Updates in Radiofrequency Ablation (RFA) for Chronic Pain

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Faculty Disclosure

	Nothing to disclose
	Yes, as follows: X

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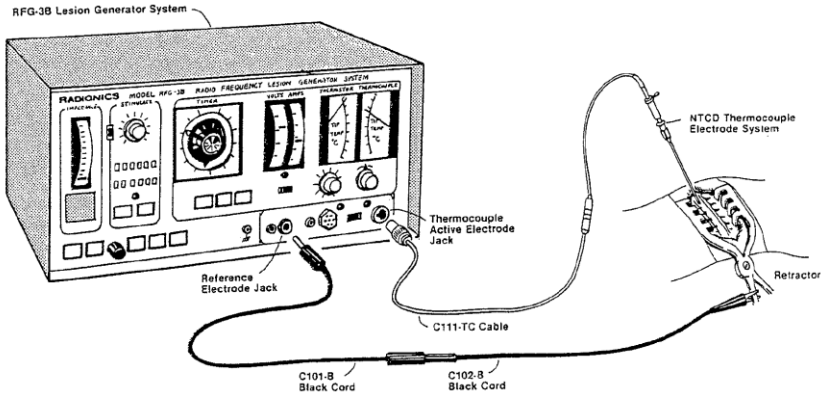
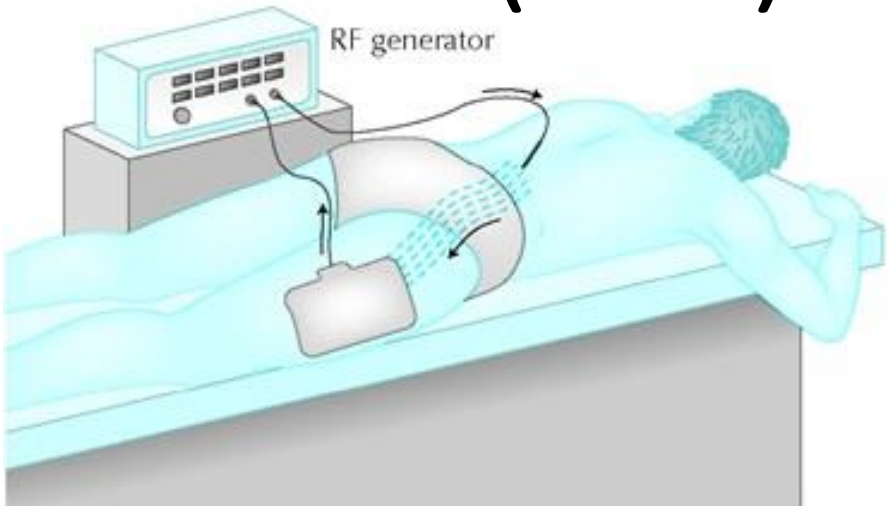
Objectives

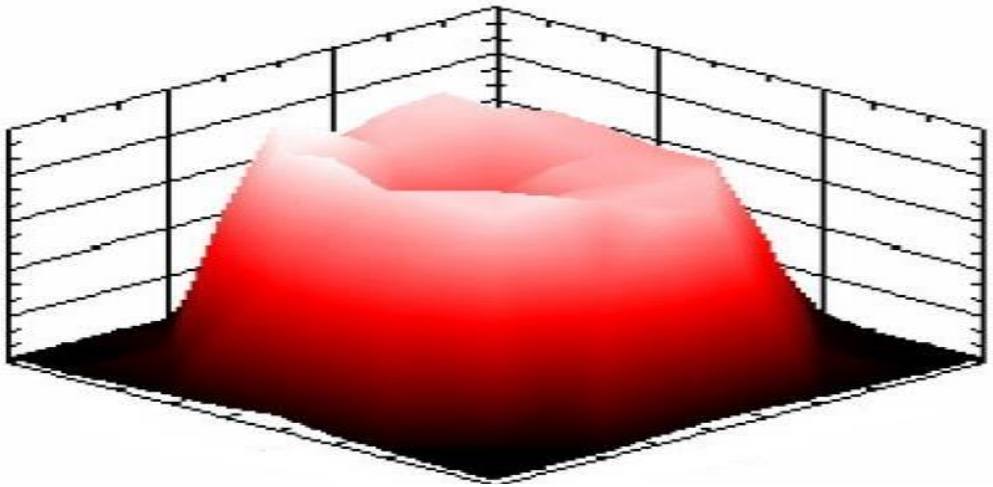


- Elucidate scientific principles governing Radiofrequency Ablation (RFA) and Cooled RFA.
- Understand ablation targets for innervation of spine and major joints.
- Apply current technological concepts to understand relevant advantages, limitations, and complications.

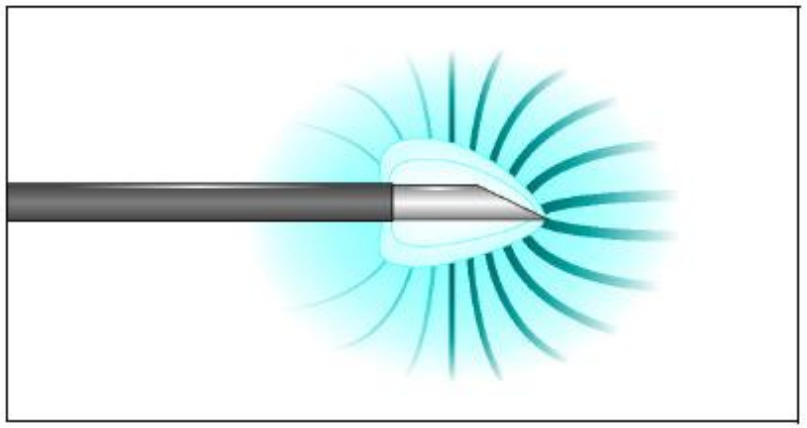
Science of Radiofrequency Ablation (RFA)

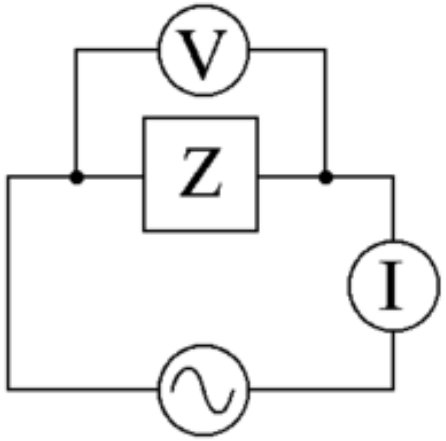
Conventional “Standard” Radiofrequency Ablation (SRFA)

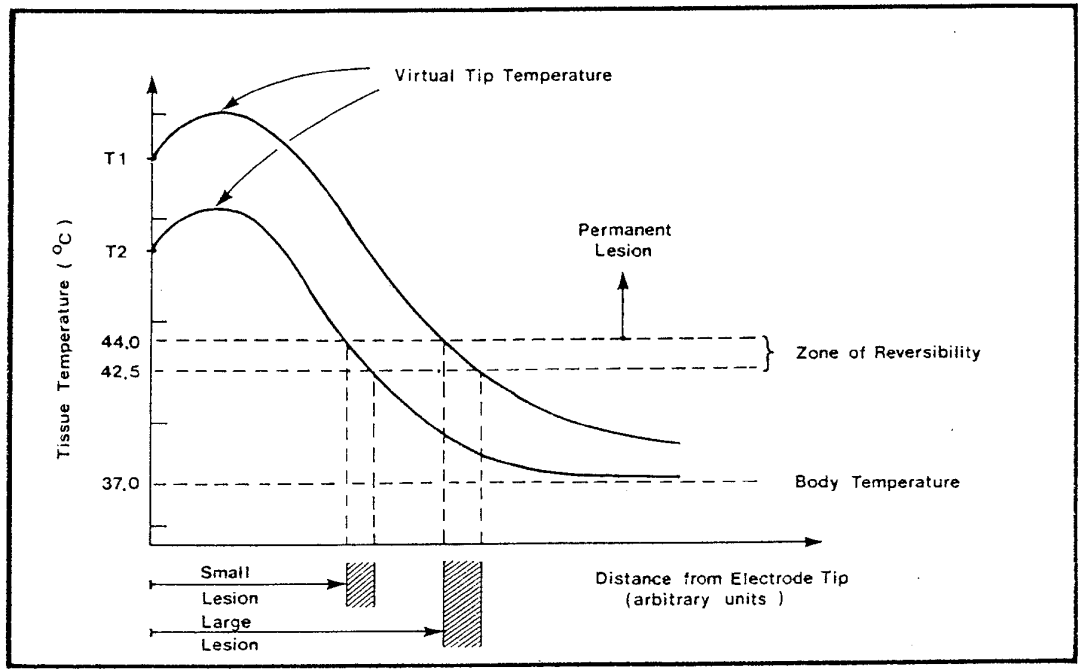




TISSUE TEMPERATURE VS. DISTANCE FROM ELECTRODE





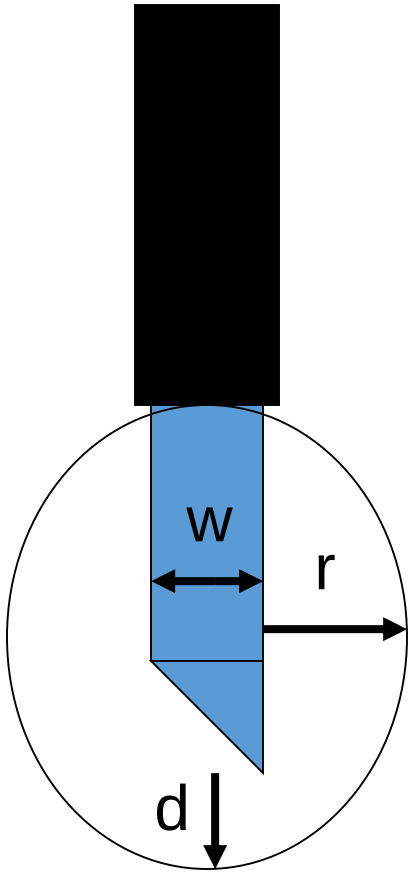


Cosman ER. Neurosurgery 1984;15(6): 945-950
Ahadian FM. Current Pain and Headache Reports 2004;8:34-40

Lesion Size Estimation (SRFA)

	SMK	RRE
w	0.7mm	1.6 mm
r	2.3 w +/- 0.4	1.6 w +/- 0.3
d	1.4 w	0.4 w

97.5% confident of coagulating tissues within <u>1.0-1.7 electrode widths</u> radially from probe.



Needle Gauge	Lesion Diameter (mm)
18	3.8-5.6
20	2.7-4.0
21	2.5-3.6

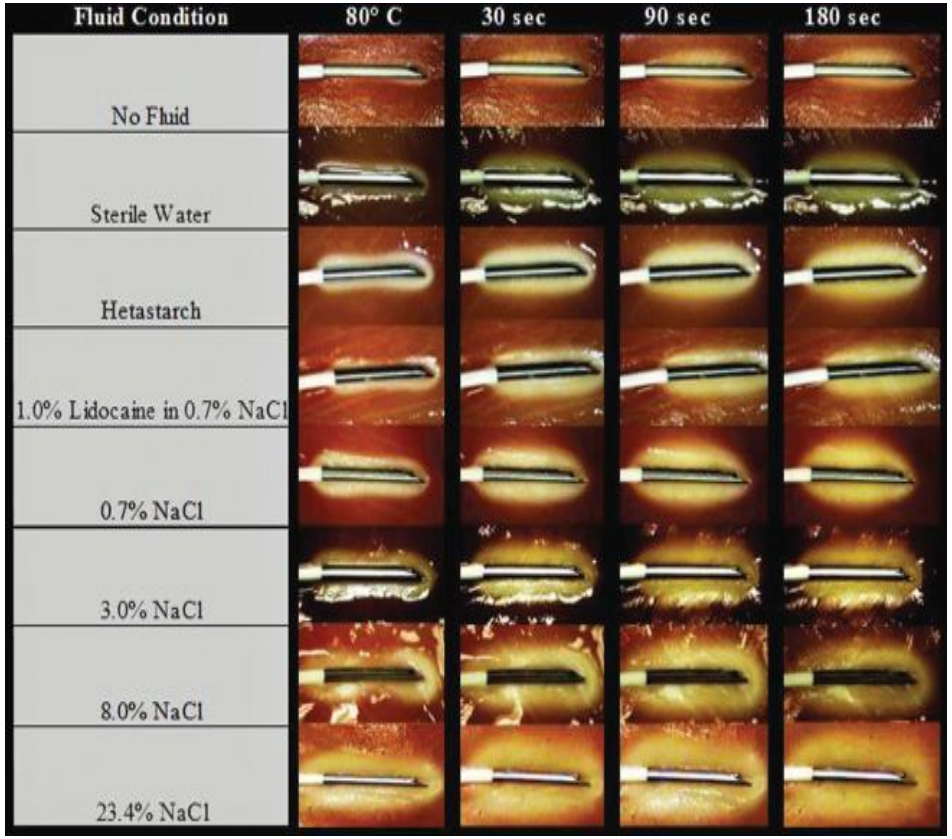
Practice Guidelines, Spinal Diagnostic and Treatment Proc., 2004, first ed., p 192.

More is Better? Augmentation and the Quest for Larger Lesions

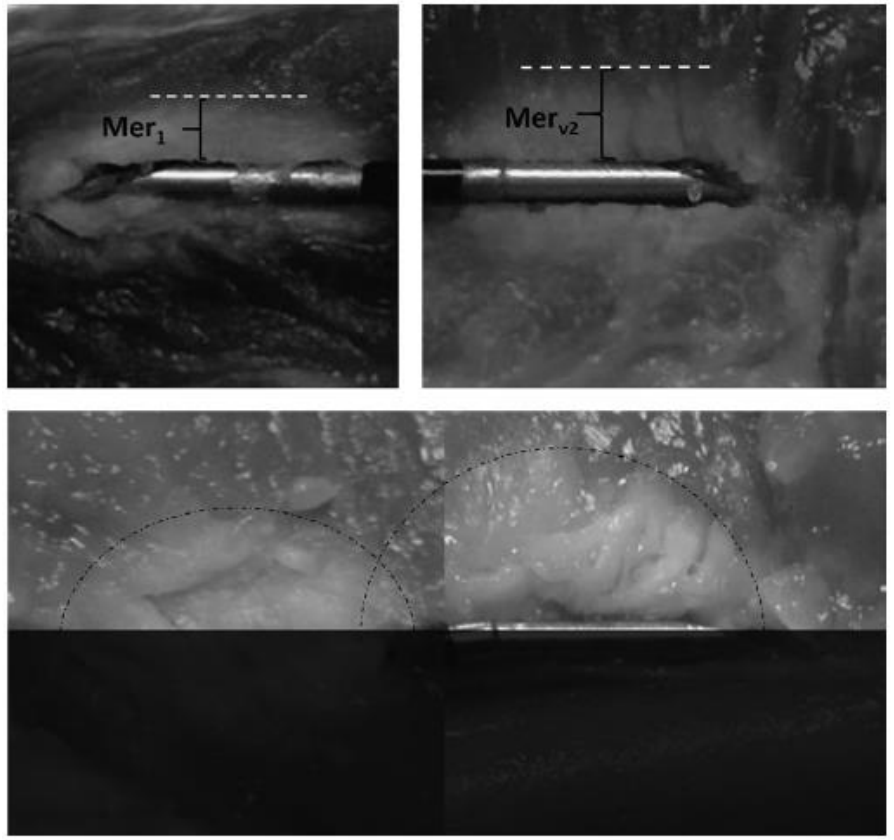
- Larger Gauge, Longer Active Tip
- Ionic Fluid Pre-Injection
- Palisading Monopolar Lesions
- Bipolar Lesions, Palisading Bipolar
- Cooled RFA
- Multi-tined RFA
- Multipolar RFA

Tissue Factors Affecting Lesions

- Fluid Pre-injection and time to 180 sec
- Bone Proximity



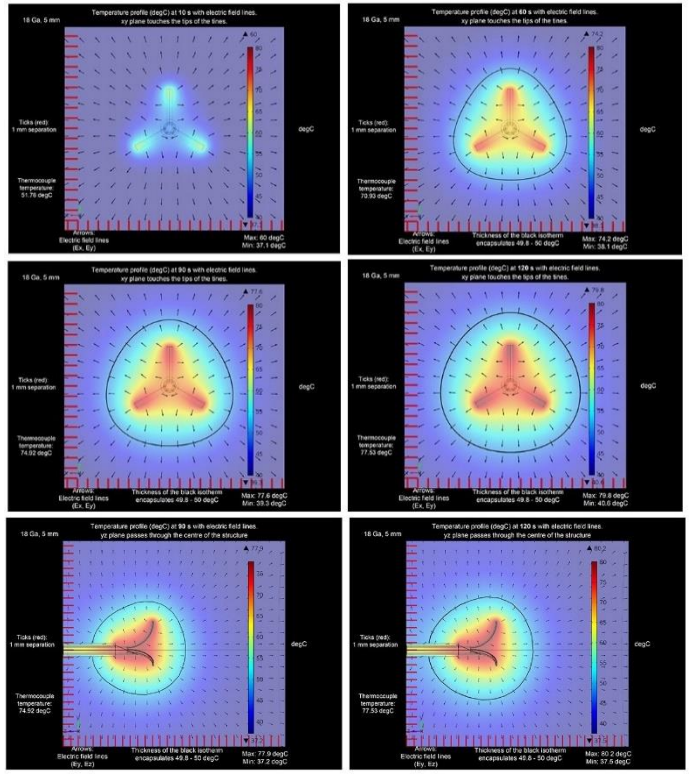
Provenzano DA, et. al. Reg Anesth Pain Med. 2015 Mar-Apr;40(2):112-24.

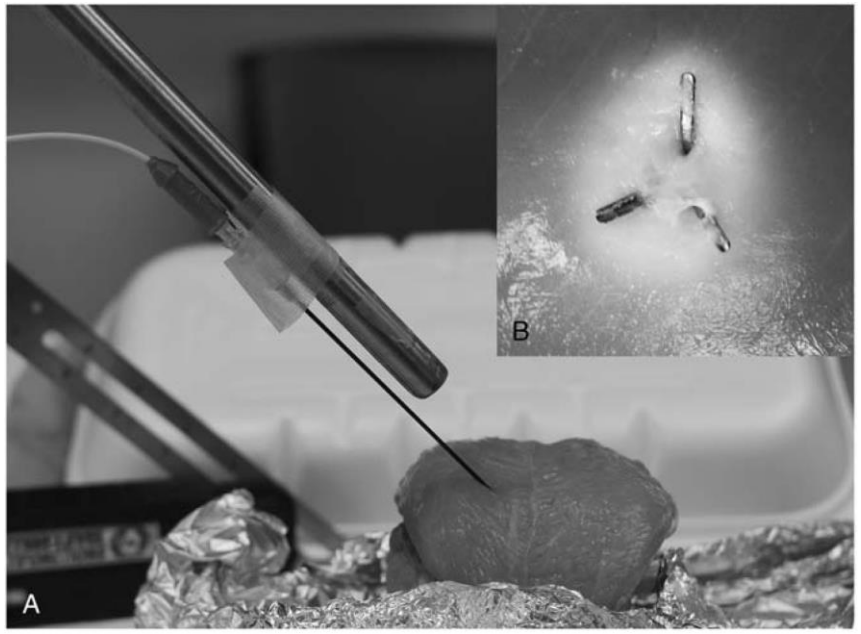


Eckmann MS, et. al. Reg Anesth Pain Med. 2015 May-Jun;40(3):270-5.

