous/osseous reconstruction

Table 2: Indications for partial knee denervation.

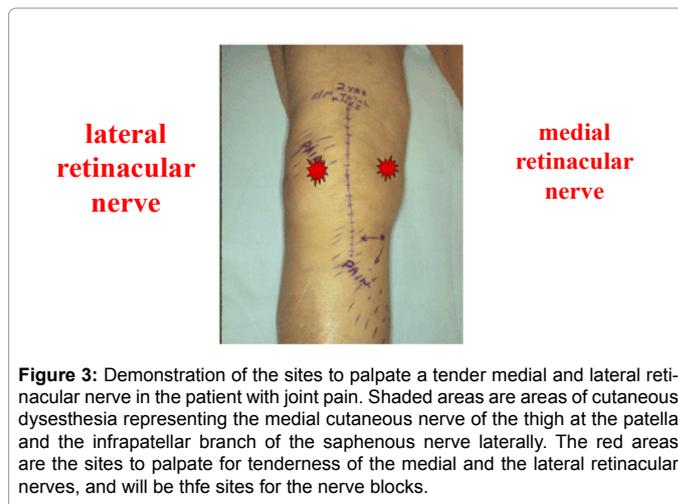


Figure 3: Demonstration of the sites to palpate a tender medial and lateral retinacular nerve in the patient with joint pain. Shaded areas are areas of cutaneous dysesthesia representing the medial cutaneous nerve of the thigh at the patella and the infrapatellar branch of the saphenous nerve laterally. The red areas are the sites to palpate for tenderness of the medial and the lateral retinacular nerves, and will be the sites for the nerve blocks.

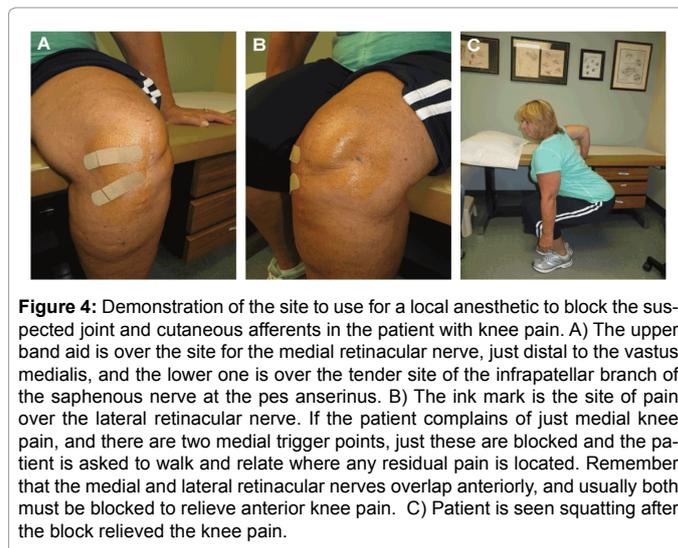


Figure 4: Demonstration of the site to use for a local anesthetic to block the suspected joint and cutaneous afferents in the patient with knee pain. A) The upper band aid is over the site for the medial retinacular nerve, just distal to the vastus medialis, and the lower one is over the tender site of the infrapatellar branch of the saphenous nerve at the pes anserinus. B) The ink mark is the site of pain over the lateral retinacular nerve. If the patient complains of just medial knee pain, and there are two medial trigger points, just these are blocked and the patient is asked to walk and relate where any residual pain is located. Remember that the medial and lateral retinacular nerves overlap anteriorly, and usually both must be blocked to relieve anterior knee pain. C) Patient is seen squatting after the block relieved the knee pain.



Figure 5: After the nerve block, there should be improved physical activity with less pain, as noted by the patient climbing the stairs and kneeling on a padded chair.

visual analog scale, say from 10 to 5, where 10 represents the worst pain, is confirmation that sufficient relief of pain has occurred to permit surgery for partial knee denervation and resection of cutaneous neuromas to proceed.

If the nerve blocks above have not reduced the pain level to less than five, or the blocks were not effective, the physical examination should go on to include other more rare sources for the nerve pain. In the patient with a knee replacement, the remaining pain may well be from an anterior femoral cutaneous nerve to be found in the proximal portions of the incision, or another branch of the infrapatellar saphenous nerve, which can have many branches, including more distal branches.

Finally, the groin should be examined to search for a Tinel sign over the lateral femoral cutaneous nerve. The patient will be noted to sit with leg extended at the hip. The mid-thigh should be examined to search for a Tinel sign over Hunter's adductor canal. This is best done with the patient supine, and the effected leg externally rotated at the hip, leaving the knee bent. This stretches the adductor muscle group over the saphenous nerve. Then just a gentle palpation over the canal produces a distally radiating painful response.

