Cooled Radiofrequency Ablation for Joint Pain (Hip, Knee, Shoulder)

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Disclosures

• Neuromodulation Fellowship Education Support Grants from Abbot, Boston Scientific, and Medtronic.
Objectives

• Elucidate scientific principles governing Radiofrequency Ablation (RFA) and Cooled RFA.

• Understand ablation targets for innervation of major joints.

• Apply current technological concepts to understand relevant advantages, limitations, and complications.
Radiofrequency: What is it?

- Electromagnetic Energy Spectrum

- Typically: **400-500 kHz**

- Low interference with human electrical conduction systems (e.g. cardiac).

- Able to produce ionic frictional heating
Conventional Radiofrequency Ablation (RFA)

Cosman ER. Neurosurgery 1984;15(6): 945-950
Ahadian FM. Current Pain and Headache Reports 2004;8:34-40
Creating Lesions in Tissue

\[ \frac{dQ}{dt} = \kappa \nabla^2 T + \frac{1}{\sigma} j^2 - \frac{dQ_c}{dt} \]

- **Heat change**
  - Per volume
  - Per time
- **Tissue Temp**
- **Current Density**
- **Heat loss**
  - To circulation

**Thermal Conductivity**

**Electrical Conductivity**

(Direct Heating)

RF Heating (indirect)

**References**

Organ LW. Applied Neurophysiology 1976/77;39:69-76
Cosman ER. Neurosurgery 1984;15(6): 945-950
More is Better? Quest for Larger Lesions

• Larger Gauge, Longer Active Tip
• Ionic Fluid Pre-Injection
• Palisading Monopolar Lesions
• Bipolar Lesions, Palisading Bipolar
• Cooled RFA
• Multi-tined RFA
• Multipolar RFA
Excessive Hyperthermic Necrosis of a Pulmonary Lobe after Hypertonic Saline-Enhanced Monopolar Radiofrequency Ablation

Tae Sung Kim,¹ Hyo K. Lim,¹ Hojoong Kim²

Example: Multi-tined Probes

- Monopolar Conventional RFA
- Functionally Larger Active Tip

Cooled (not COLD!) Radiofrequency
Cooled-Tip Ablation Results in Increased Radiofrequency Power Delivery and Lesion Size in the Canine Heart: Importance of Catheter-Tip Temperature Monitoring for Prevention of Popping and Impedance Rise

Ichiro Watanabe, Riko Masaki, Nuo Min, Naohiro Oshikawa, Kimie Okubo, Hidezou Sugimura, Toshiaki Kojima, Satoshi Saito, Yukio Ozawa, and Katsuo Kanmatsuse
Cooled RF

- Cooled RF now applied to spine ablation
  - Has been used elsewhere for increasing size of solid organ lesions to 30-50mm.
- Applied to joint denervation for pain management.
- Fluid Pre-injection may not affect lesion size\(^1\)

Bipolar Cooled RFA

• Large Strip Lesions
• Diminishing returns >24 mm

Clinical Applications of Cooled RFA

• Disc Biacuplasty
  • Best quality evidence among Thermal/RF disc ablation

• Lateral Branch Ablation (SI joint)
  • Superior results to conventional

• Spine and Major Joints
  • Potentially better efficacy, more data emerging

• Spine Tumors

Examples: Spine Cooled RFA

Lumbar Medial Branch  Thoracic Medial Branch  Cervical Medial Branch
Genicular Nerve Ablation
Genicular Nerves

Sensory branches that provide innervation of knee joint and ligaments.

Many are of sciatic origin

Saphenous, and Nerve to Vastus Medialis probably contribute to a genicular nerve network, with a small amount from Obturator N.


<table>
<thead>
<tr>
<th>Tibial Nerve Origin</th>
<th>Common Peroneal Nerve Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Superior medial genicular n</td>
<td>-Superolateral genicular n</td>
</tr>
<tr>
<td>-Inferomedial genicular n</td>
<td>-Inferolateral genicular n</td>
</tr>
</tbody>
</table>
GENICULAR NERVES

Femoral Nerve
Saphenous Nerve
Obturator Nerve
Tibial and Peroneal Nerves
Genicular nerves of the Knee

Genicular Nerves and Arteries
Genicular Conventional RFA

Genicular Conventional RFA

Percutaneous Radiofrequency Treatment for Refractory Anteromedial Pain of Osteoarthritic Knees