Example: Multi-tined Probes

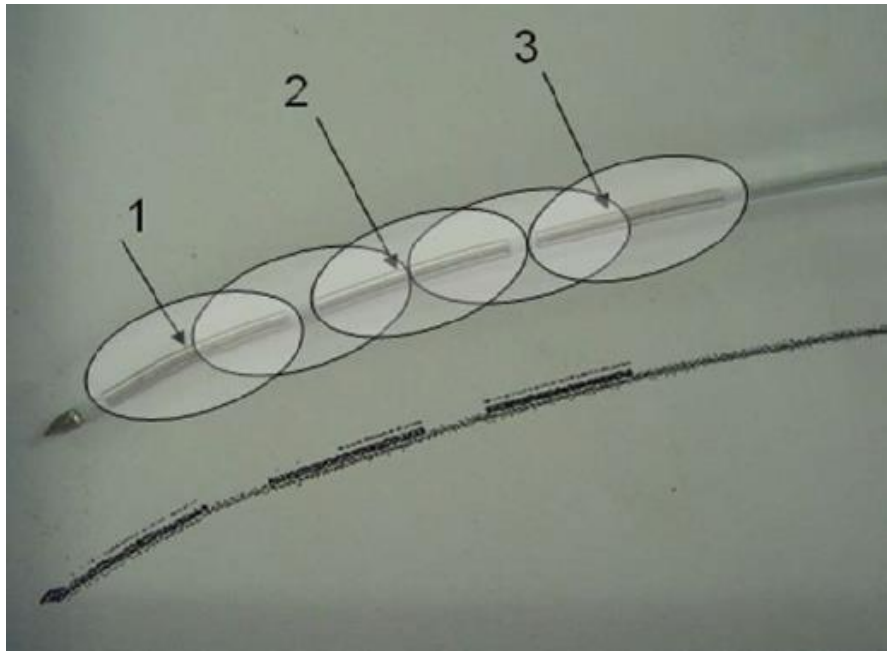
- Monopolar Conventional RFA
- Functionally Larger Active Tip

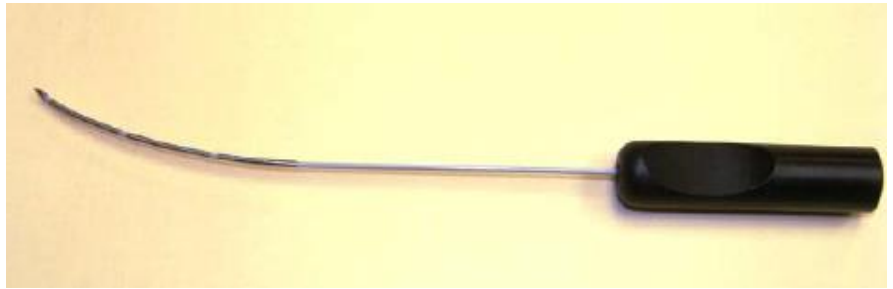


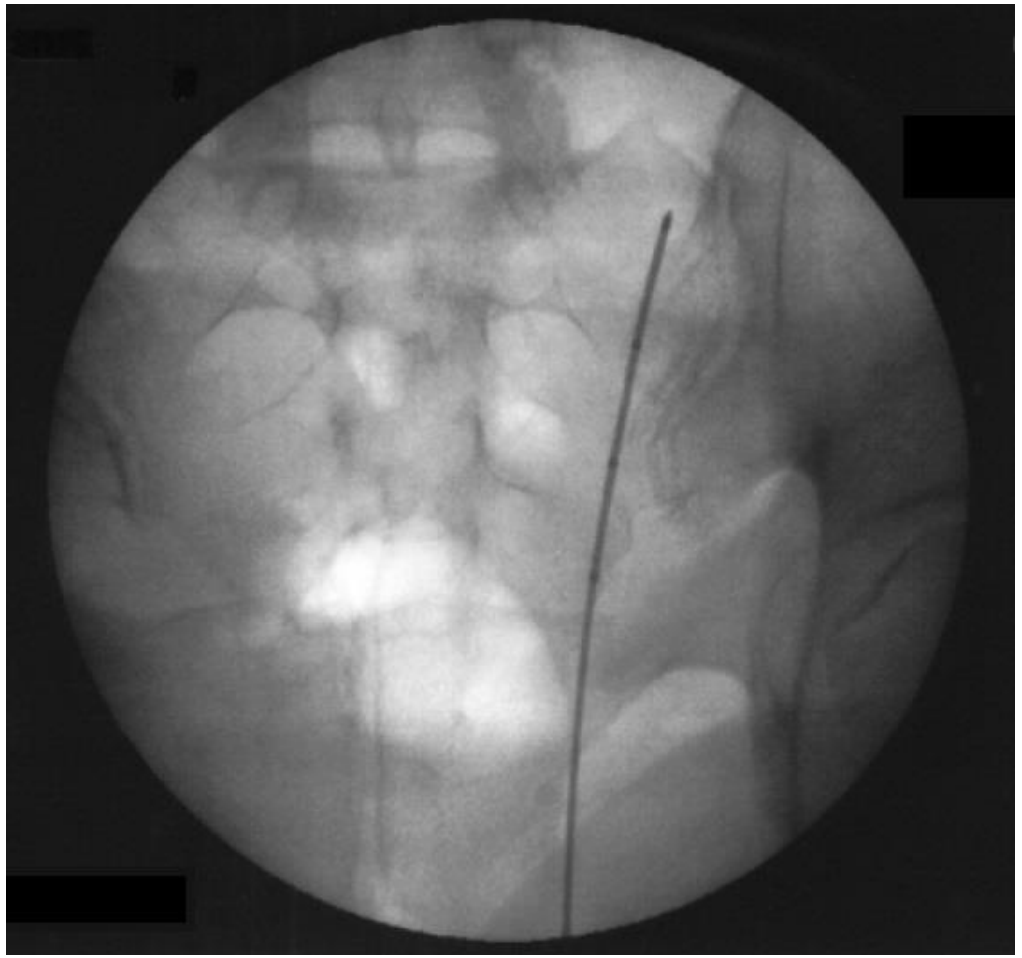


Finlayson RJ, et. al. Reg Anesth Pain Med. 2017 Jan/Feb;42(1):45-51.

Multipolar Probes





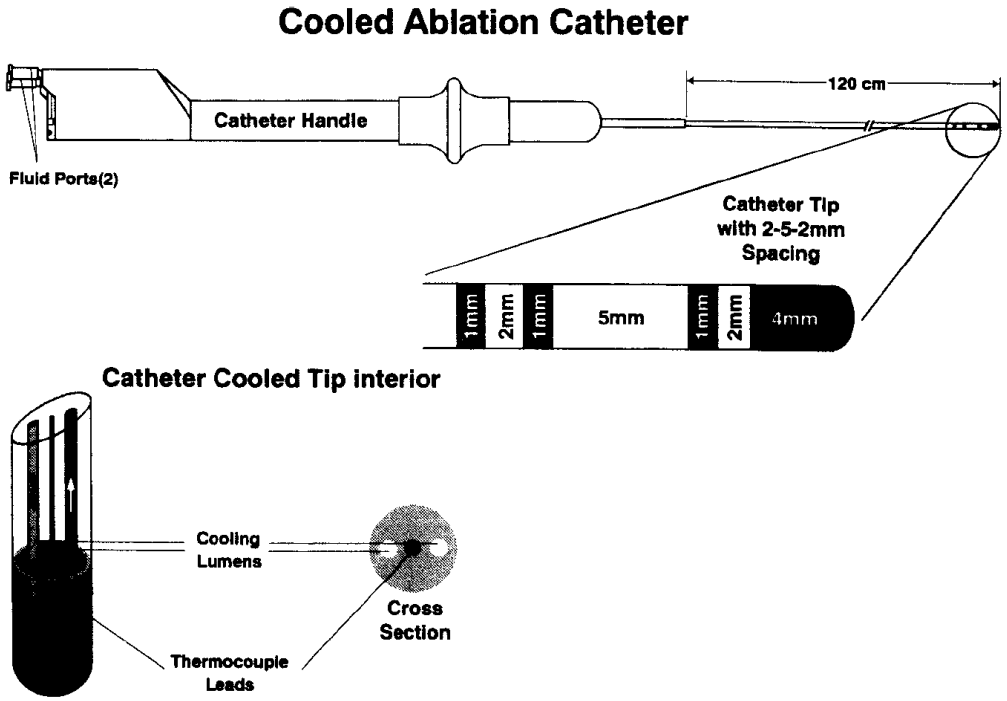


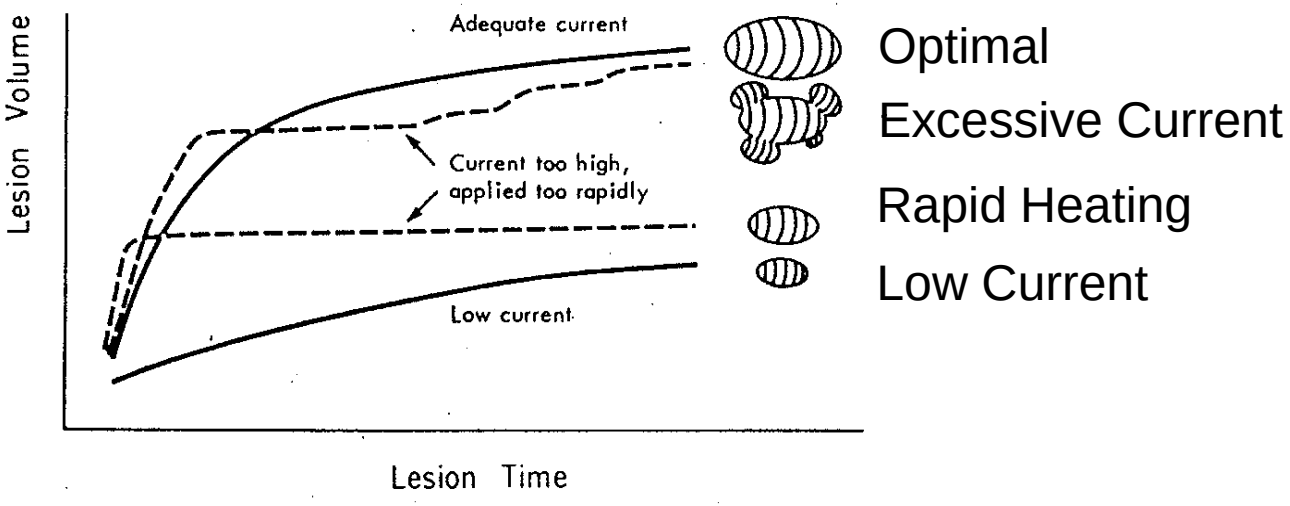
Cooled (not COLD!) Radiofrequency Ablation (CRFA)

Journal of Interventional Cardiac Electrophysiology 6, 9–16, 2002

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

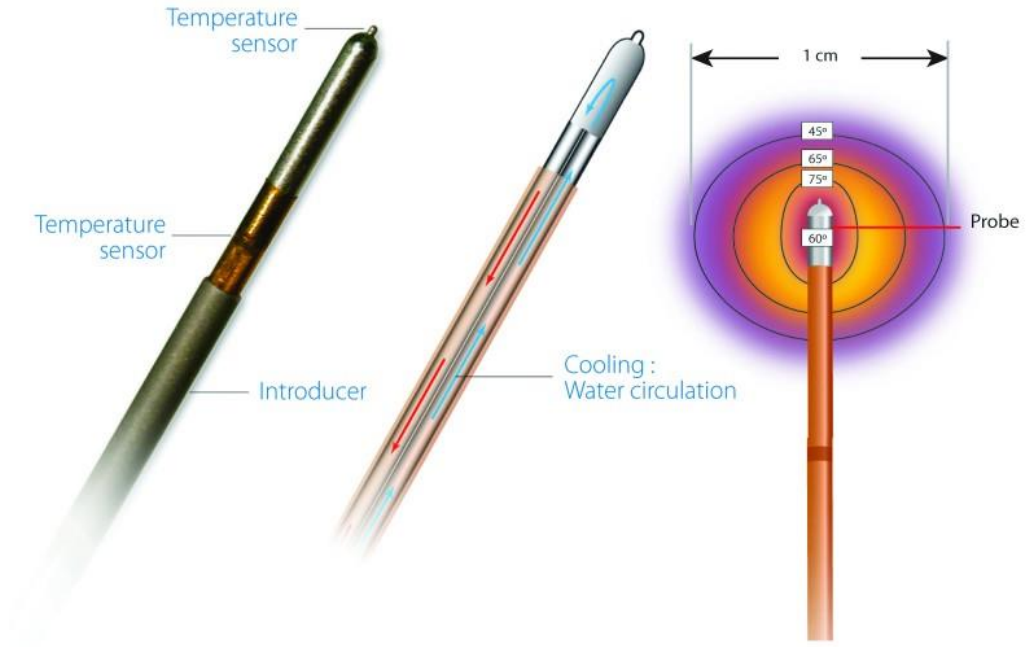
Ichiro Watanabe, Riko Masaki, Nuo Min, Naohiro Oshikawa, Kimie Okubo, Hidezou Sugimura, Toshiaki Kojima, Satoshi Saito, Yukio Ozawa, and Katsuo Kanmatsuse

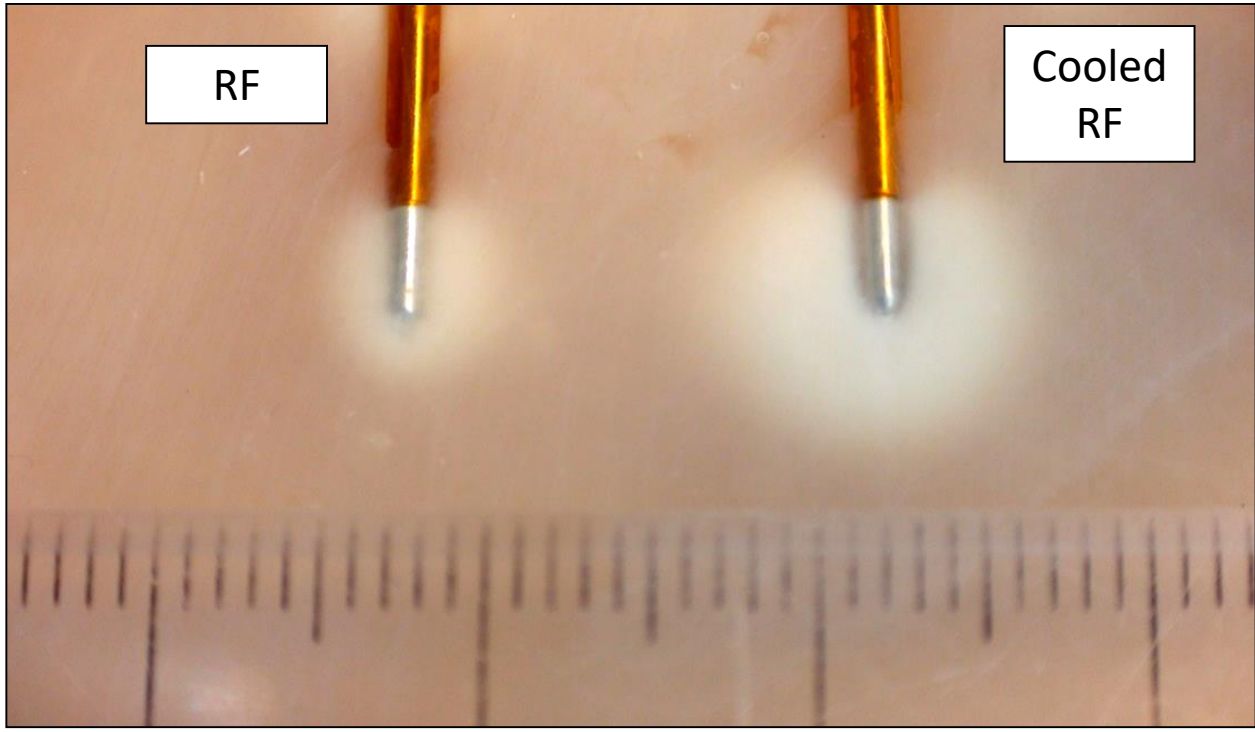




Cooled RF

- 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]

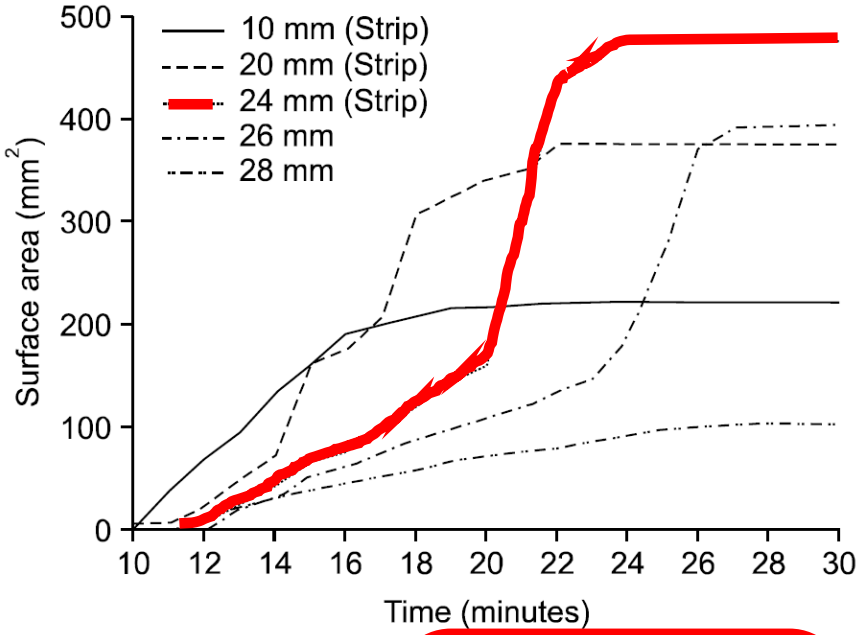


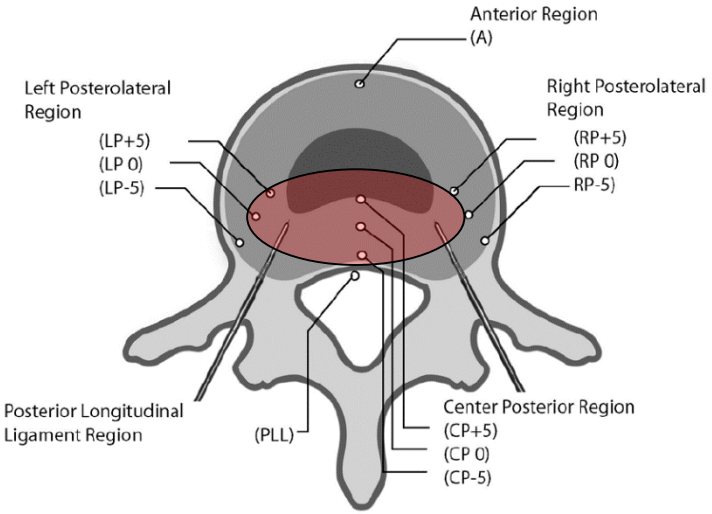


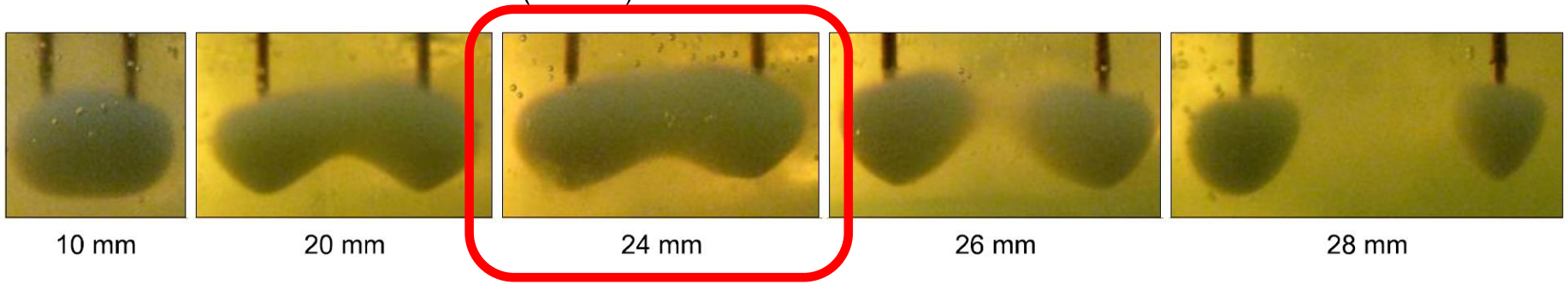
1. Wang H, et. al. Spine (Phila Pa 1976). 2016 Jun 15.

Bipolar Cooled RFA

- Large Strip Lesions
- Diminishing returns >24 mm



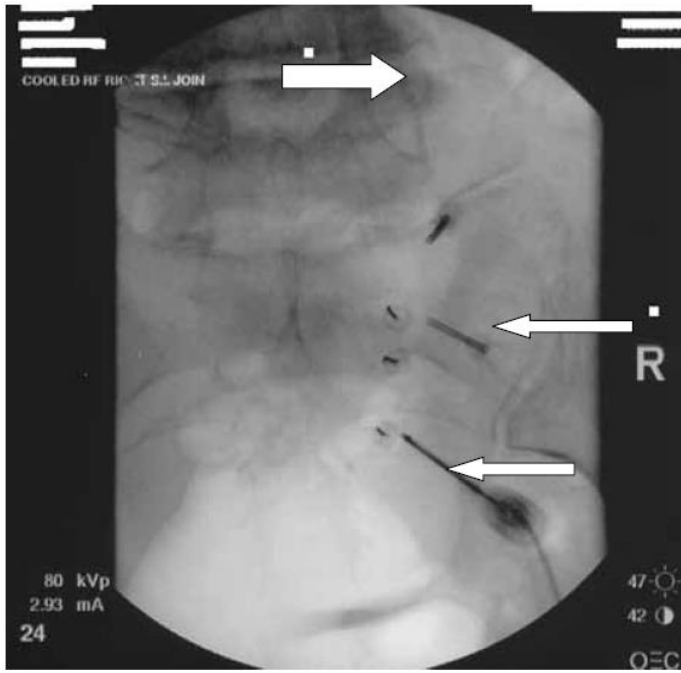


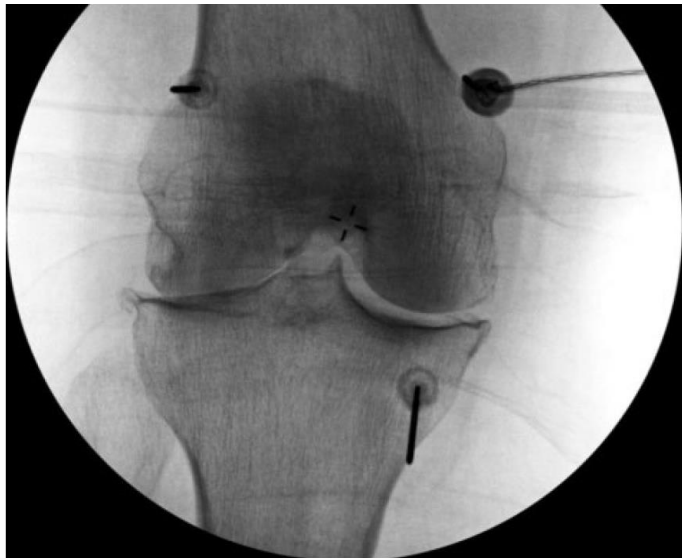


Kang SS, et. al. Korean J Pain. 2012 Jul;25(3):151-4.

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





Pauza K. Pain Physician 2008 Nov-Dec;11(5):669-76. Patel N. Pain Med. 2012 Mar;13(3):383-98.
Kapural L, et. al. Pain Med. 2015 Mar;16(3):425-31. McCormick ZL, et. al. Pain Med. 2017 Apr 19.
Stelzer W, et al. J Pain Res. 2017 Jan 13;10:183-190.
McCormick ZL, et al. Pain Med. 2017 Apr 19.

Complications summary, published and verbal reports

- Thoracic CRFA
  - Skin Burn

Walega D, Roussis C. Pain Pract. 2014 Jul;14(6):e154-8.