If the pain is below the knee joint, and laterally located, examine for tenderness in the proximal tibiofibular joint space, and if this is present, a nerve block can be done directly into this space without blocking the common peroneal nerve.

If pain is accompanied by complaints of the leg "giving out" or the foot dragging, or a "foot drop", the motor function of the common peroneal nerve must be evaluated by manual muscle testing. The common peroneal nerve must be palpated or percussed at the fibular neck, with tenderness, even without distal radiation, being considered a positive sign for nerve entrapment. Electrodiagnostic testing should be done to evaluate the common peroneal nerve and the presence of an L4/L or L5/S1 radiculopathy.

Operative Technique

The operative techniques for partial knee denervation given below have been published previously [6-9]. In general, a tourniquet is not needed. Leaving blood in the region permits the small vein on the nerves to the knee joint and to the skin to be identified more easily. Operative loupes of 3.5 x power are used. The bipolar coagulator is used set on a low level to start. Intravenous antibiotic prophylaxis is given prior to starting the procedure. A femoral nerve block is not done due to the risk of injury to the femoral nerve, but rather local anesthetic with epinephrine is infiltrated into the skin edges of the incisions at the start of the surgical procedure. Each nerve to be resected is injected with this local anesthetic prior to cauterization and resection to "shield" the central nervous system forms the pain impulses when the nerve is resected. The dressing is xeroform gauze over the incision, and then sterile 4 x 4 inch gauze, held in place with kling, and covered with a stockinette.

Finally the concept of minimizing the risk of recurrent neuroma pain must be understood. Since the sensory nerves remain alive once divided, due to their nucleus being intact in the dorsal root ganglion, nerve regeneration will occur in every joint afferent or cutaneous afferent that is divided. Alteration of the micro-environment of the nerve by implanting the proximal end of a divided sensory nerve into an innervated motor environment results in the absence of formation of a true neuroma [10]. Implanting a sensory nerve into an innervated muscle, after resecting the painful neuroma or after interruption of that nerve function by division of that nerve, results in predictable pain relief without recurrent neuroma for upper [11] and lower extremity peripheral nerves [12-14]. The location chosen to place the divided nerve will be explained for each operation described below.

Lateral Knee Denervation

An incision is outlined lateral to the patellar beginning over the distal muscle belly of the vastus lateralis. This muscle sometimes has a slight distal split in the muscle and you must be sure to be distal to the most distal portion of the vastus lateralis muscle. Then the iliotibial band (lateral retinaculum) is divided longitudinally for about 1.5 cm. Immediately adjacent to the muscle belly will be the small recurrent vessels and a 1 to 1.5 mm nerve, going from beneath the iliotibial band (biceps tendon) and across the synovium, and into the lateral joint and infrapatellar structures. This nerve is first infiltrated with Marcaine 0.5% down beneath the iliotibial band, then the nerve and vessels are cauterized towards the patella to prevent bleeding, and then placed under traction and cauterized deep beneath the iliotibial band, to prevent bleeding. The portion between the two cauterized sites is sent to pathology. The iliotibial band (lateral retinaculum) is reconstructed with two figure-of-eight sutures of 2-0 braided non-absorbable material (Figure 6).

Medial Knee Denervation

An incision is outlined medial to the patellar beginning over the distal muscle belly of the vastus medialis. Then the thin medial retinaculum is divided longitudinally for about 1.5 cm. Immediately adjacent to the muscle belly will be the small recurrent vessels and a 1 to 1.5 mm nerve, going from beneath the vastus medialis and across the synovium, and into the medial joint and infrapatellar structures. This nerve is dissected proximally beneath the retinaculum until it exists from beneath the muscle. This nerve is first infiltrated with Marcaine 0.5% down beneath the vastus medialis, then the nerve and vessels are cauterized towards the patella to prevent bleeding, and then placed under traction and cauterized deep beneath the vastus medialis, to prevent bleeding. The portion between the two cauterized sites is sent to pathology. The medial retinaculum is reconstructed with two figure-of-eight sutures of 3-0 braided non-absorbable material (Figure 7).