Masahiko Ikeuchi, MD, PhD,* Takahiro Ushida, MD, PhD,* Masashi Izumi, MD,* and Toshikazu Tani, MD, PhD*
Genicular Radiofrequency Targets
Cooled radiofrequency system relieves chronic knee osteoarthritis pain: the first case-series

Martina Bellini, Massimo Barbieri

<table>
<thead>
<tr>
<th>Table 2. WOMAC and VAS values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>VAS Mean ± SD</td>
</tr>
<tr>
<td>P value &lt; 0.01</td>
</tr>
<tr>
<td>Basal VAS</td>
</tr>
<tr>
<td>WOMAC Mean ± SD</td>
</tr>
<tr>
<td>P value &lt; 0.01</td>
</tr>
<tr>
<td>Basal VAS</td>
</tr>
</tbody>
</table>

Basal value VAS 8 ± 1.5 and WOMAC 88 ± 1.9; VAS — visual analogue scale; WOMAC — Western Ontario McMaster Universities OA index

3 patients underwent TKA during this period

Anaesthesiology Intensive Therapy 2015, vol. 47, no 1, 30–33
Emerging Data for Genicular Cooled RFA

Table 5: Logistic regression model for clinical success† following genicular nerve block

<table>
<thead>
<tr>
<th></th>
<th>β</th>
<th>P</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body mass index, kg/m²</td>
<td>0.16</td>
<td>0.025</td>
<td>1.17</td>
<td>1.02–1.35</td>
</tr>
<tr>
<td>Duration of pain at presentation, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;5</td>
<td>2.39</td>
<td>0.046</td>
<td>1</td>
<td>Reference</td>
</tr>
<tr>
<td>&gt;2–≤5</td>
<td>4.35</td>
<td>0.007</td>
<td>10.54</td>
<td>0.67–168</td>
</tr>
<tr>
<td>≤2</td>
<td></td>
<td></td>
<td>13.05</td>
<td>1.30–131</td>
</tr>
<tr>
<td>Percent pain relief from diagnostic blocks*</td>
<td></td>
<td>0.071</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50–79%</td>
<td>2.35</td>
<td>0.096</td>
<td>1</td>
<td>Reference</td>
</tr>
<tr>
<td>80–99%</td>
<td>2.57</td>
<td>0.029</td>
<td>10.91</td>
<td>1.04–115</td>
</tr>
<tr>
<td>100%</td>
<td></td>
<td></td>
<td>77.34</td>
<td>3.43–1,778</td>
</tr>
<tr>
<td>Constant</td>
<td>−6.39</td>
<td>0.012</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The primary outcome, treatment success, was defined as a combination of 50% or greater reduction in NRS score and PGIC score consistent with “very much improved” or “improved,” and no TKA. A secondary definition of treatment success was also defined based on improvement in NRS score equal to the minimal clinically important change for chronic pain: a two-point reduction [22,23]. MSQ III data were analyzed according

Conclusions. Genicular C-RFA demonstrated a success rate of 35% based on a robust combination of outcome measures, and 19% of procedures resulted in complete relief of pain at a minimum of six months of follow-up. Report of 80% or greater relief from diagnostic blocks and duration of pain of less than five years are associated with high accuracy in predicting treatment success. Further prospective study is needed to optimize the patient selection protocol and success rate of this procedure.
## Importance of Prognostic Blocks

**Cooled Radiofrequency Ablation of Genicular Nerves for Knee Osteoarthritis Pain: A Protocol for Patient Selection and Case Series**

<table>
<thead>
<tr>
<th></th>
<th>6</th>
<th>5/4</th>
<th>7/5</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline NRS (Right/Left, if applicable)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Baseline MQS3/MEq</strong></td>
<td>32.1/64</td>
<td>8/0</td>
<td>4.8/10</td>
<td>4/0</td>
</tr>
<tr>
<td><strong>Percent reduction in pain with test block</strong></td>
<td>100</td>
<td>100/100</td>
<td>86/100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Percent reduction in pain 3 month post-RFA</strong></td>
<td>100</td>
<td>90/90</td>
<td>80/50</td>
<td>90</td>
</tr>
<tr>
<td><strong>Percent reduction in pain 6 months post-RFA</strong></td>
<td>100</td>
<td>90/90</td>
<td>85/80</td>
<td>90</td>
</tr>
<tr>
<td><strong>Percent reduction in pain 9 months post-RFA</strong></td>
<td>90</td>
<td>80/80</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Reduction in MQS3 score at 6 months post-RFA</strong></td>
<td>-6.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8</td>
<td>4.8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Reduction in Morphine equivalent consumption at 6 months post-RFA</strong></td>
<td>-8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>N/A</td>
<td>10</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Complications