- Genicular CRFA
  - Hematoma
  - Skin Burn

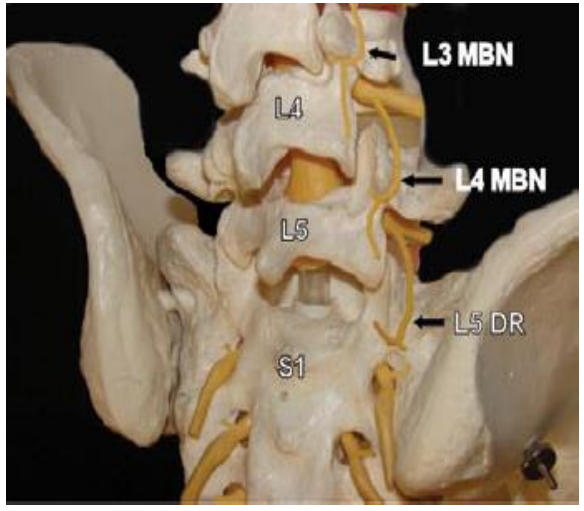
- Hip Articular CRFA
  - Femoral Artery Cannulation / Hematoma
  - Femoral Nerve Injury

Gooding I, et al. Pain Pract. 2016;16(S1):147.

Lumbar Zygapophyseal Joint Ablation for Chronic Low Back Pain

Lumbar Facet Denervation (medial branches)

- Long term treatment for “facetogenic” low back pain:
  - Segmental tenderness of the low back
  - Pain with provocation of the facet joints (quadrant loading, prone hip extension, palpation)
  - Concordant, positive response to controlled diagnostic medial branch blocks
    - >50% relief vs. >80% or more
  - Absence of radicular pain



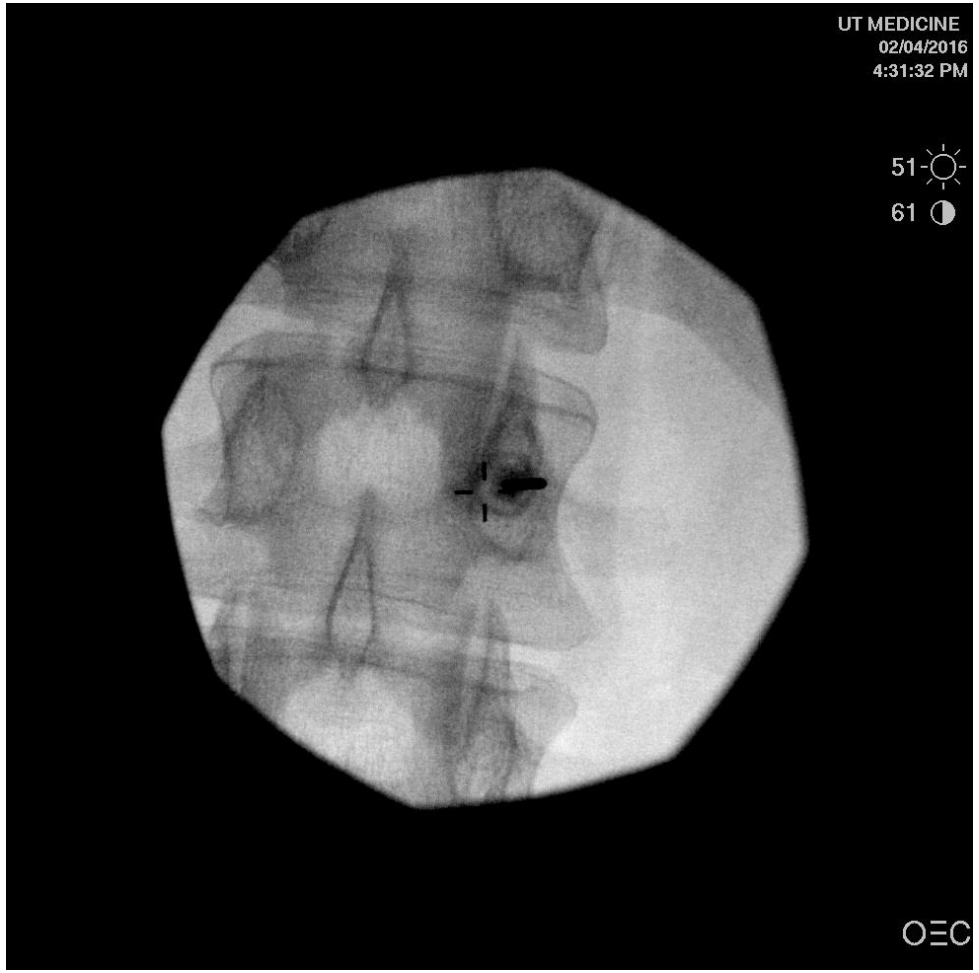
Jasper JF. Pain Physician 2008; 11:863-875.

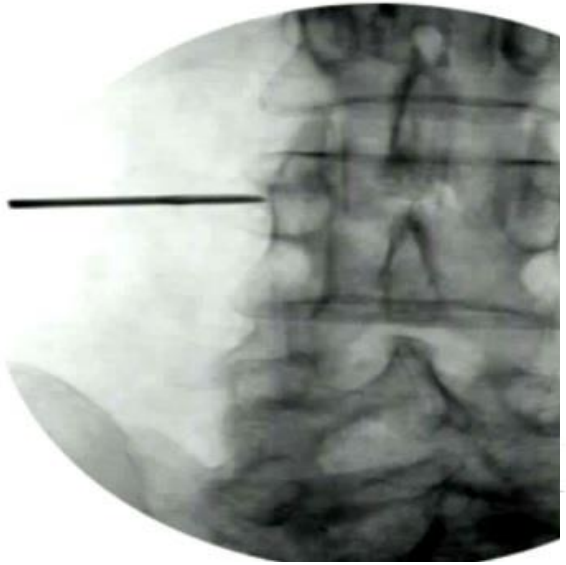
Lumbar Medial Branch SRFA: Evidence

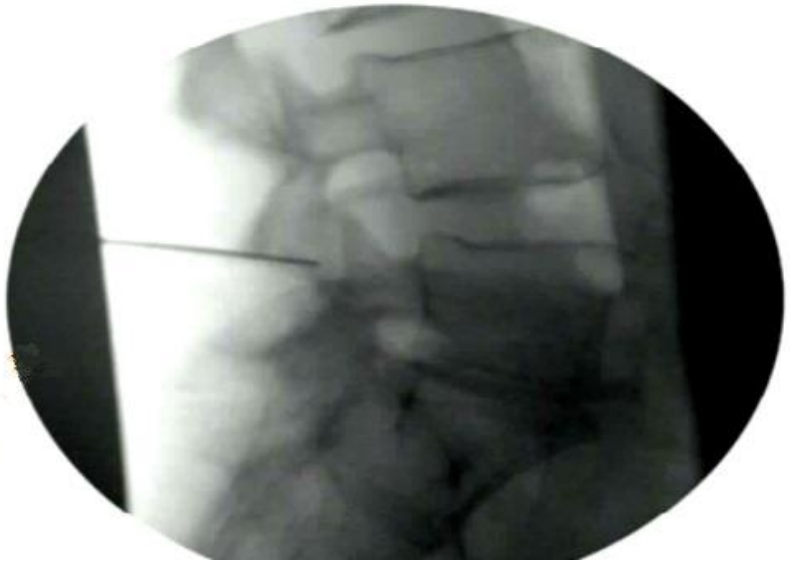
- Metanalysis of outcomes:
  - Short term improvement (1 mo.) v. placebo, pain and function: “moderate quality evidence”[1,2,3]
  - Longer duration benefit (>1 mo.): “weak evidence”
  - Outcomes tend to be better when using greater diagnostic nerve block specificity
- Sham controlled study (n=40 / 376) by Nath[4]:
  - Improved pain back pain scores at 6 months (by 2.1 NRS points compared to 0.7 for placebo), back movement, hip movement, and quality of life variables in treatment group;
  - Included subjects had >80% relief with blinded diagnostic blocks containing lidocaine and bupivacaine with concordant duration of action.
  - RFA was performed parallel to the anatomic course of the medial branch nerves
  - 22g cannula with 5mm active tip.

1. Leggett LE, Soril LJ, Lorenzetti DL, Noseworthy T, Steadman R, Tiwana S, Clement F. Radiofrequency ablation for chronic low back pain: a systematic review of randomized controlled trials. Pain Res Manag. 2014 Sep-Oct;19(5):e146-53.
2. Maas ET, Ostelo RW, Niemisto L, Jousimaa J, Hurri H, Malmivaara A, van Tulder MW. Radiofrequency denervation for chronic low back pain. Cochrane Database Syst Rev. 2015 Oct 23;(10):CD008572.
3. Lee CH, Chung CK, Kim CH. The efficacy of conventional radiofrequency denervation in patients with chronic low back pain originating from the facet joints: a meta-analysis of randomized controlled trials. Spine J. 2017 Nov;17(11):1770-1780.
4. Nath S, Nath CA, Pettersson K. Percutaneous lumbar zygapophysial (Facet) joint neurotomy using radiofrequency current, in the management of chronic low back pain: a randomized double-blind trial. Spine (Phila Pa 1976). 2008 May 20;33(12):1291-7; discussion 1298.

Lumbar Cooled RFA





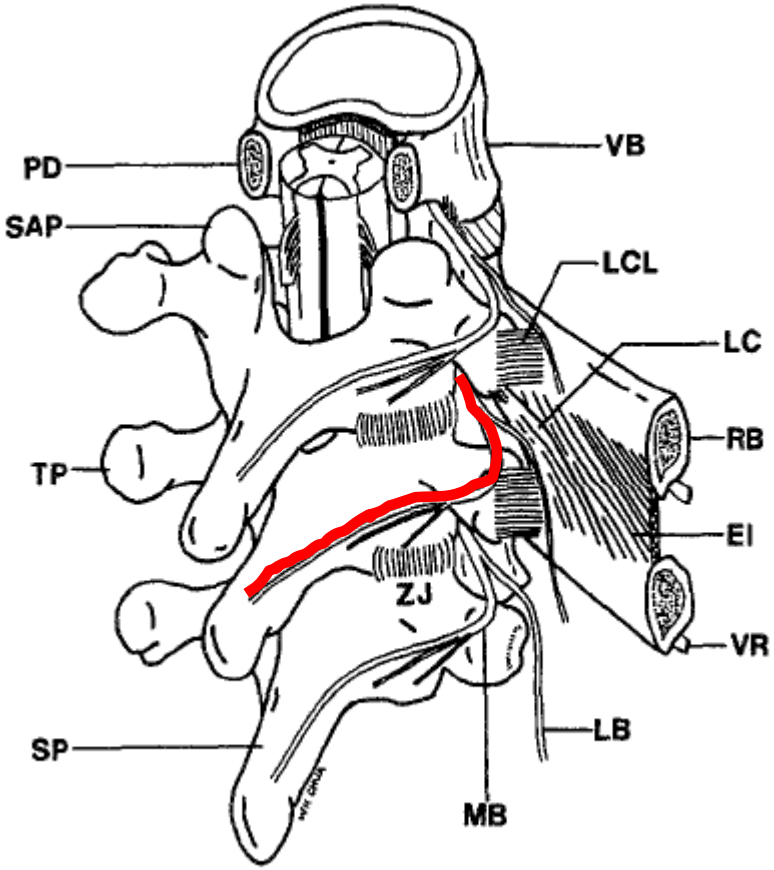


Evidence: Case reports

Thoracic Zygapophyseal Joint Ablation for Chronic Thoracic Spine Pain

Thoracic Facet Joint Syndrome

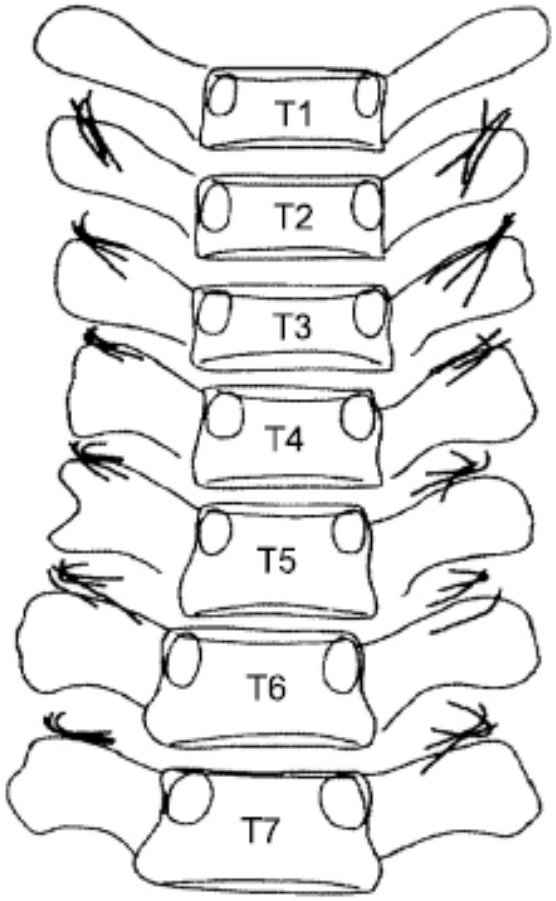
- Segmental, Axial Pain of the Thoracic Spine
  - Paraspinal Tenderness
  - May radiate anteriorly
- Lower prevalence than cervical and lumbar
- Medial Branch (MB) passes fairly laterally to the tip of the Transverse Process as it comes inferior and dorsal
- <u>Lack of significant high level evidence for TRFA</u>
- Same principles of selection and proper procedural technique apply.
  - Additional possible risk of pneumothorax
  - Nerve root injury may be less problematic

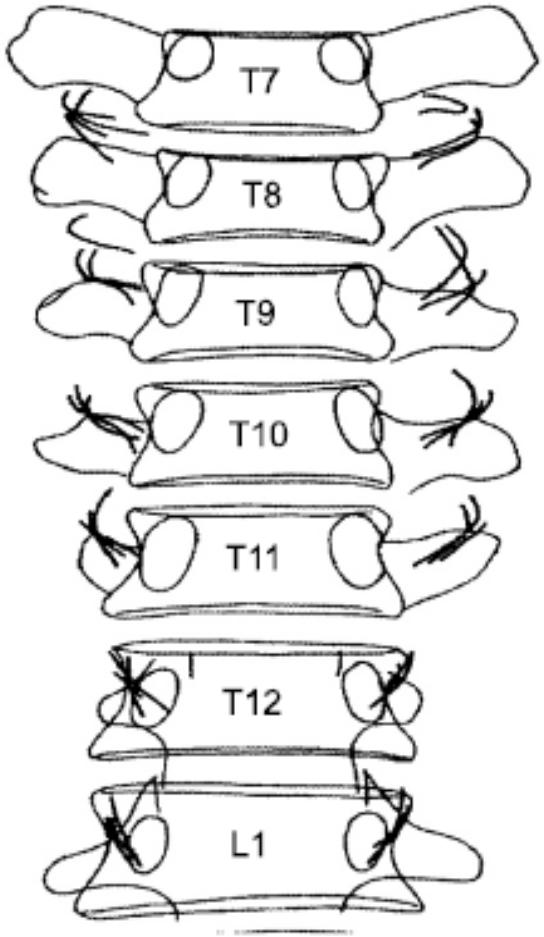


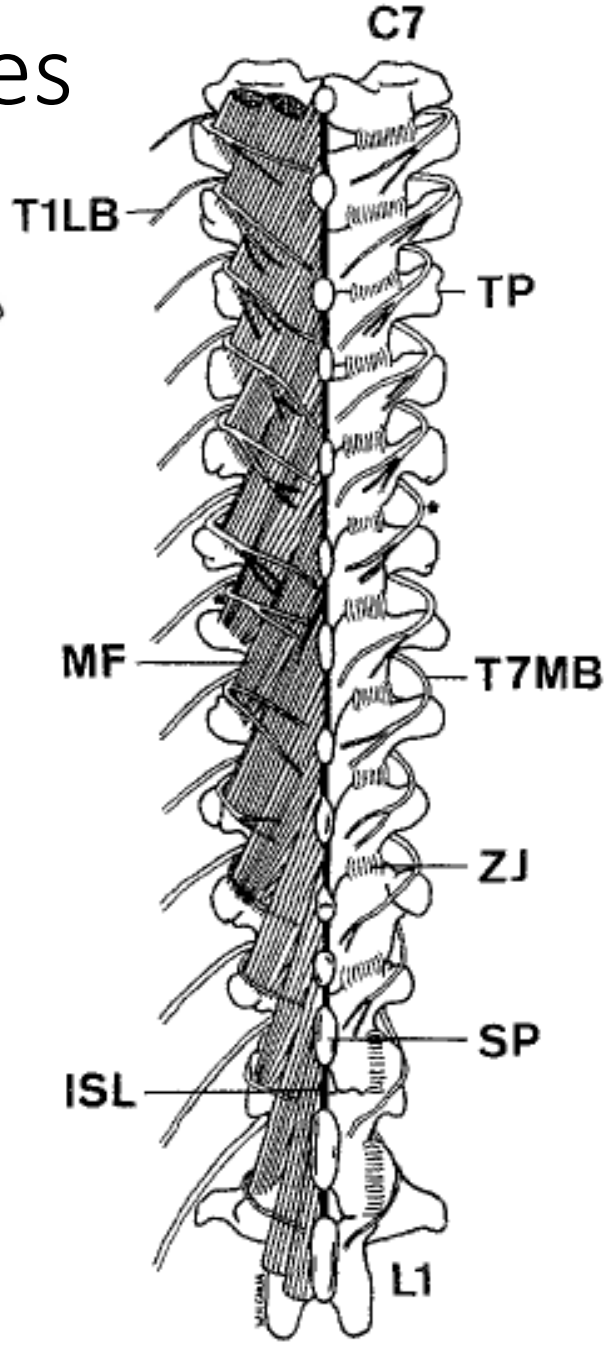
Chua WH, Bogduk N. 1995;136(3-4):140-4.

Renditions: Thoracic Medial Branches

- T1-4, 9-10
  - Lateral on TP
- T5-8
  - Superior and Medial to tip TP
- T11, T12
  - Near root of SAP

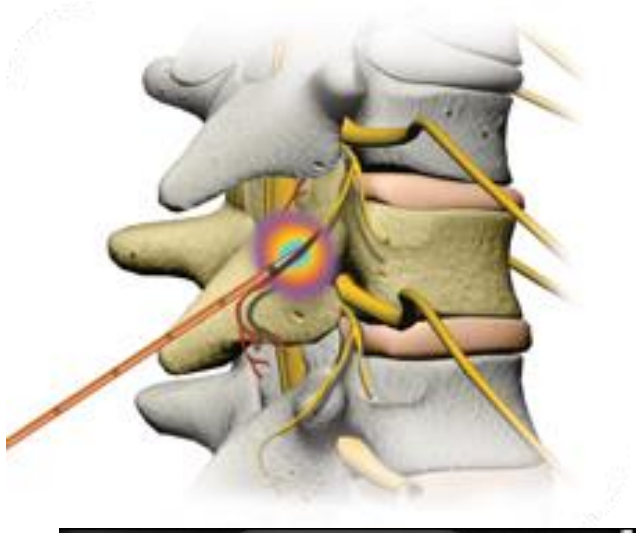


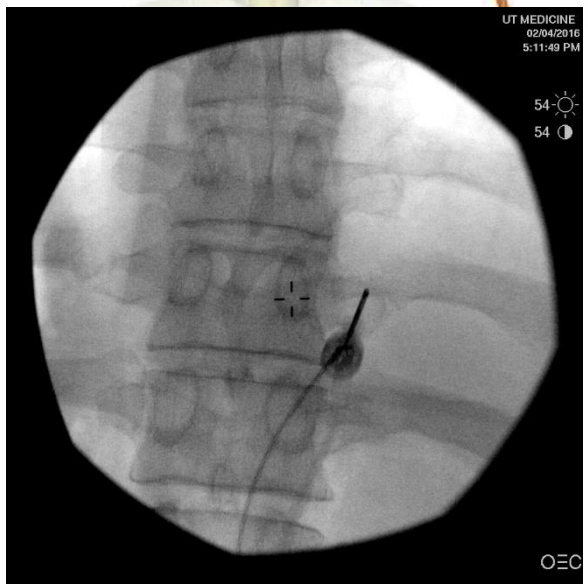




Chua WH, Bogduk N. 1995;136(3-4):140-4.

Thoracic Facet Denervation: Cooled RFA

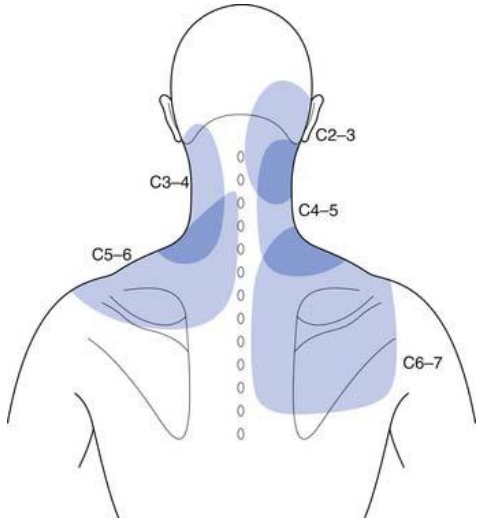




Evidence: Case reports

Cervical Zygapophyseal Joint Ablation for Chronic Cervical Spine Pain

Cervical Facet Syndrome

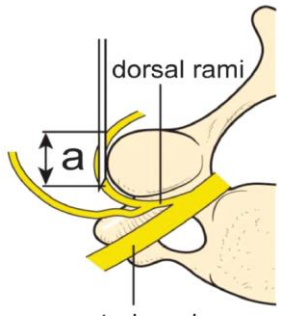


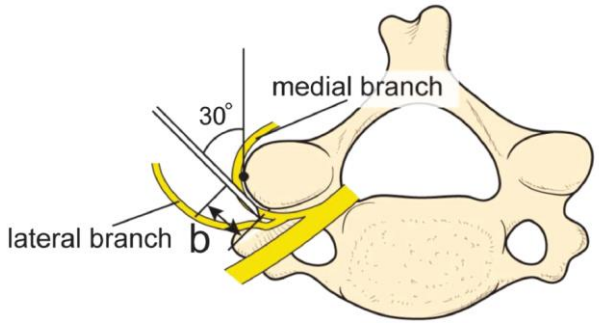
- Axial Pain of the Cervical Spine with regional radiation
  - Incidence increases later adulthood.
- Cervical medial branch nerves
  - Lie in the waist of the articular pillars of the cervical spine as they emerge from the nerve root and course posteriorly to the facet joint[1].
  - The vertical distribution of medial branches varies with spine level; best lesions may be achieved somewhat more cephalad at the C7, C6, and C3 levels; while other levels have a relatively central target.
  - Motor testing may result in local spine muscle twitch, but where applicable there should be no upper extremity movement.
  - A small number of patients may have dysesthesias or burning sensation in the overlying skin after the procedure. Severe but rare complications include dropped head syndrome and progressive kyphosis[2,3].