Resection Infrapatellar Branch of Saphenous Nerve

The saphenous nerve exits Hunter's canal in the distal thigh to become, the medial cutaneous nerve of the thigh and the infrapatellar branch of the saphenous nerve and the distal saphenous nerve. The infrapatellar branch crosses the insertion of the adductor tendons into Gurdy's tubercle beneath the deep fascia. There may already be two

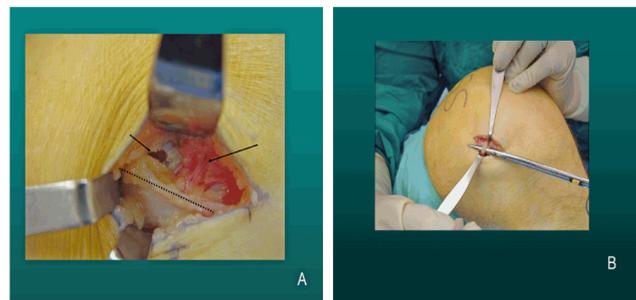


Figure 6: Lateral Knee Denervation. A) Incision is shown, lateral to patella, centered over the tender site shown in Figure 3. Vastus lateralis is shown (short arrow). The iliotibial tract is incised (dotted line) to demonstrate the lateral retinacular nerve (long arrow) adjacent to the lateral recurrent geniculate vessels. B) The lateral retinacular nerve is illustrated. C) The nerve is first infiltrated with local anesthetic, and the cauterized distally and proximally, and then divided proximally below the level of the iliotibial band so that the nerve drops into the popliteal fossa.

branches at this level. Ultimately, several terminal branches cross from medial to the lateral across the region of the tibial tuberosity to innervate the lateral knee skin. The skin proximal to this laterally is the terminal zone of innervation of the lateral femoral cutaneous nerve. Whereas the numbness is lateral, the damage to the nerve usually occurs in the axial line of the knee from an incision or medially from a scope portal. The site of the Tinel sign is around Gurdy's tubercle. The incision is longitudinal across the Tinel sign. The dissection goes deep to the fascia where the one or more branches are noted by the blood in the vein that accompanies the nerve branch. A thorough search proximally and distally must be done for more than one branch. This is the most common location for a missed remaining painful nerve. The nerve is infiltrated with Marcaine 0.5% proximally, the distal end cauterized to minimize bleeding, a segment resected for pathology, and the proximal end dissected. There is usually a clear tunnel where this nerve has transversed along or through the sartorius or other adductor muscle or tendon. The proximal end of the divided nerve, after cauterization to prevent bleeding, is turned blindly into these muscles and implanted there, proximal to the popliteal crease (Figure 8).

This nerve goes to the skin overlying the patella. This skin is traditionally shown as being innervated by an anterior femoral cutaneous nerve coming vertically down the leg. However, the skin is innervated by a branch of the saphenous and approaches this region medially. Indeed the same tender location for the medial retinacular nerve is the location for this nerve. The clinical clue is that the skin of the patella is dysesthetic. The nerve block medially will block both of these nerves. The incision used to approach the medial retinacular nerve is used. In the immediate subcutaneous tissue will be blood in the small vein that accompanies this nerve. Cauterize the nerve distally, and dissect the proximal end medially across the surface of the vastus medialis. Inject the nerve with 0.5% Marcaine proximally. Open a small window into the fascia of the vastus medialis. Implant the proximal end of the nerve loosely into this muscle (Figure 9).

Conclusion

The first group of patients selected for partial knee denervation was chosen from patients who had already had a total knee arthroplasty but who still had persistent pain for greater than 6 months unrelated to loosening, malalignment, or infection [6]. In that study, the Orthopedic Surgeons did a pre-op Knee Society Function Score and range of motion and pain assessment on the 15 patients. I independently did the partial

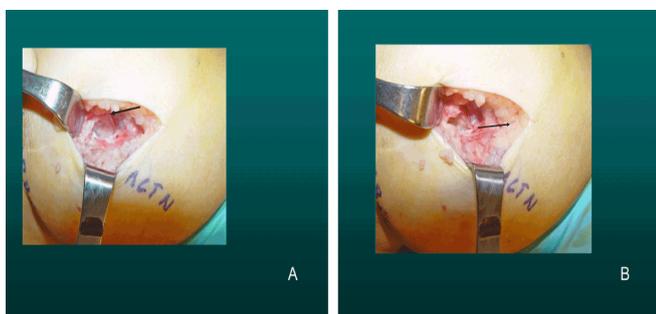


Figure 7: Medial Knee Denervation. A) Incision is shown, medial to patella, centered over the tender site shown in Figure 3. The medial retinaculum is opened. The arrow points to the medial retinacular nerve adjacent to the recurrent medial recurrent geniculate vessels. B) The nerve has been resected. The arrow points to the direction in which, beneath the medial retinaculum, the nerve has been implanted into the vastus medialis muscle. C) Closure of the medial retinaculum is shown.