Is Genicular Nerve Radiofrequency Ablation Safe? A Literature Review and Anatomical Study  
(Analysis of Reported Complications from Knee Surgery)

Soo Yeon Kim, MD\textsuperscript{1,2}, Phuong Uyen Le, DO\textsuperscript{1,2}, Boleslav Kosharskyy, MD\textsuperscript{1,2}, Alan D. Kaye, MD, PhD\textsuperscript{3}, Naum Shaparin, MD\textsuperscript{1,2}, and Sherry A. Downie, PhD\textsuperscript{2}

Of the 27 cases analyzed, 25.9\% (7/27) involved the lateral superior genicular artery, 40.7\% (11/27) involved the medial superior genicular artery, and 33.3\% (9/27) involved the medial inferior genicular artery. Most often, these vascular injuries result in the formation of pseudoaneurysm, arteriovenous fistula (AVF), hemarthrosis, and/or osteonecrosis of the patella. Although rare, these complications carry significant morbidities. Based on the detailed dissections and review of the literature, our investigation suggests that vascular injury is a possible risk of genicular RFA. Lastly,
Genicular Branch (and Artery) Ultrasonography

Fig. 1. (a) Transverse ultrasound image of the knee at the level of the femoral medial epicondylo. Superior medial genicular nerve (thick arrow) and the corresponding artery (thin arrow) were visualized. (b) The needle (arrows) was placed to the bony cortex 1 cm anterior to the peak of the adductor tubercle for the superior medial genicular nerve.

Fig. 2. (a) Longitudinal ultrasound image of the knee at the level of the tibial medial epicondylo. Inferior medial genicular nerve (thick arrow) and the corresponding artery (thin arrow) were visualized using power doppler. (b) The needle (arrows) was placed to the bony cortex at the midpoint between the peak of the tibial medial epicondylo (square) and the lateral fibers inserting into the tip of the medial collateral ligament (star) for inferior medial genicular nerve.


Genicular Block/RFA Ultrasound

Source: Dr. Vincente Roques
H. Universitario Virgen de la Arrixaca. Unidad de Dolor Quiron Murcia
Genicular Block/RFA Ultrasound

Source: Dr. Vincente Roques
H. Universitario Virgen de la Arrixaca. Unidad de Dolor Quiron Murcia
Genicular Block/RFA Ultrasound

Source: Dr. Vincente Roques
H. Universitario Virgen de la Arrixaca. Unidad de Dolor Quiron Murcia
### Ultrasound Views for Genicular Block

<table>
<thead>
<tr>
<th>View Type</th>
<th>Coronal/Longitudinal</th>
<th>Transverse View</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superomedial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inferomedial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Superolateral</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Superior Mid-Femoral</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inferolateral</strong></td>
<td></td>
<td>(Caution)</td>
</tr>
</tbody>
</table>

*Caution:* Proceed with caution when applying the inferolateral approach.
Obturator and Femoral Articular Nerve Ablation
• Anteromedial joint: obturator nerve
• Anterolateral joint: femoral nerve
• Posterosuperior joint: sciatic nerve
• Posteroinferior joint: nerves to quadratus femoris muscle
• Posterolateral joint: superior gluteal nerve
Percutaneous Radiofrequency Lesioning of Sensory Branches of the Obturator and Femoral Nerves for the Treatment of Non-Operable Hip Pain

Atif Malik, MD, Thomas Simopolous, MD, Mohamed Elkersh, MD, Musa Aner, MD, and Zahid H. Bajwa, MD

- Case series: 4 patients
- Single diagnostic nerve block: 1ml Marcaine 0.25%
- SRFA treatment
- All 4 had reduction in VAS
  - 3 had improved function
  - 2 had reduction in pain meds
- One patient reported numbness at the hip
Anterior Hip Articular Branches

Articular branches of Obturator nerve

Groin pain

Articular branches of Femoral nerve

Thigh pain

Trochanteric pain

Percutaneous Radiofrequency Lesioning of Sensory Branches of the Obturator and Femoral Nerves for the Treatment of Hip Joint Pain

Masahiko Kawaguchi, M.D., Keiji Hashizume, M.D., Toshio Iwata, M.D., and Hitoshi Furuya, M.D.
Regional Anesthesia and Pain

• N: 14 patients
• Single diagnostic block: nerve/joint
• RF: obturator in 9, obturator and femoral in 5
• VAS: 6.8 to 2.7
• 86% had 50% relief for 1-11 months

Fig 2. Anatomic drawing of the articular branches of obturator and femoral nerves. Arrows indicate the points directed by the needle for the radiofrequency lesioning of the articular branches of obturator and femoral nerve. The dotted area indicates the hip joint capsule.
Outcomes Continued


Percutaneous radiofrequency denervation in patients with contraindications for total hip arthroplasty.
Rivera F¹, et al.