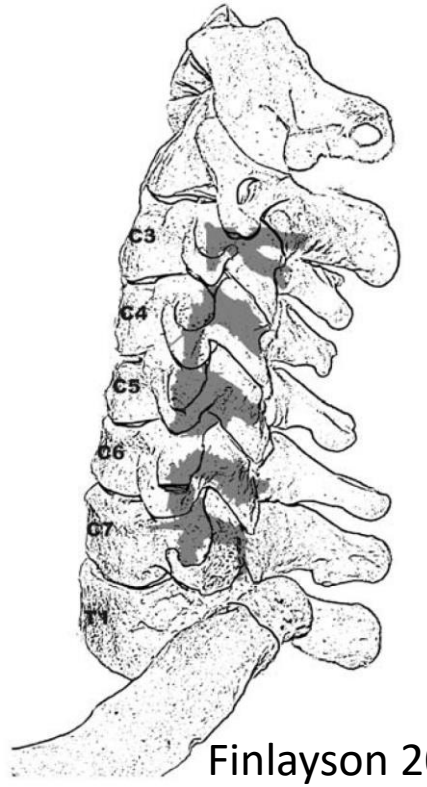
1. Bogduk N. The clinical anatomy of the cervical dorsal rami. Spine (Phila Pa 1976). 1982 Jul-Aug;7(4):319-30.
2. Stoker GE, Buchowski JM, Kelly MP. Dropped head syndrome after multilevel cervical radiofrequency ablation: a case report. J Spinal Disord Tech. 2013 Dec;26(8):444-8.
3. Ahmed MM, Lake WB, Resnick DK. Progressive severe kyphosis as a complication of multilevel cervical percutaneous facet neurotomy: a case report. Spine J. 2012 Oct;12(10):e5-8.

Cervical Spine Updates

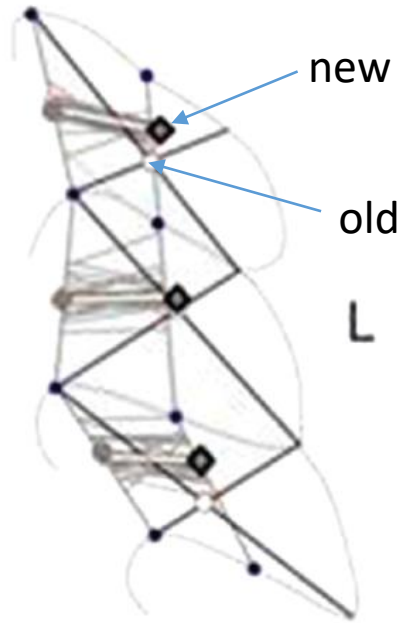
- Quantitative Neuroanatomy (Kweon 2014)
  - Medial Branch – double branches – esp. C4, C5
  - Lateral Branch and relation to posterior tubercle
  - Size – up to 1.2 +/- 0.2 mm (C4, C5)
  - Angle of approach – cephalad-anterior slope
  - Discussions:
    - Consider double lesions
    - Anterior/posterior, Superior/inferior landmarks
    - Straight and curved needles
    - Parasagittal vs oblique approaches
- Vascular Anatomy (Finlyason 2016)
  - Mean Diameter 1.25 mm
  - Implications for injections / procedures







Finlayson 2016



Kweon 2014

Cervical Facet Denervation

- 58-74% pain relief at 12 months in prospective studies.[1]

- Paraspinal tenderness only clinical factor that predicts better success (vs. opioids, pain w/extension or occipital radiation).[2]

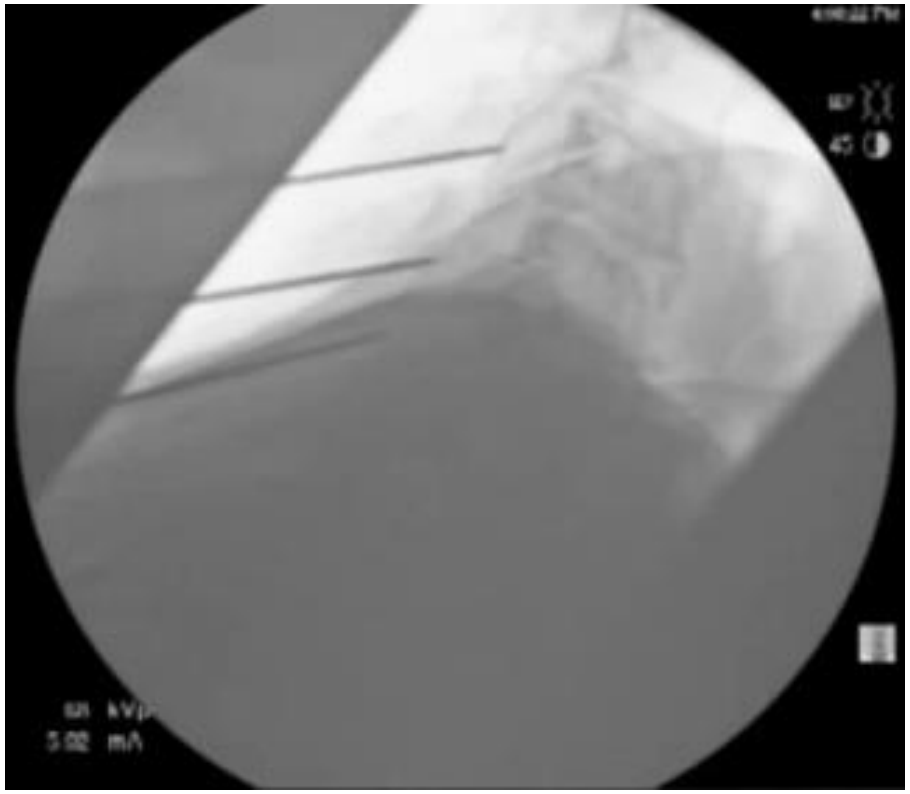
- Double Blind, Sham Controlled RCT, n=24 from 54.[3]
  - **3 controlled blocks** (normal saline, lidocaine, bupivacaine)
  - Prognostic block successful if -> **100% pain relief**
  - C3/4 through C6/7 eligible; **C2/3 excluded.**
  - Extensive **3 hour procedure** w/multiple lesions per level
  - Median time >50% Pain Relief **263 v 8 days**.

1. Falco F, et al. Pain Physician 2009; 12:323-344
2. Cohen S, et al. Reg Anesth Pain Med 2007;32:495-503
3. Lord S, et al. N Engl J Med 1996;335:1721-6

Cervical Cooled RFA

AP

LATERAL



Evidence: Case reports

Deep Ascending Cervical Arteries: Unpublished Case Report of Temporary Blindness

Swain AR, et. al. American Society of Regional Anesthesia and Pain Medicine, Medically Challenging Case Abstract. Fall 2010 (26).

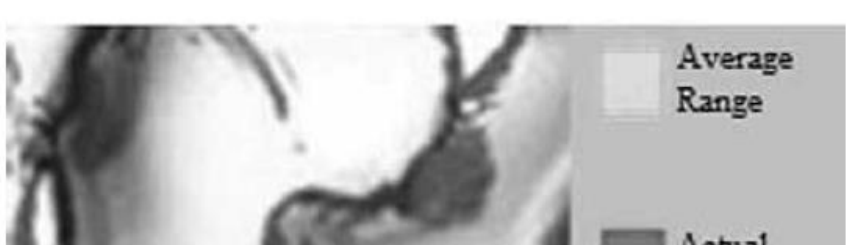
Sacroiliac Joint Ablation for Chronic Sacroiliac Pain

Sacroiliac Joint Pain

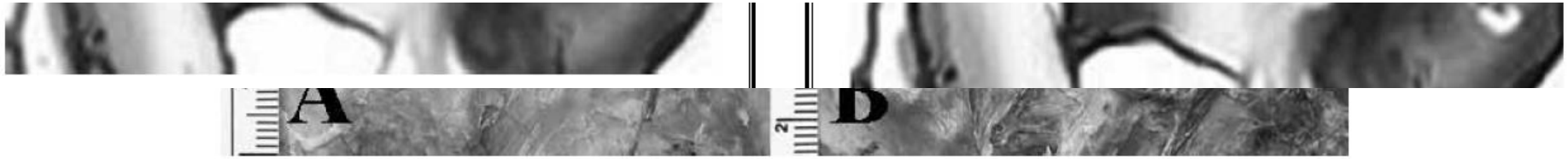
- Chronic sacroiliac (SI) joint pain remains a challenge for diagnosis
- Physical exam maneuvers are notably non-specific in the identification of sacroiliac joint pain. (PSIS tenderness, Faber maneuver, etc.)
- Portions of the innervation of the sacroiliac joint are dorsal and accessible to block or RFA[1], yet some are ventral and not accessible.
- Lateral branch nerves emerge from the sacral foramina and course over the sacrum in variable depths, laterally to the sacroiliac joint.
- The concentration of neural innervation appears to be near S1 and S2, but can include S3 and the dorsal ramus of L5[1].
- Controlled diagnostic blocks are believed to be the best method to prognosticate suitability for lateral branch RFA.

1. Cox RC, Fortin JD. The anatomy of the lateral branches of the sacral dorsal rami: implications for radiofrequency ablation. Pain Physician. 2014 Sep-Oct;17(5):459-64.

Sacral Lateral Branch Anatomy

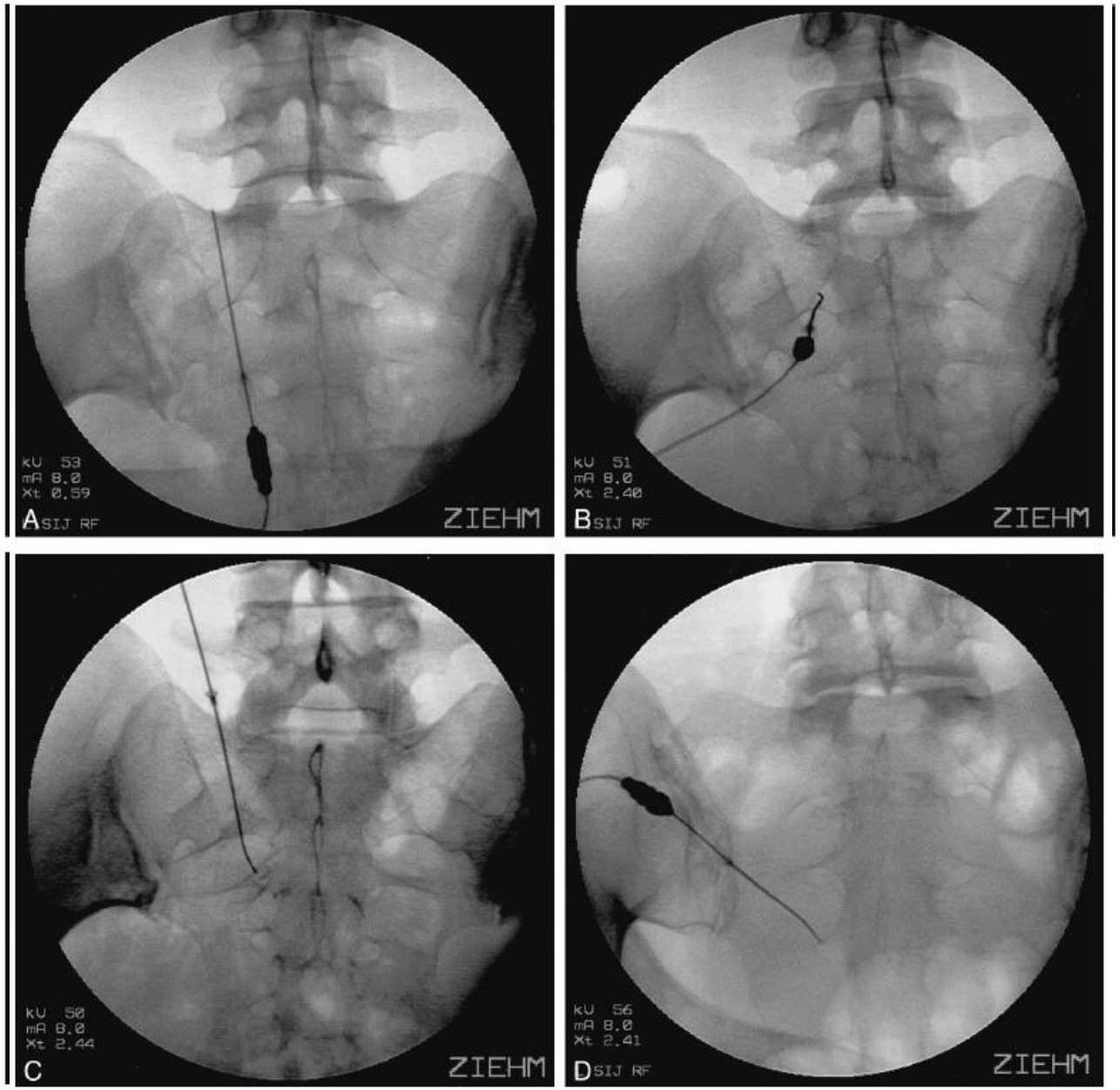


Author	Dorsal Rami Contribution	Ventral Rami Contribution	L5 contribution
Solonen, 1957	S1 and S2	Yes (L4, L5 and S1)	Yes
Ikeda, 1991	L5, S1-S4	Yes (L5 and S2)	Yes
Grob et al, 1995	S1-S4	No	No
Yin et al, 2003	L5, S1-S3	Not studied	Yes
McGrath and Zhang, 2004*	S2-S4	Not studied	Not studied
Szadek et al, 2008†	Not studied	Yes(L4 and L5)	Yes
Willard et al, 2010	L5, S1-S4	Not studied	Yes

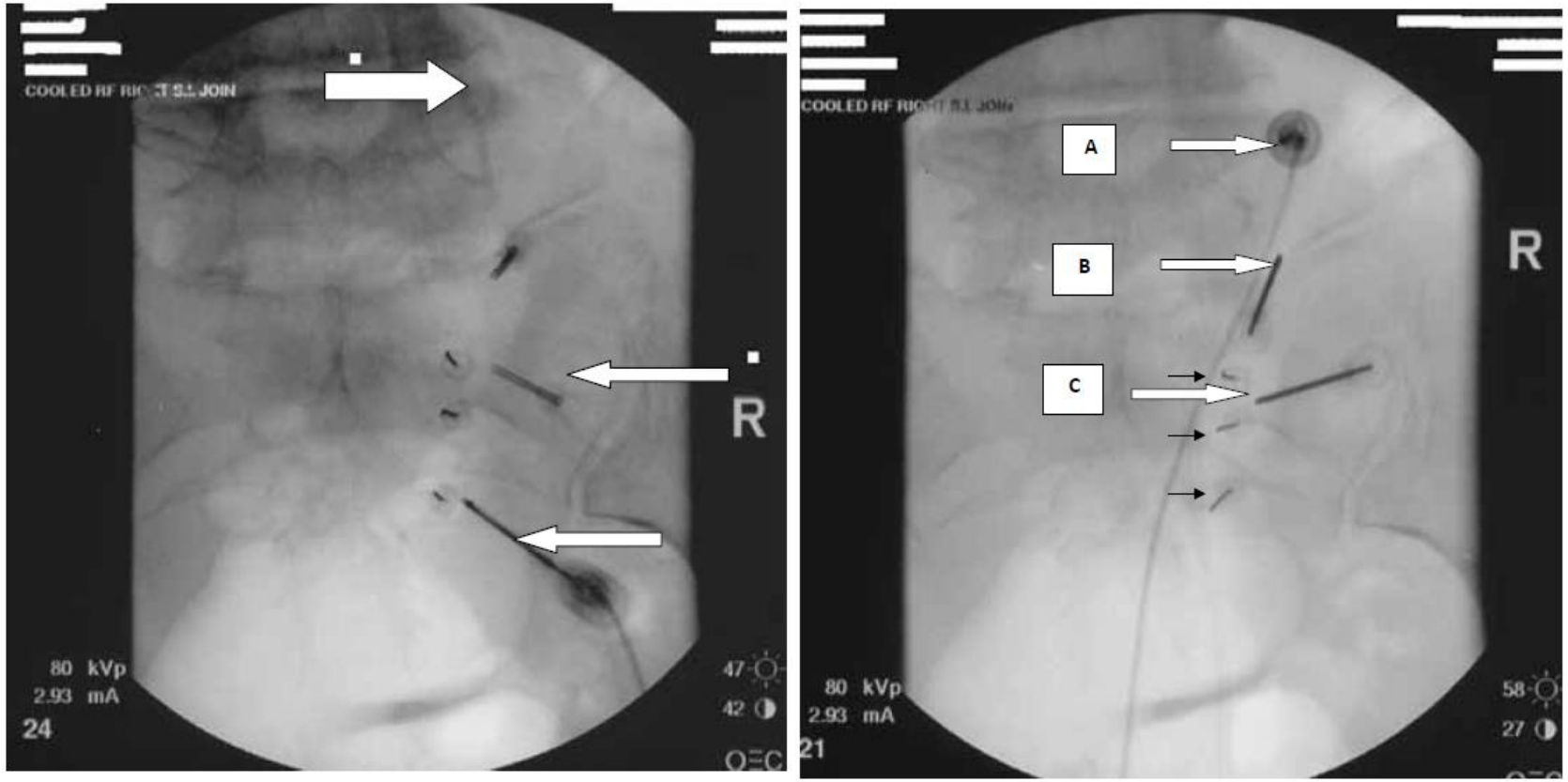


Cox RC. Pain Physician. 2014 Sep-Oct;17(5):459-64.

Sacral Lateral Branch SRFA



SIJ CRFA



Ramasubba C. Pain Physician. 2013 Jan;16(1):1-8.

SIJ Cooled RFA RCT

	Treatment		Sham		
Outcome Measure	Mean	SD	Mean	SD	*P* Value
NRS for pain (0–10)	(N = 34)		(N = 17)		
1-month change	–2.7	2.6	–1.7	2.0	0.160
3-month change	–2.4	2.7	–0.8	2.4	0.035
6-month change	–2.5	2.6	—	—	—
9-month change	–2.7	2.7	—	—	—
SF-36 bodily pain (0–100)	(N = 33)		(N = 16)		
1-month change	15	17	2	11	0.006
3-month change	16	26	–1	13	0.019
6-month change	14	22	—	—	—
9-month change	20	23	—	—	—
SF-36 physical functioning (0–100)	(N = 32)		(N = 16)		
1-month change	10	17	5	12	0.238
3-month change	14	19	3	12	0.040
6-month change	14	23	—	—	—
9-month change	18	21	—	—	—
Oswestry disability scale (0–100)	(N = 32)		(N = 15)		
1-month change	–12	14	–4	11	0.046
3-month change	–11	17	2	6	0.011
6-month change	–13	16	—	—	—
9-month change	–15	16	—	—	—

At 3-month follow-up, 47% of treated patients and 12% of sham subjects achieved treatment success. At 6 and 9 months, respectively, 38% and 59% of treated subjects achieved treatment success

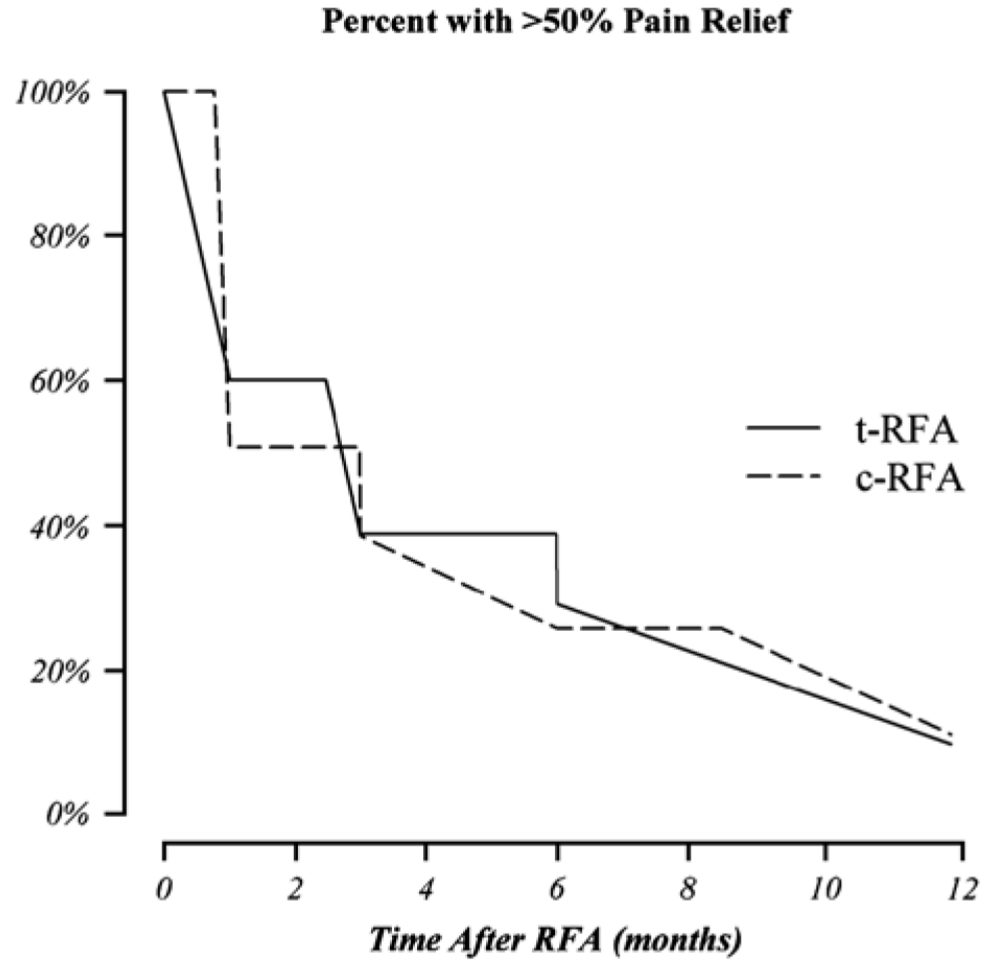
Patel N. Pain Med. 2012 Mar;13(3):383-98.