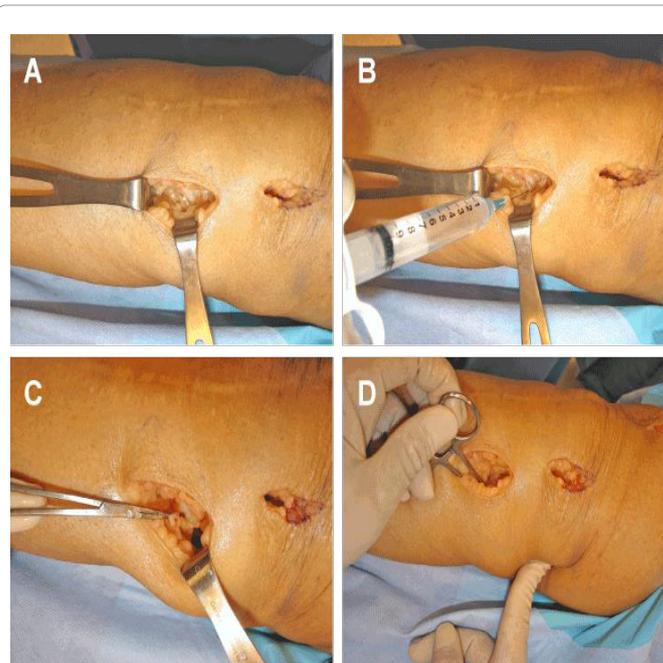


Figure 8: Resection of the Infrapatellar Branch of the Saphenous Nerve. A) Woman 9 years after total knee arthroplasty whose knee is shown from medial aspect demonstrating sites of pain over the anterior femoral cutaneous nerve (proximally), over the medial cutaneous nerve of the thigh (and medial retinacular nerve), and over the infrapatellar branch of the saphenous nerve. B) The infrapatellar branch is noted overlying Gurdy's tubercle. C) The nerve is infiltrated with local anesthetic prior and then D) cauterized and divided. E) The proximal end of the nerve is dissected and implanted into an adductor muscle medially (location denoted by finger at the popliteal fossa. F) A search must be made proximally for other infrapatellar branches. One is shown here in the incision used to resect the medial cutaneous nerve of the thigh and the medial retinacular nerves.

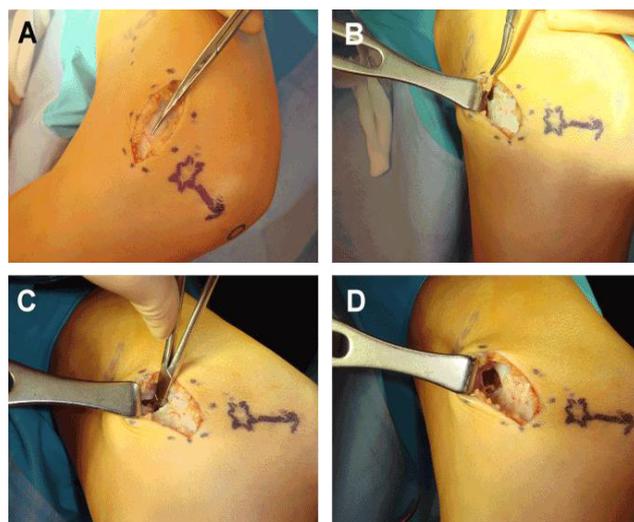


Figure 9: Resection of the Medial Cutaneous Nerve of the Thigh. A 23 year old with a direct injury to the knee resulting in pain over the patellar region. A) Site of Tinel and nerve block that eliminated the pain. B) Medial cutaneous nerve of the thigh demonstrated by the scissors' tips in the subcutaneous plane. This is superficial to the medial retinaculum. C) The nerve has been divided distally and dissected proximally. Here it is held by the clamp. D) A window is made in the fascia over the vastus medialis into which the proximal end of the nerve will be implanted.

knee denervation, and the Orthopedic Surgeons did the post-operative assessment. A total of 45 nerves were resected in 15 patients: both the medial and lateral retinacular nerve and the infrapatellar branch of the saphenous nerve were removed in each patient. All patients reported subjective improvement in the immediate postoperative period. This improvement was maintained at a mean follow-up of 12 months. It was concluded that selective knee denervation is indicated in the management of persistent knee pain of neuroma origin after total knee arthroplasty.