• 16 pts
• 8 pts ≥ 50% pain relief at 6 months.
• Statistically improvement in WOMAC scores.
Radiological Anatomy of the Obturator Nerve and Its Articular Branches: Basis to Develop a Method of Radiofrequency Denervation for Hip Joint Pain

Stephan Locher, MD,1 Helge Burmeister, MD,1 Thomas Böhlen, MD,1 Urs Eichenberger, MD,1 Christophoros Stoupis, MD,2 Bernhard Moriggl, MD, Prof,3 Klaus Siebenrock, MD, Prof,1 and Michele Curatolo, MD, Prof*

Results

• 10 cadavers, 4 bilateral
• The obturator nerve and its articular branches were marked by wires.
• Their radiological relationship to the bone structures on fluoroscopy was imaged and analyzed.
• A MRI on 20 patients to confirm soft tissue in pathway.
RFA Approach, Femoral and Obturator Branches
A Novel Technique for Obturator Articular Branch Block

John DiMuro, M.D. †, Jeffrey D. Petersohn, M.D. ‡, Robert D. Menzies, M.D. §, Carlo D. Franco, M.D. †‡, Asokumar Buvanendran, M.D. ††

‡SpineNeNe, Reno, NV; †PainCare, PC Linwood, NJ, Department of Anesthesiology and Perioperative Medicine Drexel University College of Medicine, Philadelphia, PA; ‡Southwest Sports and Spine, FT. Worth, TX; §Department of Anesthesiology and Pain Management, Rush University Medical Center, Chicago, IL; †Department of Anesthesiology and Pain Management, JHS Hospital of Cook County, Chicago, IL

- Anatomic study (n = 6)
- **Purpose**: Describe a novel approach to the obturator articular branch to reduce risk for neurovascular injury
- **Method**: Nerve branches identified, overlaid with steel wire, and correlated with radiographic landmarks
- **Anatomy**: Obturator branch traverses anterior ischia (Fig 1) and enters capsule 1-3 cm deep to femoral bundle, visible on true PA radiograph (Fig 2)
- **Technique**:
  - Patient supine
  - Abduction for true PA of femoral head, acetabulum, and incisura
  - Line drawn from incisura to ischial tuberosity – extended to medial thigh to mark needle entry
  - Needle steered to target site (Fig 3) following ischial surface
Anterior Hip Innervation
Future: Posterior Hip Innervation

1) Superior Gluteal N
2) Nerve to Quad Fem

? Inferior Gluteal N
Complications

WIP16-0157  FEMORAL NERVE INJURY FOLLOWING COOLED RADIOFREQUENCY LESIONING FOR THE TREATMENT OF HIP PAIN DESPITE ULTRASOUND GUIDANCE AND MOTOR TESTING
I. Gooding, E. Voogd, C. Sigmon

motor testing. Despite the safety measures employed, the patient developed quadriceps weakness following the procedure with numbness along the femoral and saphenous nerve distribution. EMG performed 6 weeks after the procedure noted no voluntary motor unit action potentials consistent with severe femoral neuropathy.
Complications summary, published and verbal reports

• Genicular CRFA
  • Hematoma
  • Skin Burns

• Hip Articular CRFA
  • Femoral Artery Cannulation / Hematoma
  • Femoral Nerve Injury
More is Better?

- 61 y/o patient
- T1-4 thoracic facet pain
- H/O posterior fusion C3-T1
- Probes placed at superiorlateral aspect of T2-T5 transverse process
- RFA 60 deg C, 150 seconds
- During RFA, patient complains of severe local pain at 90 sec
- Skin blanching noted
- Healing ultimately took 5 months

Shoulder Nerve Ablation?
Hilton’s Law and Neurologic Innervation

• Hilton’s Law (1863)

  “The same trunks of nerves whose branches supply the groups of muscles moving a joint furnish also a distribution of nerves to the skin over the insertions of the same muscles; and—what at this moment more especially merits our attention—the interior of the joint receives its nerves from the same source.”
Hilton’s Law Applied to Glenohumeral Joint