Comparative Outcomes of Cooled Versus Traditional Radiofrequency Ablation of the Lateral Branches for Sacroiliac Joint Pain

Jianguo Cheng, MD, PhD, Jason E. Pope, MD,* Jarrod E. Dalton, MA,†‡ Olivia Cheng, BA,* and Albatoul Bensitel, MD‡*

Factor	t-RFA (N = 30)	c-RFA (N = 58)	*P*
Male sex (%)	17	26	0.33
Age (y; mean ± SD)	61 ± 13	55 ± 13	0.03*
Body mass index [kg/m^2; median (quartiles)]	28 [24, 33]	28 [24, 35]	0.78†
Location of pain: back (%)	97	95	0.69
Location of pain: referred to the thigh (%)	87	84	0.78
Gradual onset (vs. sudden) (%)	76	71	0.61
Pain with extension or axial rotation (%)	53	60	0.53
Tenderness over sacroiliac joint (%)	100	97	0.30
Duration of pain [y; median (quartiles)]	4 [3, 5]	4 [2, 8]	0.80†
Chronic opioid use (%)	63	69	0.59
Previous spine surgery (%)	13	38	0.02
Multiple pain symptoms (%)	90	91	0.83
Employed full time (%)	33	44	0.34
Disabled (%)	20	11	0.22
Diabetes (%)	10	10	0.96
Smoker (%)	33	29	0.70
NRS pain score before RFA	6 ± 2	7 ± 2	0.53
Levels of RFA (%)			
L5/S1/S2	10	12	<0.001*
L5/S1/S2/S3	40	72	
S1/S2/S3	17	14	
L4/L5/S1/S2/S3	33	2	
No. lesions per level (%)			
1	40	7	<0.001
2	60	93	
Use of steroids after RFA (%)	43	69	0.02

- No radicular etiology / spinal stenosis
- LBP >3 months
- 2x SI joint injections using 3mL of local anesthetic and 40mg triamcinolone.
- >50% pain relief



Evidence for Sacroiliac Joint Ablation

- Outcomes for SRFA of the SI joint show low evidence for intermediate term (1-6 mo) improvement in pain[1].
- Recent meta-analysis including 7 cooled RFA trials of mixed retrospective and prospective or placebo controlled design spanning follow-up of 3-24 months
  - Mean reduction in pain of about 3.8 points on NRS
  - Modified Oswestry Disability scale improvement of 18 points after treatment
  - More high quality prospective study needed to improve the power of the findings[2].
- Sham Controlled RCT exists, treatment outcomes diverge by 3-9 months[3].
- Multipolar RFA has observational data and requires more prospective study[4].

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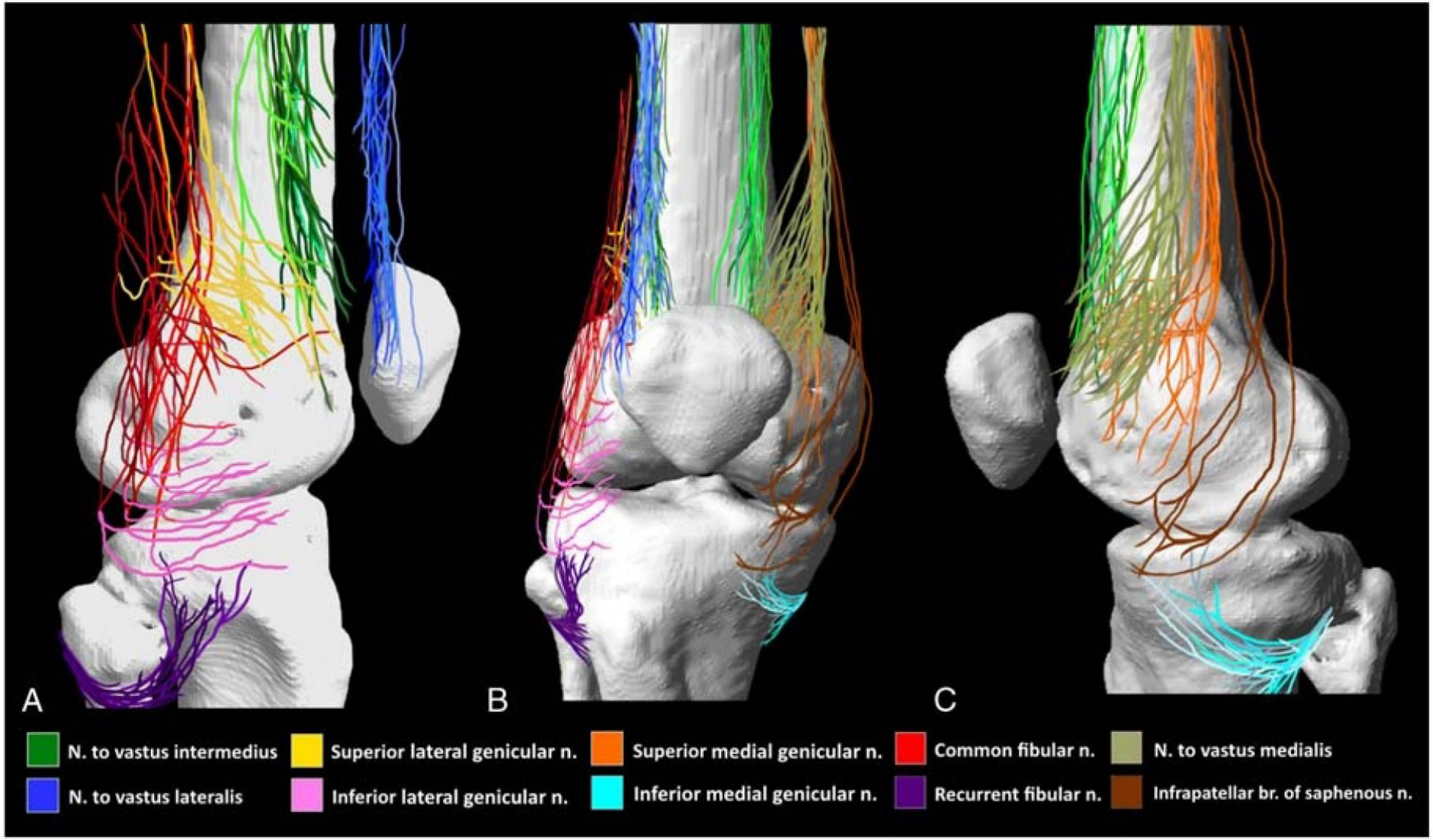
3. Patel N, Gross A, Brown L, Gekht G. A randomized, placebo-controlled study to assess the efficacy of lateral branch neurotomy for chronic sacroiliac joint pain. Pain Med. 2012 Mar;13(3):383-98.
4. Schmidt PC, Pino CA, Vorenkamp KE. Sacroiliac joint radiofrequency ablation with a multilesion probe: a case series of 60 patients. Anesth Analg. 2014 Aug;119(2):460-2.

Genicular Nerve Ablation for Chronic Knee Pain

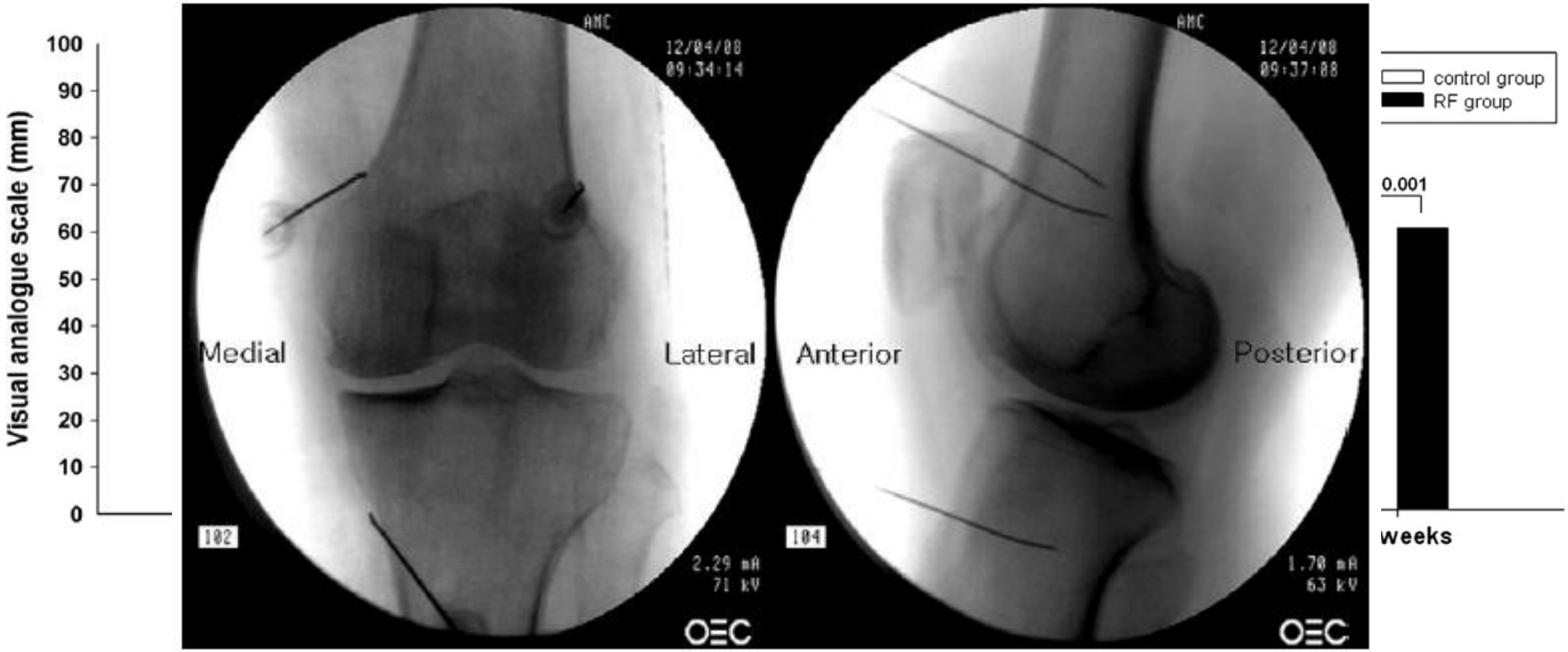
Anatomical Study of the Innervation of Anterior Knee Joint Capsule

Implication for Image-Guided Intervention

John Tran, HBSc, Philip W.H. Peng, MBBS,† Karen Lam, MD,† Ehtesham Baig, MD,† Anne M.R. Agur, PhD,* and Michael Gofeld, MD†*



Genicular Conventional RFA



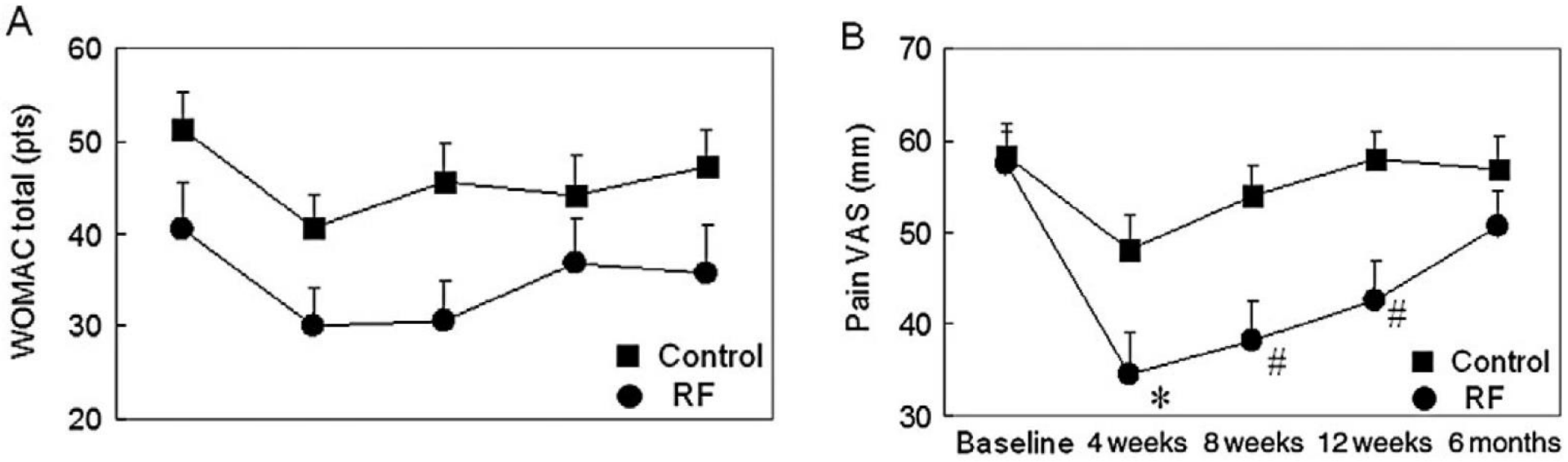
Choi WJ, et. al. Pain. 2011 Mar;152(3):481-7.

Genicular Conventional RFA

Pain Medicine 2011; 12: 546–551
Wiley Periodicals, Inc.

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*



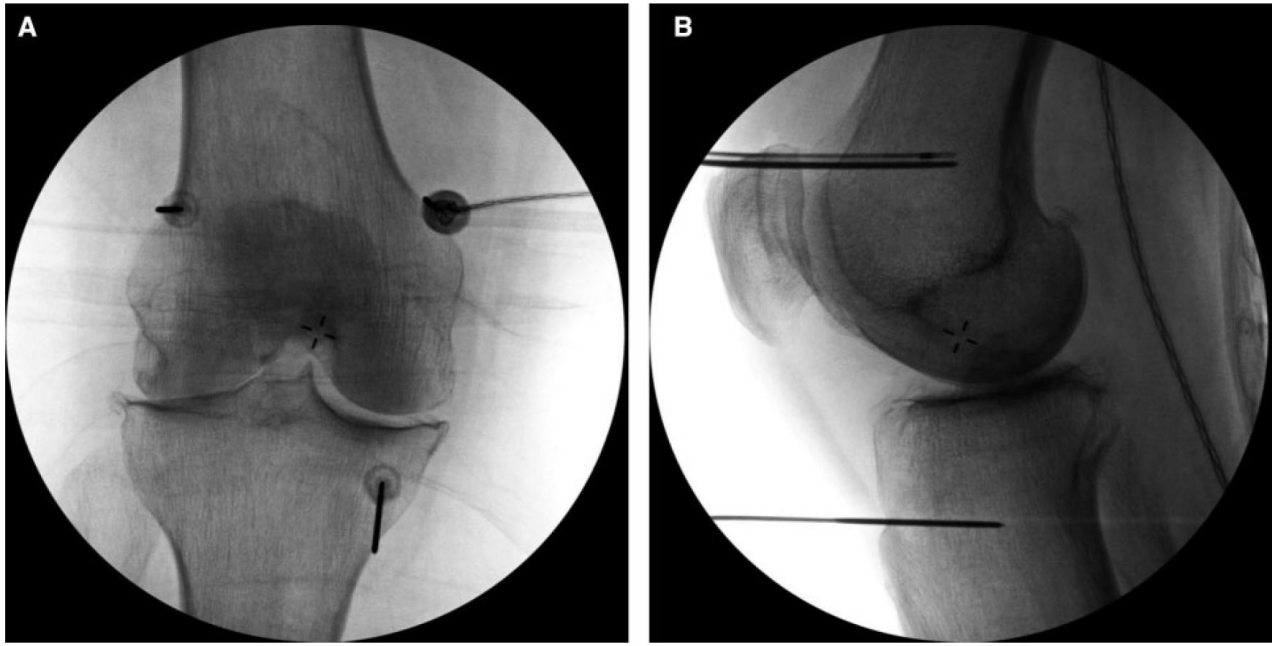
Emerging Data for Genicular Cooled RFA

Cooled Radiofrequency Ablation of the Genicular Nerves for Chronic Pain due to Knee Osteoarthritis: Six-Month Outcomes

Zachary L. McCormick, MD,* Marc Korn, MD,† Rajiv Reddy, MD,‡ Austin Marcolina, BS,§ David Dayanim, MD, MS, MHA,¶ Ryan Mattie, MD,‖ Daniel Cushman, MD,|||| Meghan Bhave, MD,† Robert J. McCarthy, PharmD,† Dost Khan, MD,† Geeta Nagpal, MD,† and David R. Walega, MD†

Setting. Academic pain medicine center.

Subjects. Consecutive patients with knee OA and 50% or greater pain relief following genicular nerve blocks who underwent genicular nerve C-RFA.



	Number of Patients (N = 33) Number of Treated Knees (N = 52)
Age, y	66 (62–77)
Sex	
Male	10 (30)
Female	23 (70)
Body mass index, kg/m^2	31 (24–38)
Duration of pain at presentation,* y	
≤2	10 (19)
>2–≥5	24 (46)
>5	18 (35)
Smoker	2 (6)
>3 alcoholic drinks/d	1 (3)
History of arthroscopic surgery in symptomatic knee*	13 (25)
Marital status	
Married/partnered	19 (58)
Single/widowed	14 (42)
Numeric rating score for pain (0–10)*	8 (7–9)
Medication Quantification Scale III score	6 (3–8)
Percent pain relief from diagnostic blocks*	
50–79%	12 (23)
80–99%	6 (12)
100%	34 (65)
Bilateral procedures	19 (57)
Duration between procedure and follow-up,* mo	8 (6–10)

Emerging Data for Genicular Cooled RFA

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

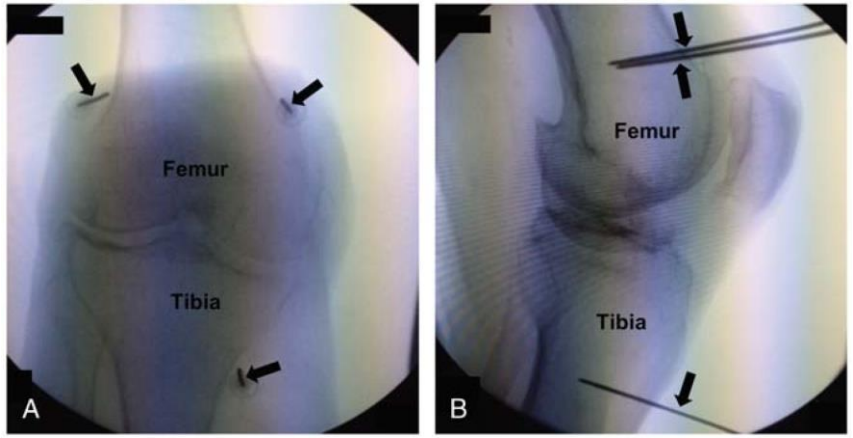
	β	*P*	OR	95% CI
Body mass index, kg/m^2	0.16	0.025	1.17	1.02–1.35
Duration of pain at presentation, y		0.023		
>5	2.39	0.046	1	Reference
>2–≤5	4.35	0.007	10.54	0.67–168
≤2			13.05	1.30–131
Percent pain relief from diagnostic blocks*		0.071		
50–79%	2.35	0.096	1	Reference
80–99%	2.57	0.029	10.91	1.04–115
100%			77.34	3.43–1,778
Constant	–6.39	0.012		

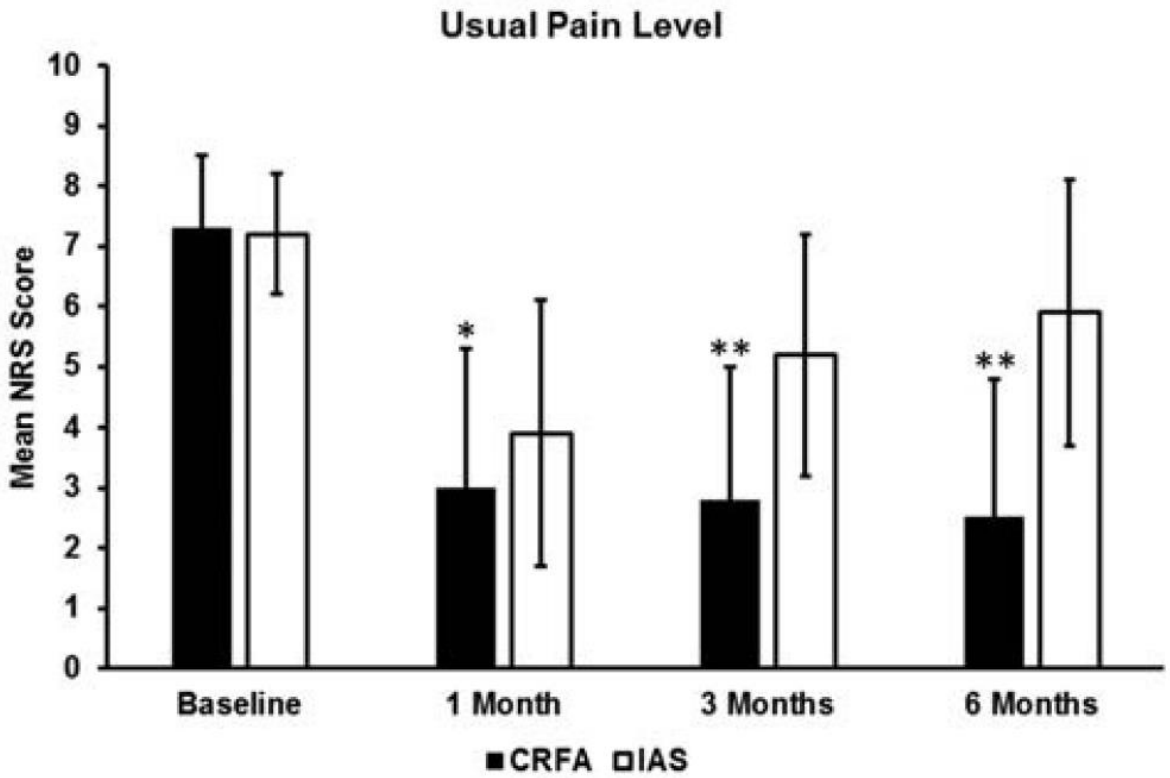
The primary outcome, treatment success, was defined as a combination of 50% or greater reduction in NRS score and PGIC score consistent with "very much improved" or "improved," and no TKA. A secondary definition of treatment success was also defined based on improvement in NRS score equal to the minimal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