The next series to be reported included 70 patients [7]. Some of these patients also had persistent knee pain after total knee replacement, but now the indications were extended to those with chronic pain after knee trauma, or tibial osteotomy. In patients with nontotal knee arthroplasty pain, arthrosis, synovitis, ligamentous instability, and meniscal derangement had been excluded as a source of pain. Sixty of the 70 (86%) patients were satisfied with the denervation procedure as judged by direct questioning and a reduction in their preoperative pain visual analog score of 5 or more points. The average Knee Society score improved from a preoperative mean of 51 points (range, 40-62 points) to a follow-up mean of 82 points (range, 15-100 points). Forty-nine of 70 (70%) patients had final Knee Society objective scores greater than 80. There was no difference in patient satisfaction whether the followup period was less than 2 years or more than 2 years. It was concluded that partial knee denervation is indicated in the management of intractable knee pain after exhaustion of traditional approaches to any structural or infectious etiologies and after successful selective nerve block.

In the year 2000, a series of 344 patients were reviewed [8]. Of these patients, 255 had a previous total knee arthroplasty and 89 patients had knee trauma. Most patients had several nerves removed. No patient had only one nerve removed. All patients required removal of the medial and the lateral retinacular nerves, and most required removal also of the medial cutaneous nerve of the thigh and the infrapatellar branch of the saphenous nerve. Nerves least often removed were the anterior femoral cutaneous and the distal saphenous nerve. About one half of the patients, especially if there had been knee trauma required a neurolysis of the common peroneal nerve. The proximal tibiofibular joint required denervation in patients with fractures of the fibula, or those who had a Marquet procedure of patellofemoral tracking, or a high tibial osteotomy or a tibial plateau fracture. The results for the whole series were that 70% had an excellent result, 20% had a good result, 5% had some improvement, and 5% were not improved. No patient was neurologically downgraded or made worse. No knee implant or hardware was exposed. No patient had to be hospitalized to treat infection.

A review of knee denervation patients on our office computer from January of 2001 through December of 2013 includes 232 additional patients. Each patient has not been reviewed at this time. The overall experience remains the same as that obtained in our 2000 data review.

The main contra-indication to a partial knee denervation would be the presence of an unstable knee. Without the presence of mechanical stability, relieving pain would lead to ambulation on an unstable knee with the likelihood of falling. Other relative contra-indications are those of surgery in general, such as infection, bleeding and anesthetic risk. In the person who has already had a total knee arthroplasty, there is also the risk of having an implant become infected. To the best of my knowledge, this has not happened yet.

Other clinical studies

Despite the earlier work done on partial wrist denervation [15-

18], and extended to the shoulder [19,20] and ankle [21-23], the Orthopedic community has been hesitant to accept the concept that knee pain can be of neural origin. There have been very few studies published related to partial knee denervation, and except by someone trained by me [24-27]. In the reports from Germany, between May of 1995 and June of 1999, 45 knees were partially denervated using the "Dellon technique". This work was in a trauma center in Murnau and the study included both patients with direct knee injury as well as those with knee reconstruction for osteoarthritis who had joint replacement. The report included 34 patients, 11 with bilateral knee pain, whose age ranged from 25 to 86 with a mean of 34 years. In the post-operative time frame from 6 to 18 months, 70% of the patients reported "a reduction in pain", and after 4 years, 50% "still confirmed a positive result". Complications included one hematoma and two seromas which resolved with conservative management.

A recent study, from Turkey, evaluated the innervation of the patella in 30 knees of 15 formaldehyde-fixed cadavers [28]. A nerve from the vastus medialis, which is the nerve described above [1], entering the patella "superomedially", and a nerve "from the vastus lateralis, entering the patella superolaterally" were identified. The origin of these was not described, and their superolateral nerve "from the vastus lateralis" is probably the nerve described above that originates from the sciatic nerve, crosses in front of the vastus lateralis [1]. I would interpret their anatomic study in the fixed cadavers as confirming our observations reported in 1994. These authors then went on to confirm that these nerves are patellar pain afferents, by performing a local anesthesia block in 32 knees of 20 patients with patellofemoral pain [28]. They observed a significant difference between the visual analogue scale (VAS) scores before and after local anesthetic injections ($p < 0.01$). Again, I would interpret their observations to confirm that knee pain can be of neural origin from the medial and the lateral retinacular nerves, as described above. A recent meta-analysis of prophylactically denervating the patella with a unipolar cautery at the time of total knee arthroplasty and patellar resurfacing demonstrated a significant reduction in anterior knee pain compared to patients having the same procedure but without an attempt to remove the terminal branches of the medial and lateral retinacular nerves [29]. This approach also probably removes the terminal branches of the nerve to the quadratus intermedius that innervates the pre-patellar bursa.

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