<table>
<thead>
<tr>
<th>Nerve (origin)</th>
<th>Muscles moving joint</th>
<th>Cutaneous innervation</th>
<th>Explanation</th>
<th>Articular branch</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suprascapular (C5-C6)</td>
<td>Supra and infraspinatus</td>
<td>Yes or axillary</td>
<td>Same nerve or same source</td>
<td>Yes</td>
<td>Same nerve</td>
</tr>
<tr>
<td>Lateral pectoral</td>
<td>Pectoralis major (clavicular head)</td>
<td>Sensory branch (variations) or axillary</td>
<td>Same nerve or same source</td>
<td>Yes</td>
<td>Same nerve</td>
</tr>
<tr>
<td>Medial pectoral (C8-T1)</td>
<td>Pectoralis major (sternal head), <em>chondro-epitochlearis</em></td>
<td>Sensory branch of lateral pectoral or axillary</td>
<td>Double innervation or neural communication (ansa pectoralis)</td>
<td>Lateral pectoral branch</td>
<td>Double innervation or neural communication (ansa pectoralis)</td>
</tr>
<tr>
<td>Upper subscapular (C5-C6)</td>
<td>Subscapularis</td>
<td>Axillary</td>
<td>Same source</td>
<td>Yes (controversial) or axillary</td>
<td>Same nerve or same source</td>
</tr>
<tr>
<td>Lower subscapular (C5-C6)</td>
<td>Subscapularis, teres major</td>
<td>Axillary</td>
<td>Same source</td>
<td>Yes (controversial) or axillary</td>
<td>Same nerve or same source</td>
</tr>
<tr>
<td>Thoracodorsal (C5-C6-C7)</td>
<td>Latissimus dorsi, <em>axillary arch</em></td>
<td>Axillary</td>
<td>Same source</td>
<td>Lateral pectoral branch</td>
<td>Same source</td>
</tr>
<tr>
<td>Axillary (C5-C6)</td>
<td>Deltoid, teres minor</td>
<td>Yes</td>
<td>Same nerve</td>
<td>Yes</td>
<td>Same nerve</td>
</tr>
<tr>
<td>Musculo-cutaneous (C5-C6-C7)</td>
<td>Biceps, coraco-brachialis</td>
<td>Yes</td>
<td>Same nerve</td>
<td>Lateral pectoral branch</td>
<td>Same nerve</td>
</tr>
<tr>
<td>Radial (C5-C6-C7-C8-T1)</td>
<td>Triceps</td>
<td>Yes</td>
<td>Same nerve</td>
<td>Yes or from posterior cord</td>
<td>Same nerve or same source</td>
</tr>
</tbody>
</table>

Neurologic Innervation: Joint Capsule

Anterior Shoulder Joint

- Subscapular Branches
- Axillary Nerve (Anterior Branch)

- Lateral Pectoral Nerve (Articular Branch)

Neurologic Innervation: Joint Capsule

**Posterior Shoulder Joint**
- Suprascapular Nerve
  - Superior Articular Branch
  - Inferior Articular Branch
- Axillary Nerve

**Superior Shoulder Joint**
- Suprascapular Nerve
  - Superior Articular Branch
  - Lateral Pectoral Nerve

Lateral Pectoral Nerve Block

• **Indications**
  - Anterior superior shoulder capsule, AC joint, lateral clavicle, subacromial bursa

• **Landmarks**
  - Deltopectoral groove
  - Clavicle
  - Coracoid Process

• **Technique**
  - At confluence of these 3 landmarks
  - Medial aspect of coracoid
  - Just under the clavicle
  - (Upper subscapular N can be reached 2 cm beyond and lateral)

• **Ultrasound Guided**
  - Has been described for breast surgery but techniques appear distal to articular fibers

Cadaveric Study of the Articular Branches of the Shoulder Joint

Maxim S. Eckmann, MD,* Brittany Bickelhaupt, MD,† Jacob Fehl, MD, † Jonathan A. Benfield, DO,* Jonathan Curley, MD,‡ Ohmid Rahimi, PhD,§ and Ameet S. Nagpal, MD, MS, Med*
First Cases, UT Health San Antonio (in press)
Possible arterial injury — use finder needle/US?
Summary: Technical Advances in RFA

- **Beginning: Reliability**
  - Closed loop temperature control

- **Later: Versatility**
  - All shapes and sizes

- **Current: Larger and Larger Lesion Sizes**
  - Possibly improved outcomes
  - New complications
  - Safe trajectories are needed

*Thank you!*