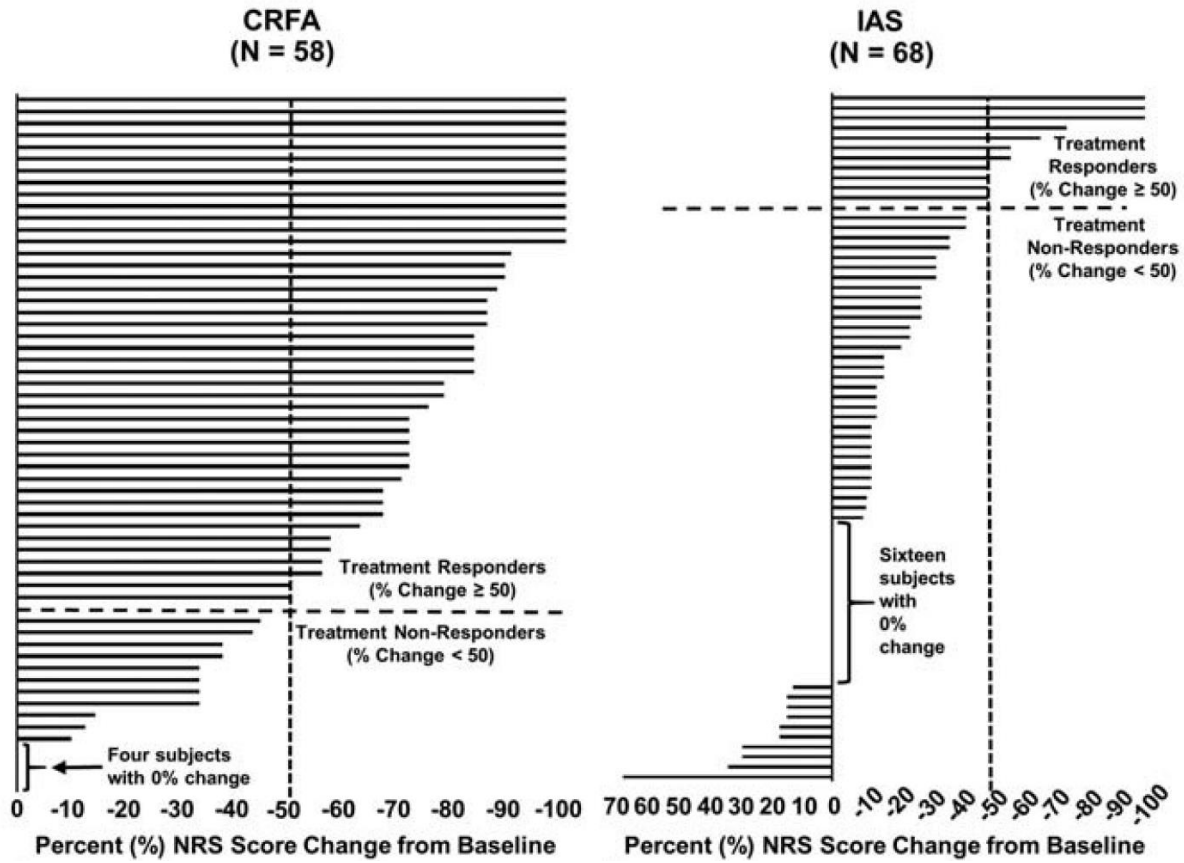
Conclusions. Genicular C-RFA demonstrated a success rate of 35% based on a robust combination of outcome measures, and 19% of procedures resulted in complete relief of pain at a minimum of six months of follow-up. Report of 80% or greater relief from diagnostic blocks and duration of pain of less than 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.

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

Tim Davis, MD, Eric Loudermilk, MD,† Michael DePalma, MD,‡ Corey Hunter, MD,§ David Lindley, DO,|| Nilesh Patel, MD,** Daniel Choi, MD,†† Marc Soloman, MD,‡‡ Anita Gupta, DO, PharmD,§§ Mehul Desai, MD,|||| Asokumar Buvanendran, MD,*** and Leonardo Kapural, MD, PhD†††*







Prognostic Blocks?

- **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.**
- McCormick ZL[1], Reddy R[2], Korn M[3], Dayanim D[4], Syed RH[5], Bhave M[6], Zhukalin M[7], Choxi S[8], Ebrahimi A[9], Kendall MC[10], McCarthy RJ[3], Khan D[3], Nagpal G[3], Bouffard K[4], Walega DR[3].

29 subjects -> Prognostic Block* -> CRFA	=	58.6% pain responders**
25 subjects -> NO BLOCK -> CRFA	=	64.0% pain responders

* Block volume 1 ml

**Responder Rate - ≥ 50% pain relief at 6 months; WOMAC Osteoarthritis Index responders also 55 and 60% respectively

Radiofrequency techniques to treat chronic knee pain: a comprehensive review of anatomy, effectiveness, treatment parameters, and patient selection

David E Jamison[1,2]
Steven P Cohen[1–6]

Predictors of success
Medial compartment osteoarthritis and concordant pain
Large and/or multiple lesions
Controlled prognostic blocks

Predictors of failure
Greater disease burden (eg, longer duration of symptoms, greater disability)
Previous surgery
Opioid use
Psychopathology
Diffuse pain symptomatology (fibromyalgianess)

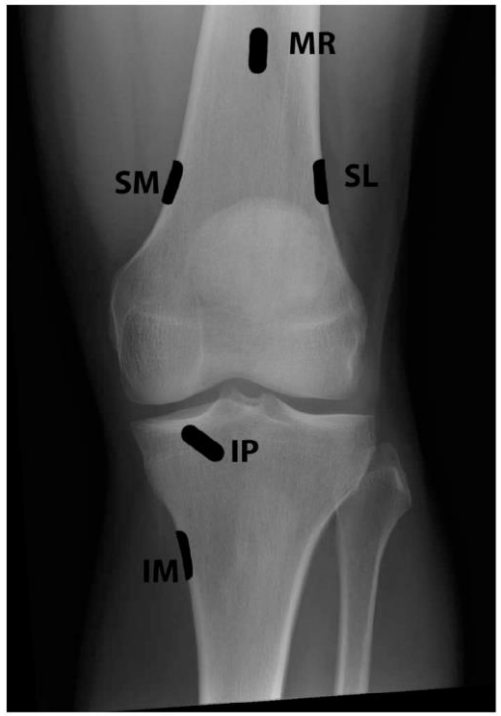


Figure 1 Anterior-posterior radiograph of the knee depicting locations for genicular nerve targeting.
Abbreviations: IM, inferomedial; IP, infrapatellar; MR, medial retinacular; SL, superolateral; SM, superomedial.

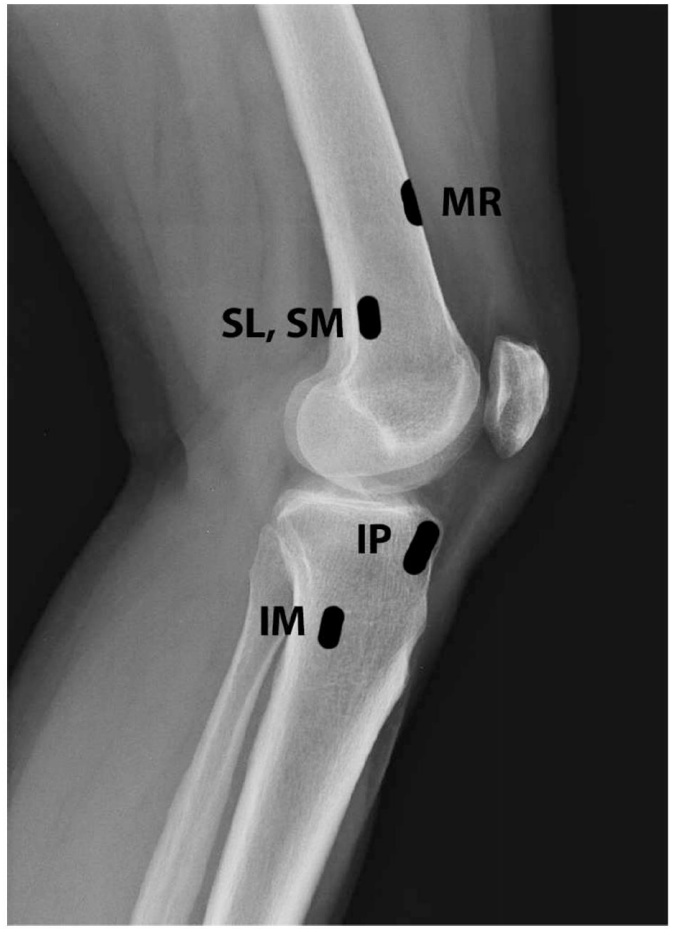
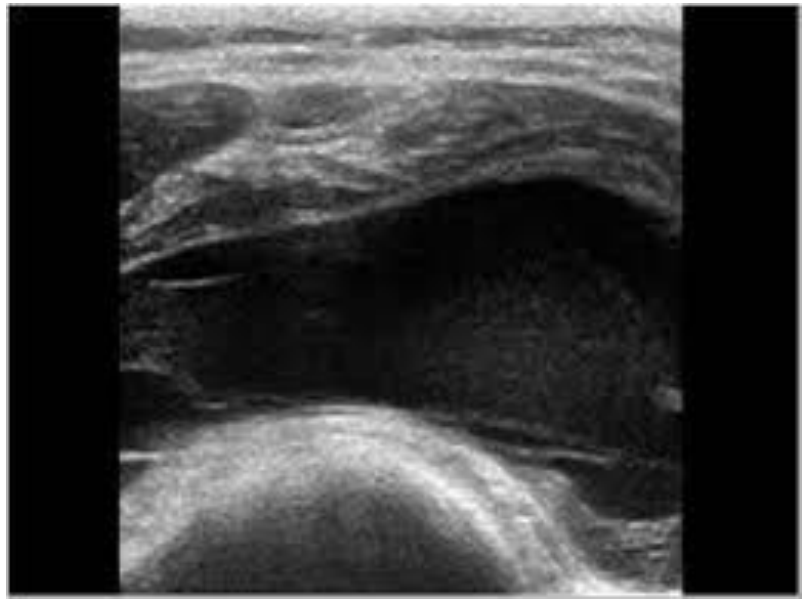


Figure 2 Lateral radiograph of the knee depicting locations for genicular nerve targeting.
Abbreviations: IM, inferomedial; IP, infrapatellar; MR, medial retinacular; SL, superolateral; SM, superomedial.

Complications and Side Effects

- Hypoesthesia
- Superficial / Skin burn
- Hematoma
- Arterial Injury / Osteonecrosis
- Septic Arthritis
- Pes Anserine Tendon Injury



Jamison DE, Cohen SP. Radiofrequency techniques to treat chronic knee pain: a comprehensive review of anatomy, effectiveness, treatment parameters, and patient selection. J Pain Res. 2018 Sep 18;11:1879-1888.

Khanna A, Knox N, Sekhri N. Septic Arthritis Following Radiofrequency Ablation of the Genicular Nerves. Pain Med. 2019 Jan 28.

Conger A, McCormick ZL, Henrie AM. Pes Anserine Tendon Injury Resulting from Cooled Radiofrequency Ablation of the Inferior Medial Genicular Nerve. PM R. 2019 Mar 12.

Genicular RFA / Knee OA Outcomes

- Articular sensory nerves emerge from several branches the femoral, sciatic obturator N[1,2,3].
- Two early randomized, sham controlled RCT's of RFA showed responders of up to 12 weeks.
- CRFA has been studied; a prospective study demonstrated 19% chance of complete pain relief, as well as a 35% chance of minimum clinically important difference:
  - "improved" global perceived effect, >= 50% NRS pain improvement, and avoidance of surgery[4].
- Genicular CRFA compares favorably to corticosteroid injection in providing a higher responder rate at 6 and 12 months with better functional improvement from OA[5,6].
- Cryoneurolysis may also out-perform sham control for up to 90 days[7].
- PRP may outperform viscosupplementation with Hyaluronic Acid[8].
- Pre-operative ablation did not appear to improve pain outcomes after TKA[9].

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3. Franco CD, et. al. Innervation of the Anterior Capsule of the Human Knee: Implications for Radiofrequency Ablation. Reg Anesth Pain Med. 2015 Jul-Aug;40(4):363-8.
4. McCormick ZL, et. al. Cooled Radiofrequency Ablation of the Genicular Nerves for Chronic Pain due to Knee Osteoarthritis: Six-Month Outcomes. Pain Med. 2017 Sep 1;18(9):1631-1641.
5. Davis T, et. al. 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. Reg Anesth Pain Med. 2018 Jan;43(1):84-91.
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8. Han Y, Huang H, Pan J, Lin J, Zeng L, Liang G, Yang W, Liu J. Meta-analysis Comparing Platelet-Rich Plasma vs Hyaluronic Acid Injection in Patients with Knee Osteoarthritis. Pain Med. 2019 Mar 7.

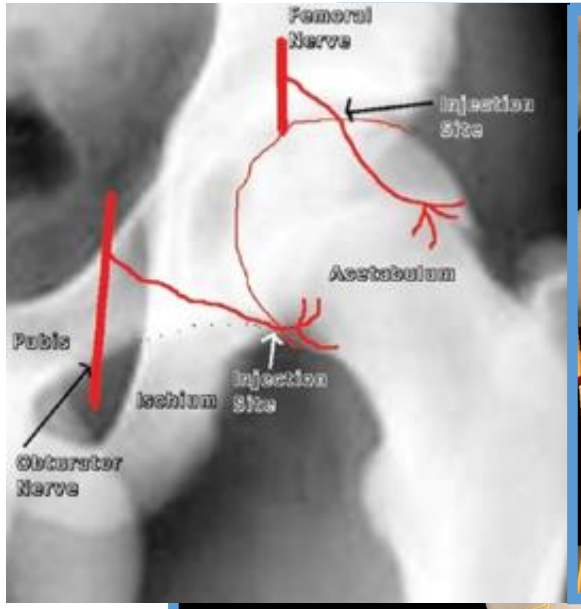
Obturator and Femoral Articular Nerve Ablation For Chronic Hip Pain

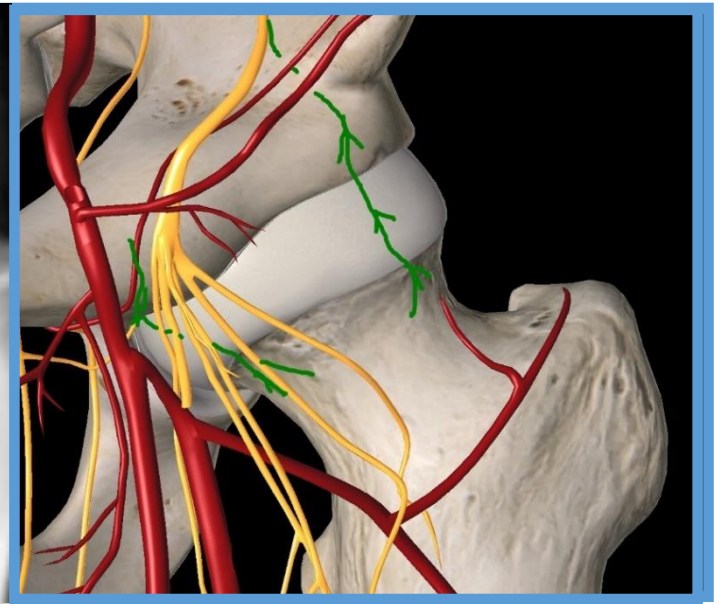
The sensory innervation of the hip joint - An anatomical study

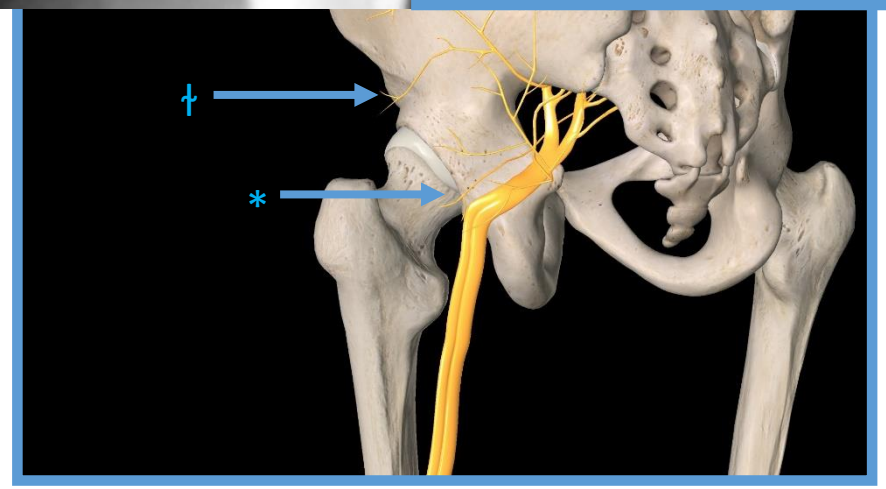
K. Birnbaum[1], A. Prescher[2], S. Heßler[1] and K.-D. Heller[1]

Surg Radiol Anat (1997) 19: 371-375

- Anteromedial joint: obturator nerve
- Anterolateral joint: femoral nerve
- Posterosuperior joint: sciatic nerve
- Posteroinferior joint: nerves to quadratus femoris muscle*
- Posterolateral joint: superior gluteal nerve†







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Case Series of Hip Denervation

Kawaguchi M, et. al. Reg Anesth Pain Med. 2001 Nov-Dec;26(6):576-81.

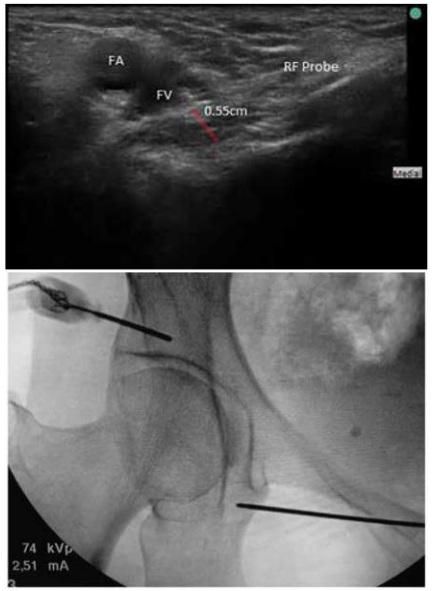
- N = 14 patients; Single diagnostic block: nerve/joint; RFA: obturator in 9, obturator and femoral in 5; mean VAS: 6.8 to 2.7
- 86% had 50% relief for 1-11 months

Rivera F[1], et al. Orthopedics. 2012 Mar 7;35(3):e302-5.

- N = 16 pts; 8 pts ≥ 50% pain relief at 6 months;
- Statistically significant improvement in WOMAC scores.

Kapural L, Jolly S, Mantoan J, Badhey H, Ptacek T. Pain Physician 2018; 21:279-284

- N: 62 screens w diagnostic blocks, 52 recommended to proceeded to RFA (>50% pain relief from block), 23 met inclusion (180 day f/u, completed RFA)
- 52 Hip denervations performed, no vascular complications, 1 case of neuritis/groin pain x1 week
- Ultrasound used in combination with fluoroscopy
- Mean VAS pain score 7.6 → 2.3 ($p < 0.01$); First RFA gave "pain relief" from 30-320 days.
- Mean ~ 150 d



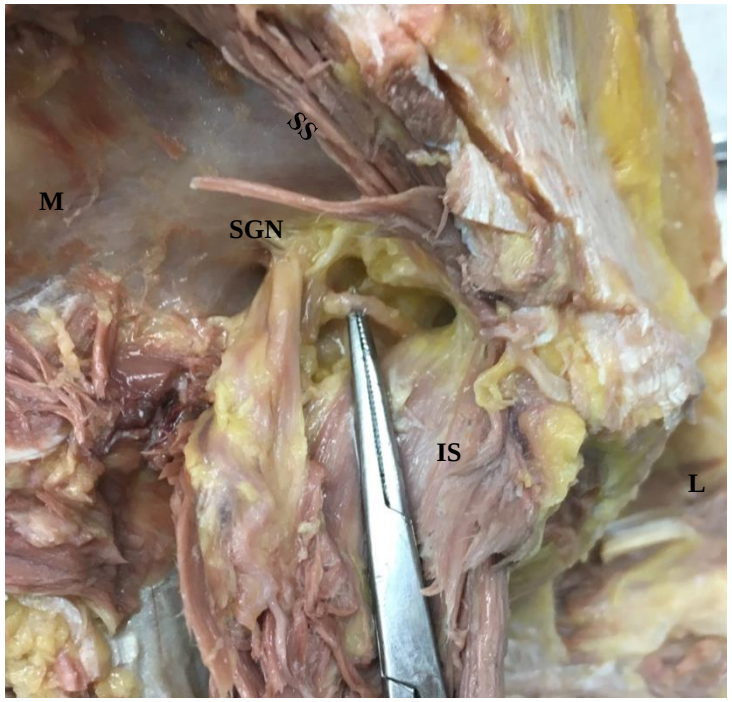
Hip Articular Nerve Ablation and Outcomes

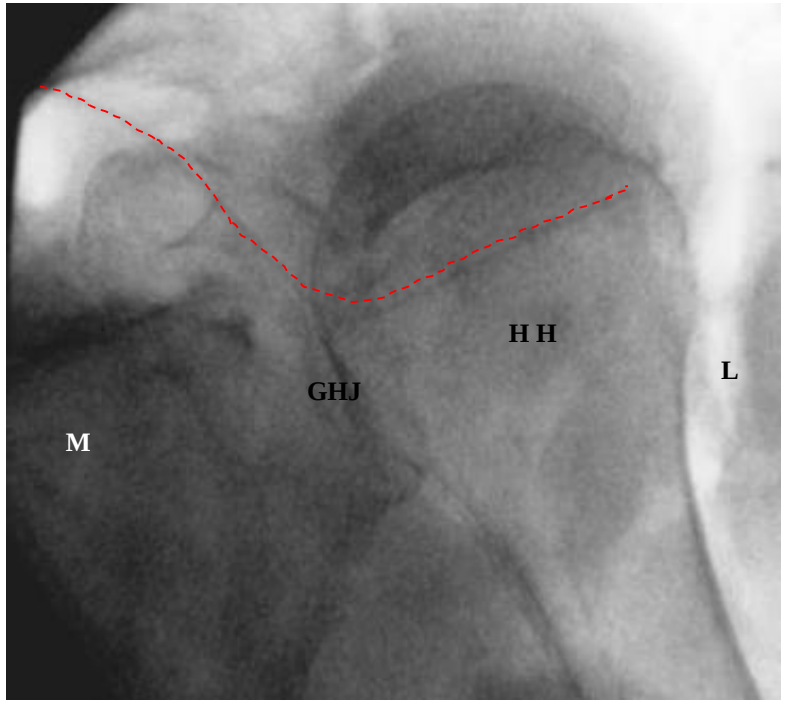
- The obturator and femoral nerve send articular nerve branches to the anterior hip joint[1]. The posterior hip is innervated at least by the nerve to quadratus femoris and the superior gluteal nerve.
- The anterior nerves have been ablation targets in an attempt to palliate severe, non-operable hip pain. Analogous diagnostic paradigms for diagnostic nerve blocks are applied.
- Several case series of SRFA suggest some promise for ablation over the superior portion of the acetabulum and inferomedial portion of the acetabulum.
- Femoral nerve and arterial injury have occurred[2].
- No RCTs are available as of the time of this review.
- CRFA has been developed for this procedure; case series of 23 patients showed mean “pain relief” duration ~150 days (30-320) and no major complications.[3]

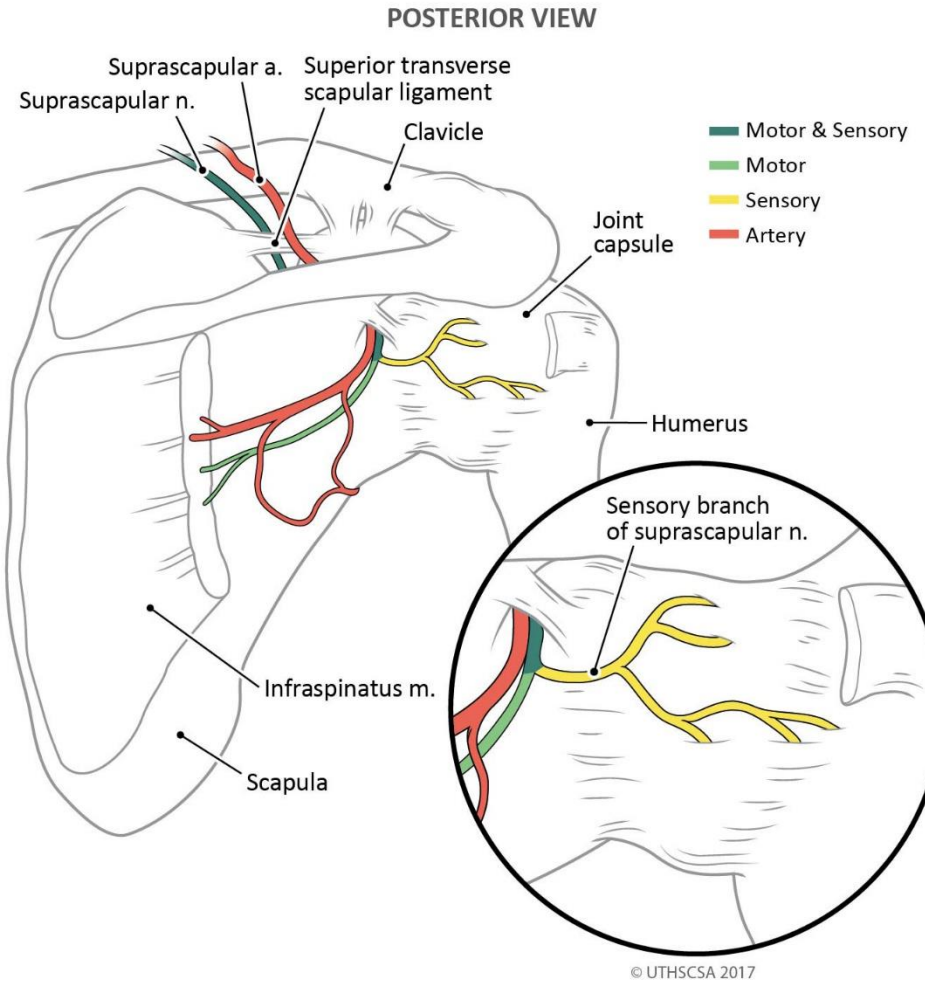
1. Short AJ, Barnett JJG, Gofeld M, Baig E, Lam K, Agur AMR, Peng PWH. Anatomic Study of Innervation of the Anterior Hip Capsule: Implication for Image-Guided Intervention. Reg Anesth Pain Med. 2018 Feb;43(2):186-192.
2. Gooding I, et al. Femoral Nerve Injury Following Cooled Radiofrequency Lesioning For the Treatment of Hip Pain Despite Ultrasound Guidance and Motor Testing. Pain Pract. 2016;16(S1):147
3. Kapural L, Jolly S, Mantoan J, Badhey H, Ptacek T. Pain Physician 2018; 21:279-284

Shoulder Nerve Ablation

Suprascapular Nerve (SN) – Posterior View



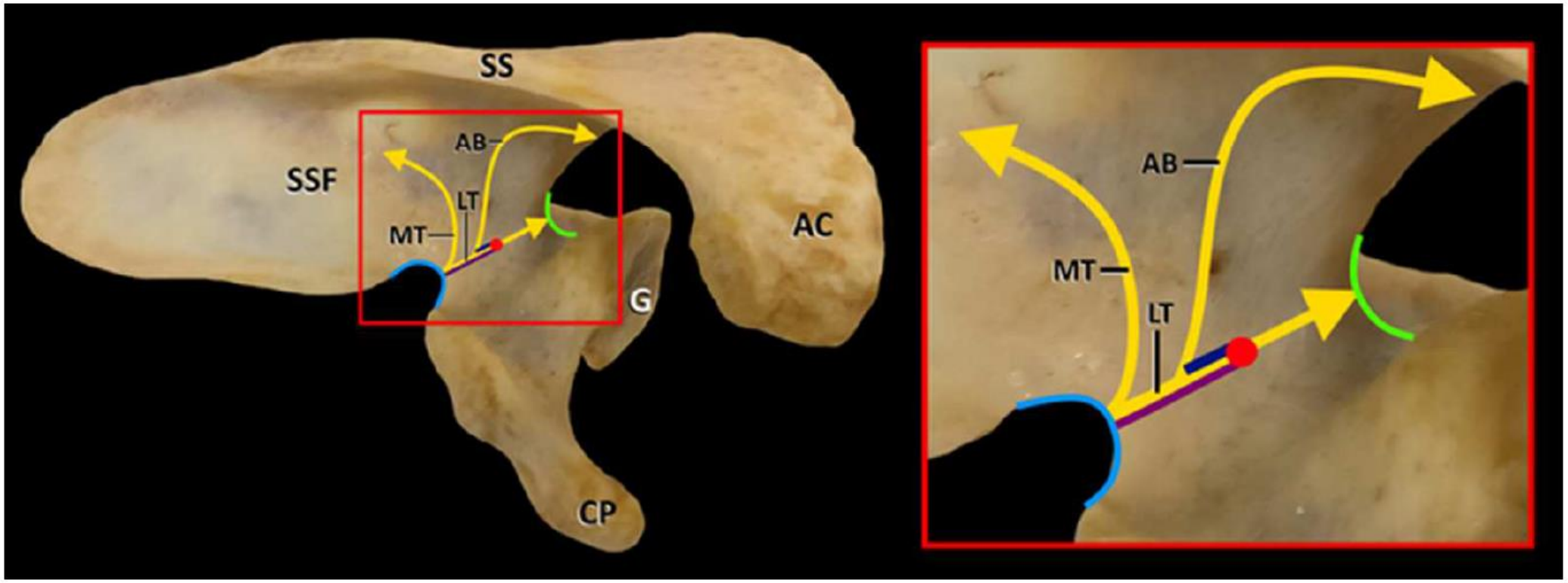




Legend: SS - Supraspinatus; IS - Infraspinatus; SGN – Spinoglenoid Notch; M – Medial; L - Lateral

Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

Suprascapular Nerve – Medial and Lateral Trunks – Superior View



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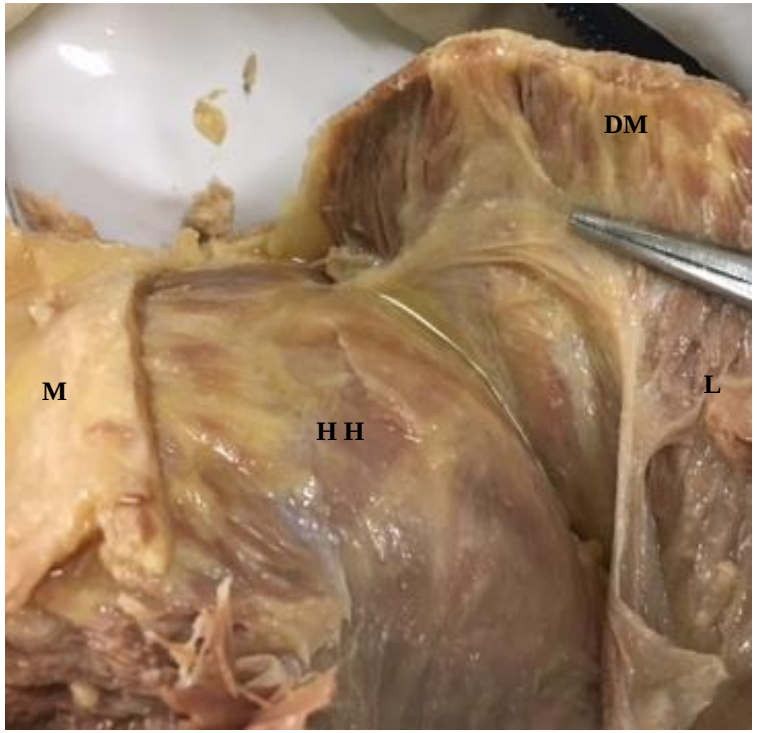
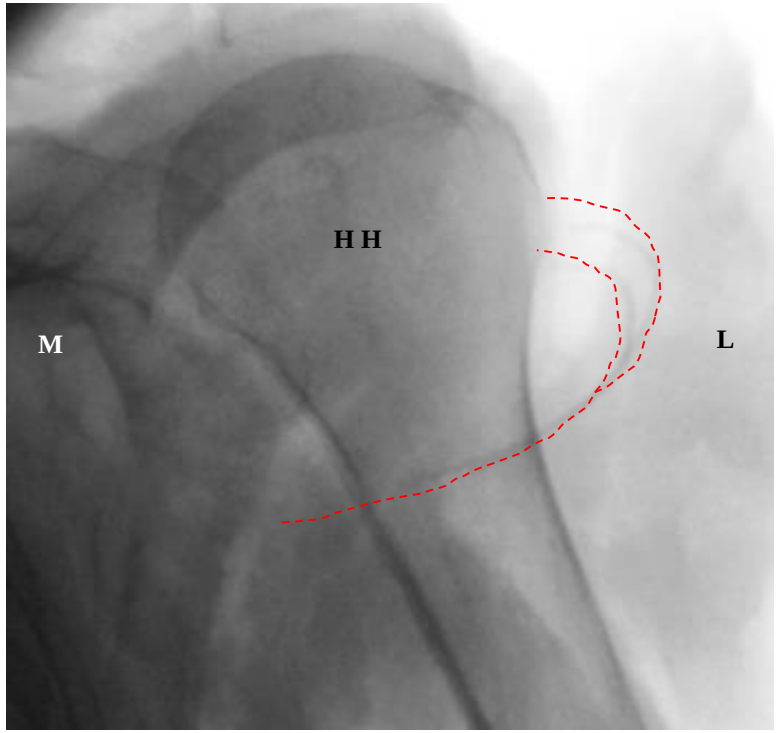
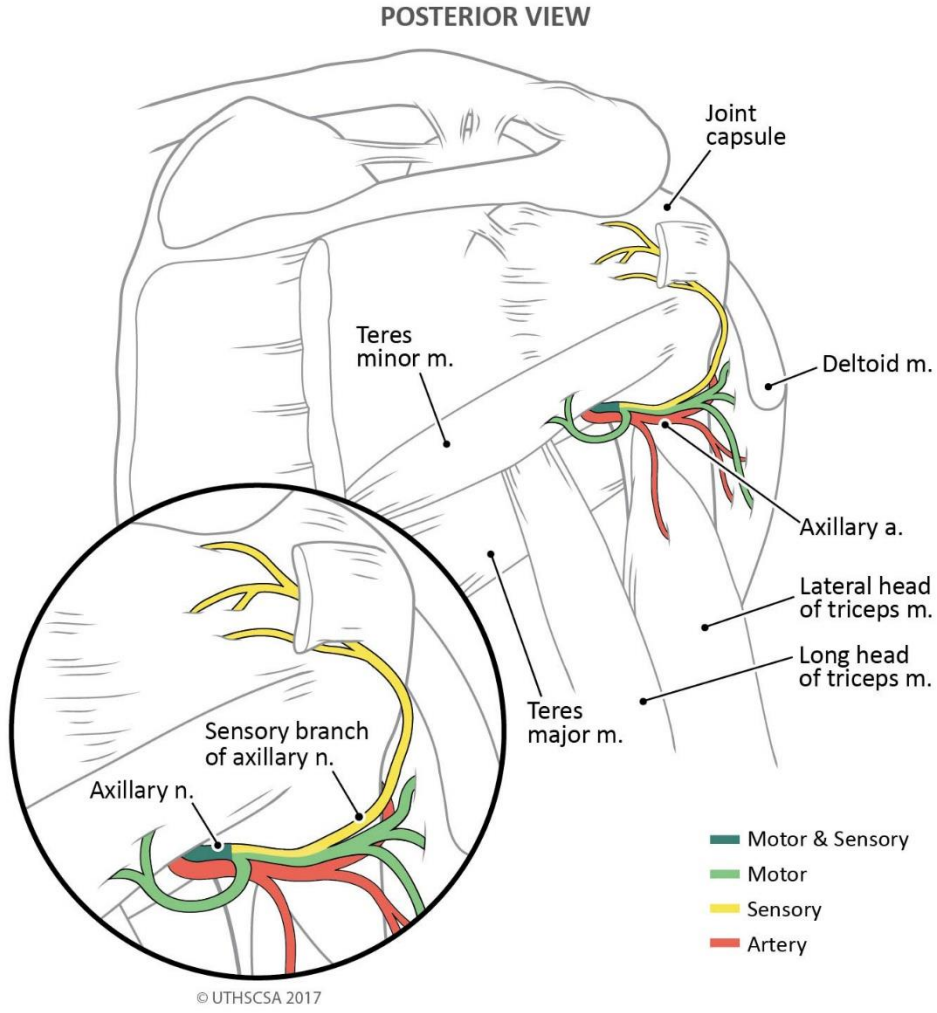
Tran, John, University of Toronto, Surgery (Division of Anatomy);
Peng, Philip, Toronto Western Hospital, University Health Network, Anesthesia;
Agur, Anne, University of Toronto, Surgery (Division of Anatomy)

Axillary Nerve (AN) – Posterior View

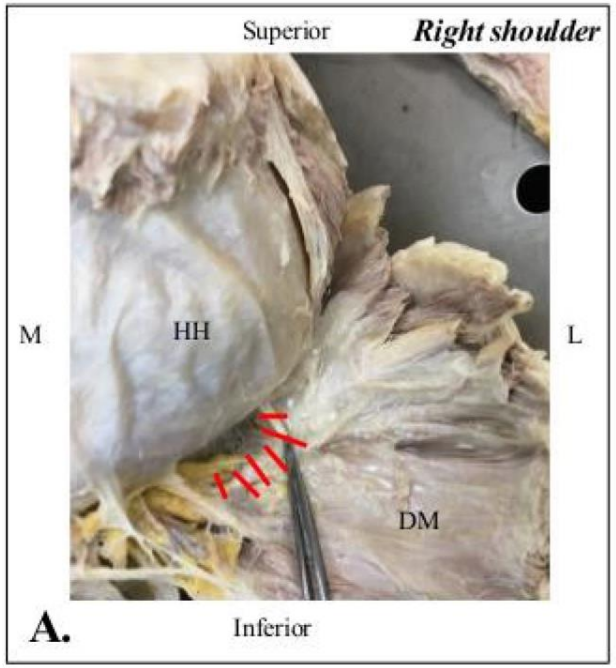


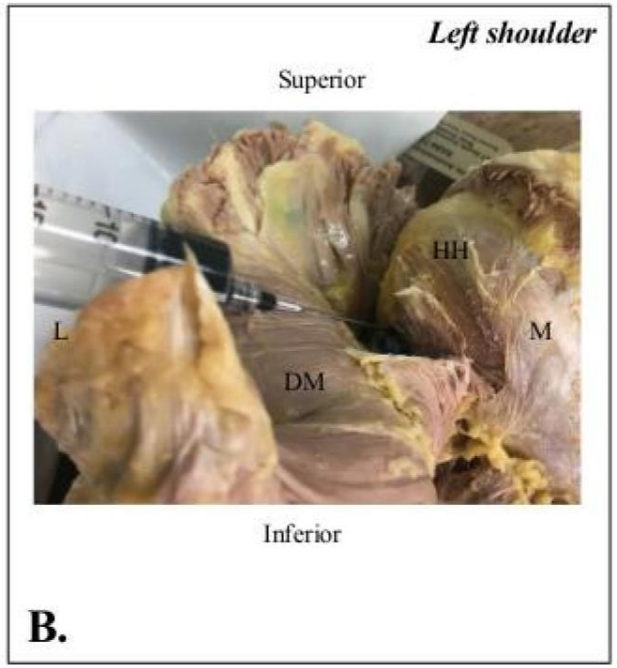


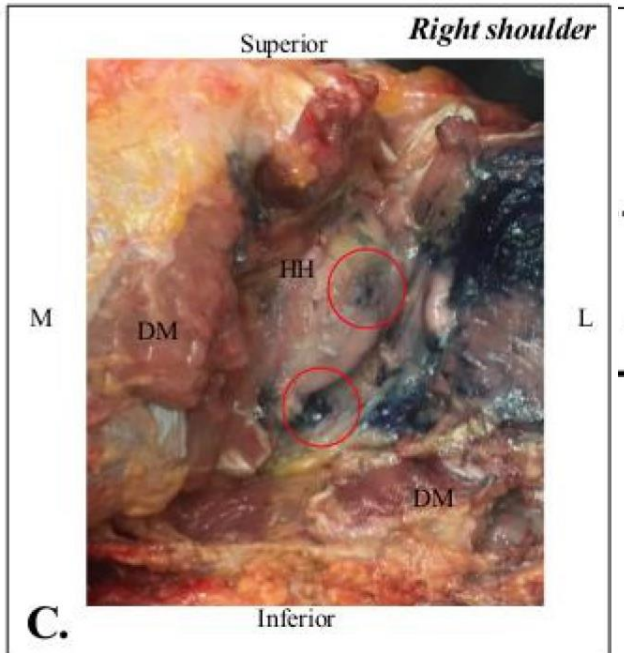
Legend: DM – Deltoid Muscle; HH – Humeral Head;
M – Medial; L - Lateral

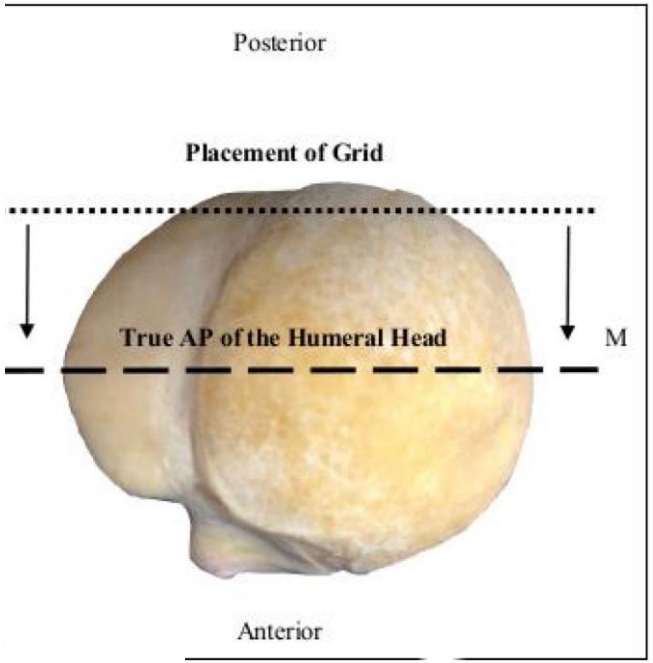


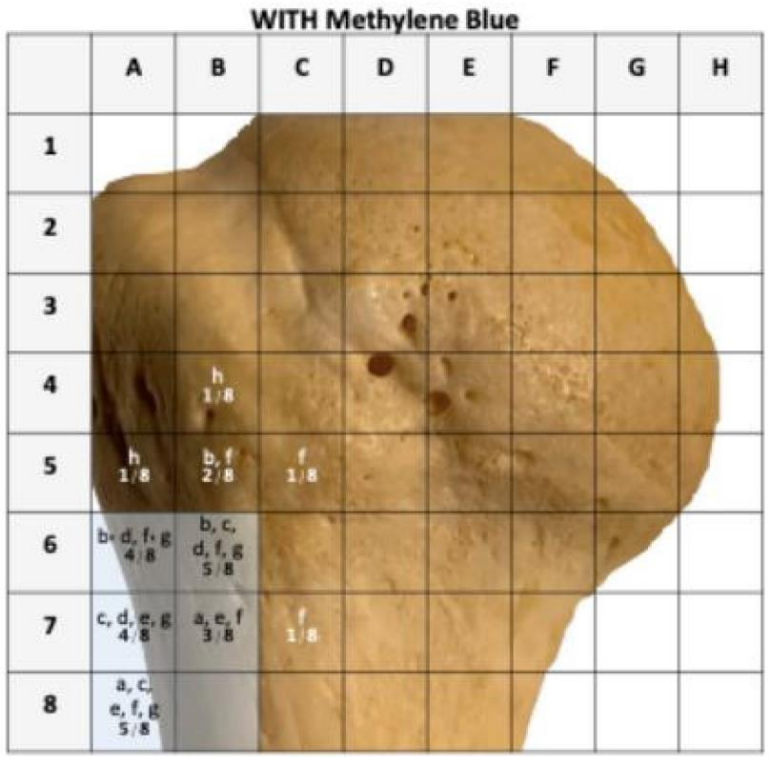
Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.







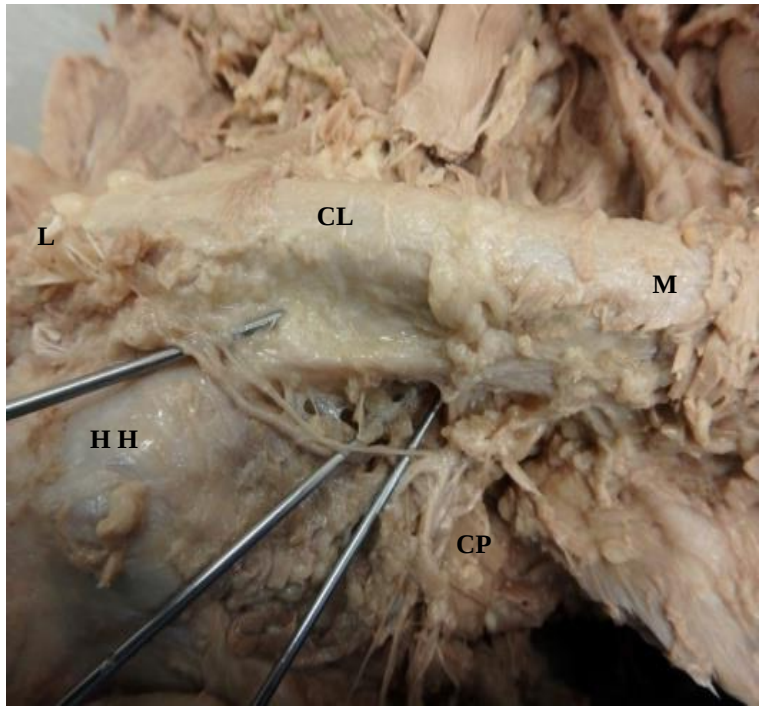


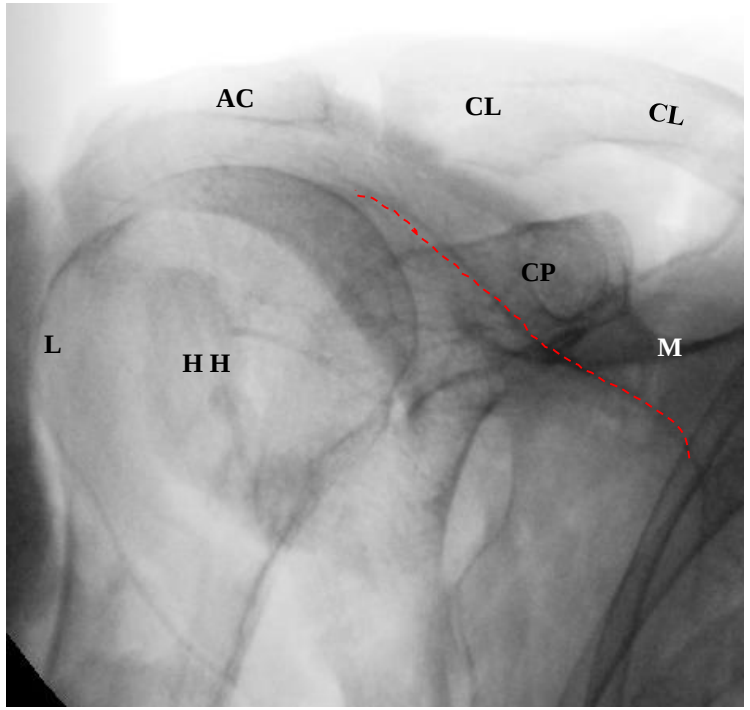


Quantitative analysis of the distal, lateral, and posterior articular branches of the axillary nerve to the shoulder: implications for intervention

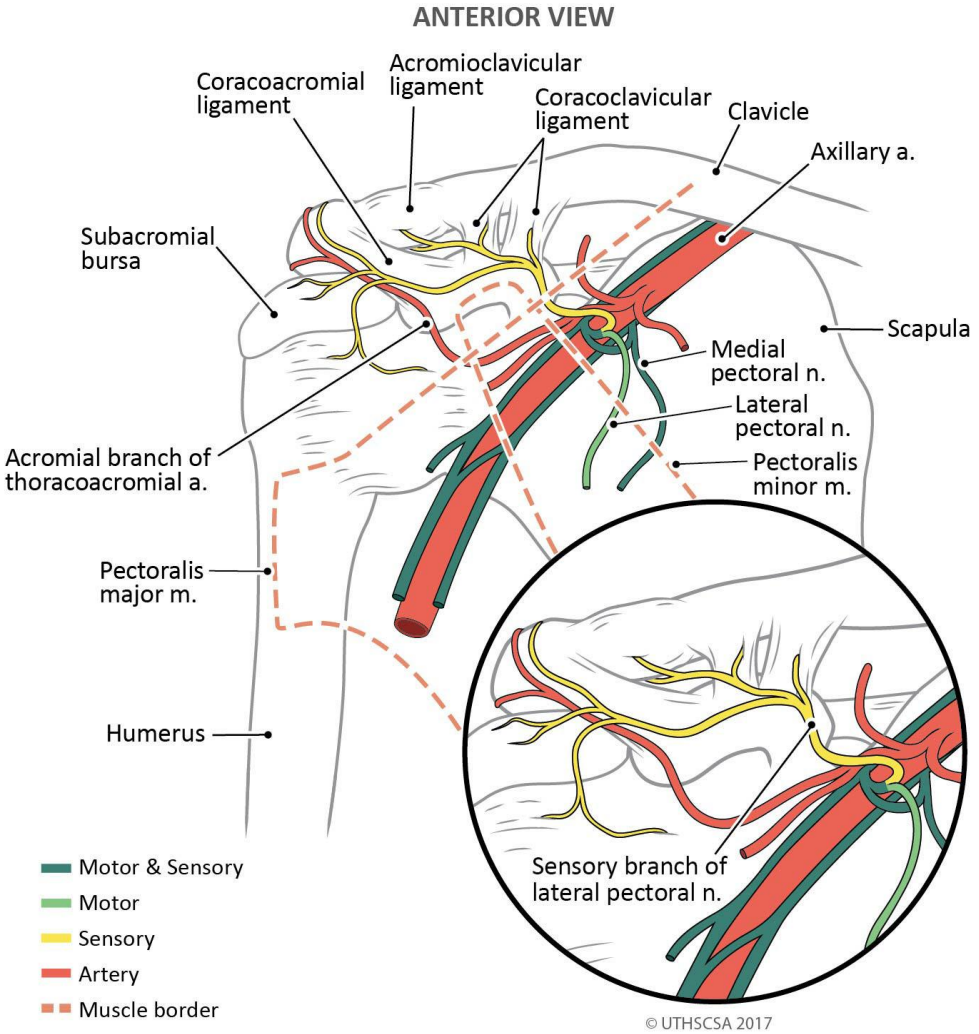
Brittany Bickelhaupt,[1] Maxim S Eckmann,[2] Caroline Brennick,[1] Omid B Rahimi[3]

Lateral Pectoral Nerve (LPN) – Anterior View





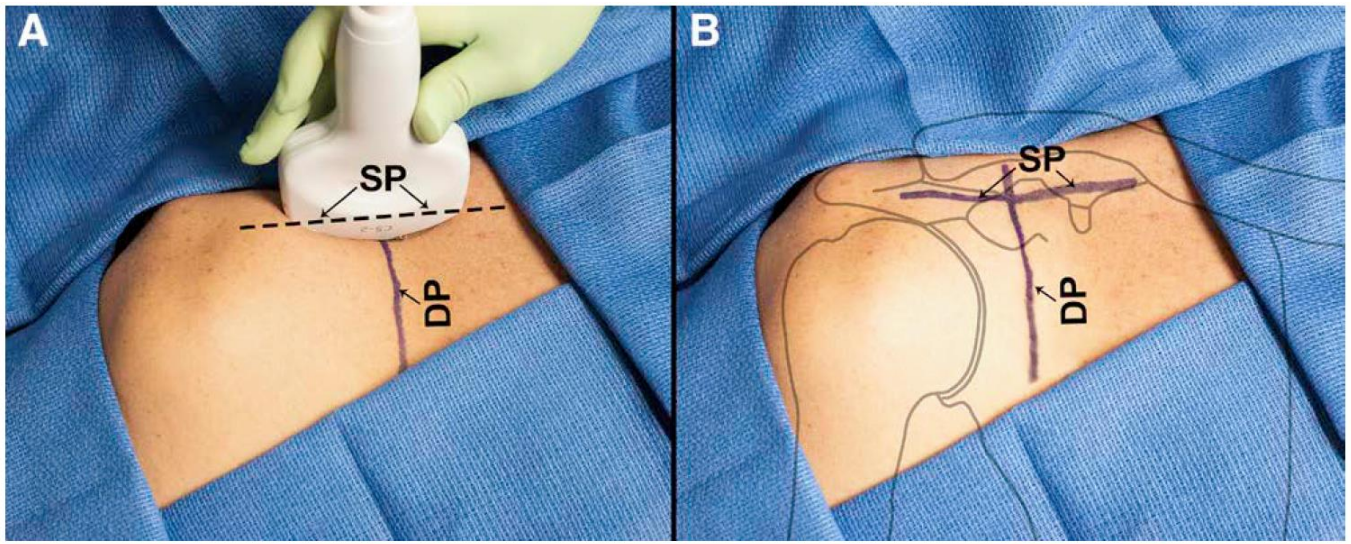
Legend: CL - Clavicle; HH – Humeral Head; CP – Coracoid Process; M – Medial; L - Lateral

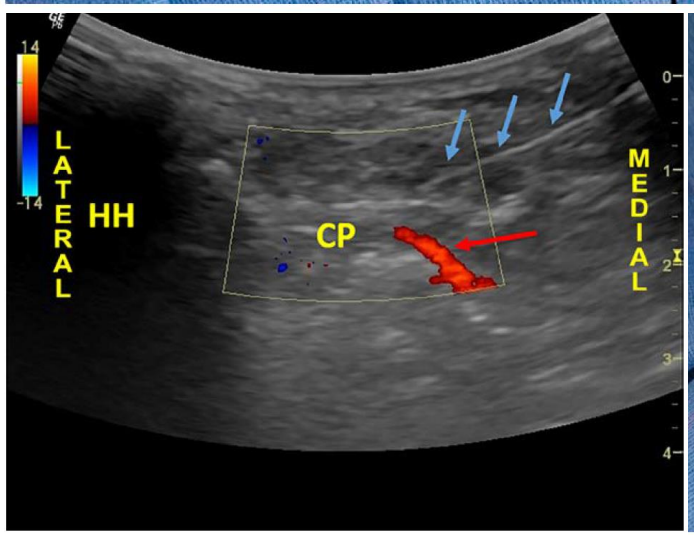


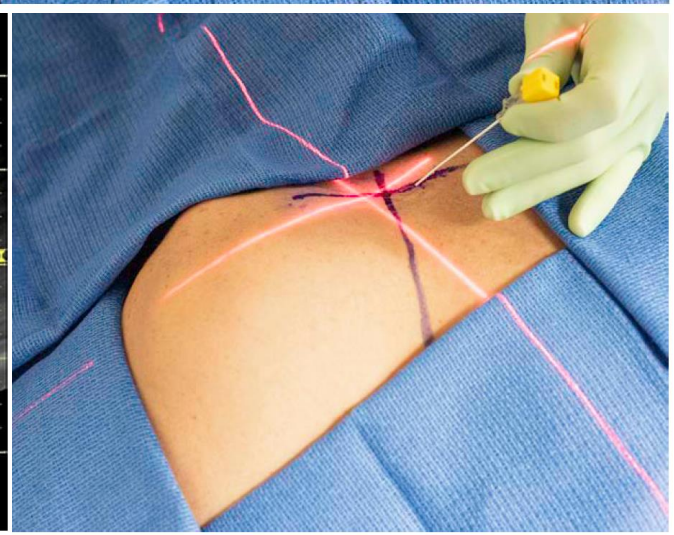
Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of t Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.

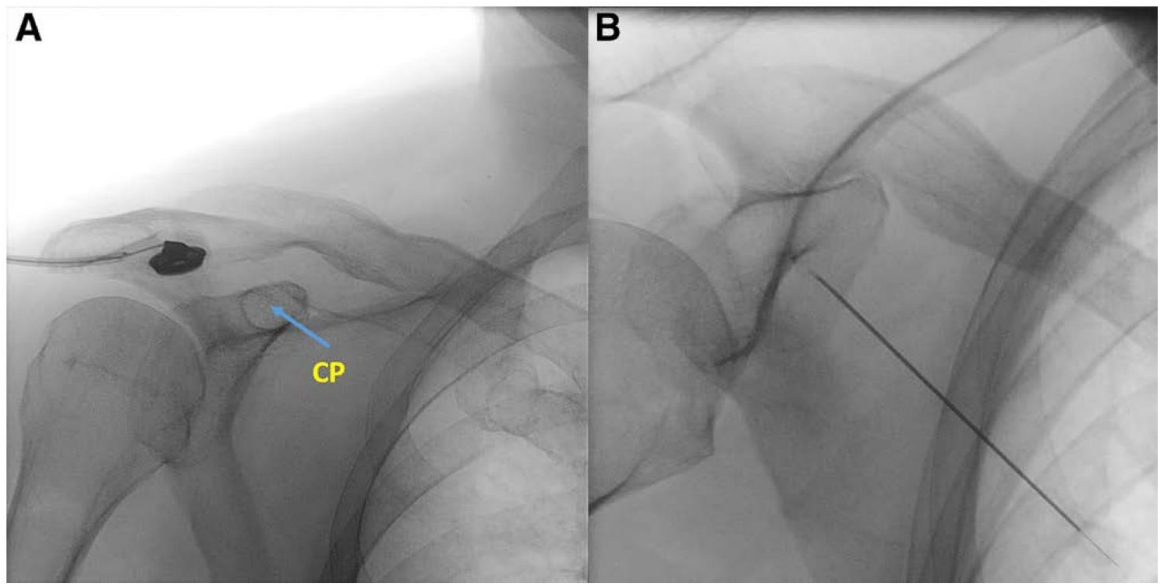
Thermal Radiofrequency Ablation of the Articular Branch of the Lateral Pectoral Nerve: A Case Report and Novel Technique

Maxim S. Eckmann, MD,* Bryan K. Lai, MD,* Marco A. Uribe III, MD,† Samir Patel, DO,* and Jonathan A. Benfield, DO‡

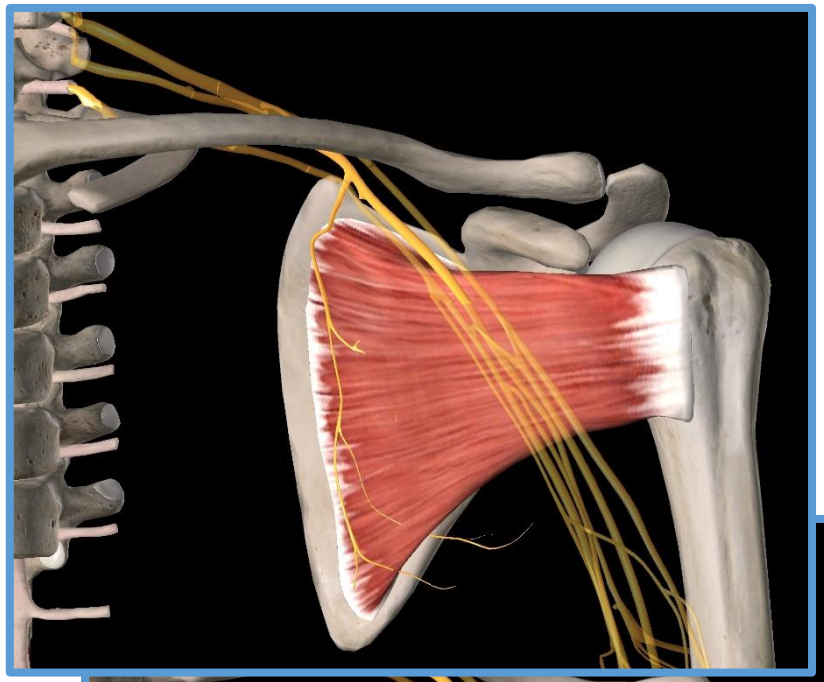


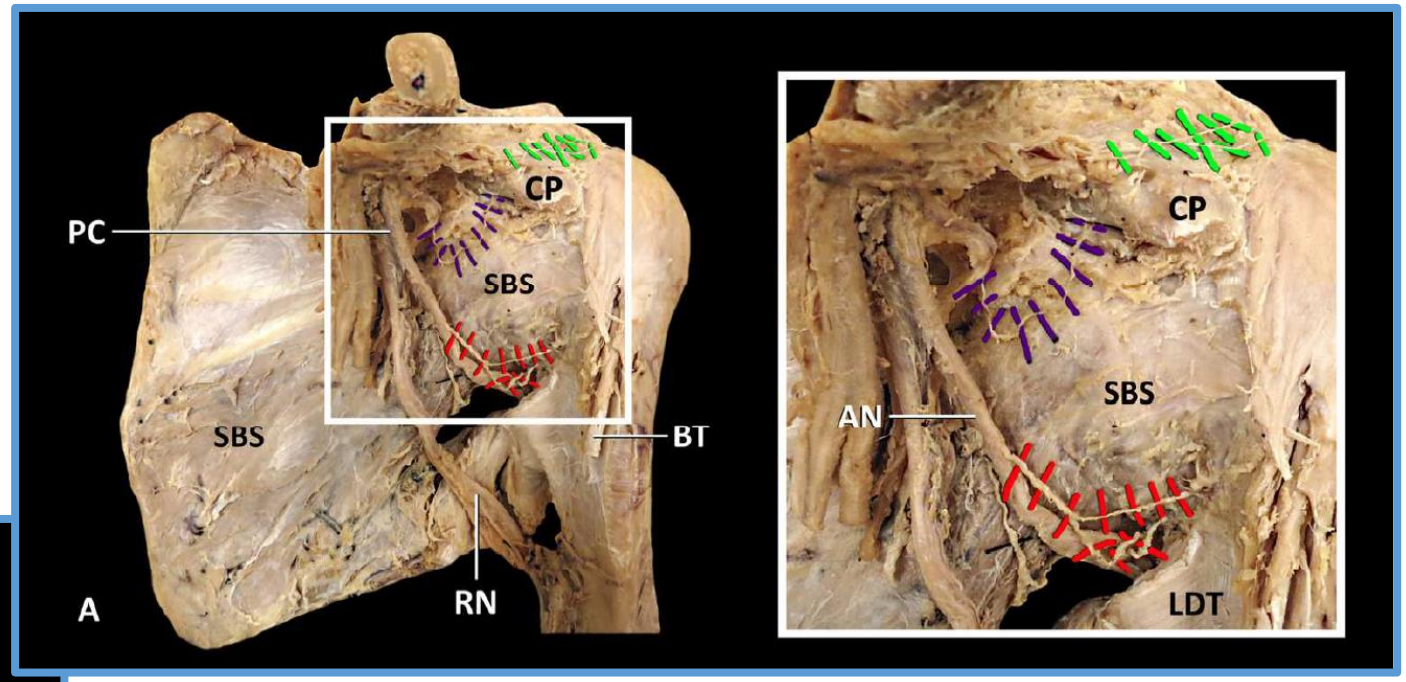


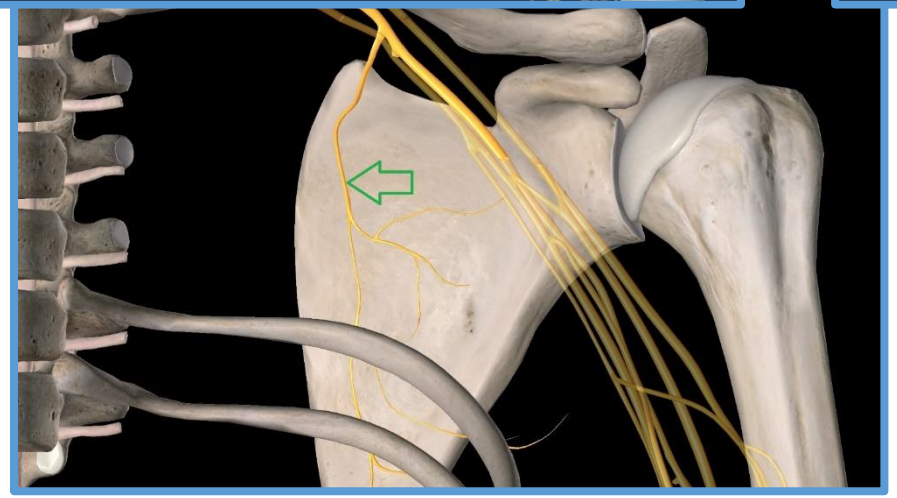




Nerve to subscapularis







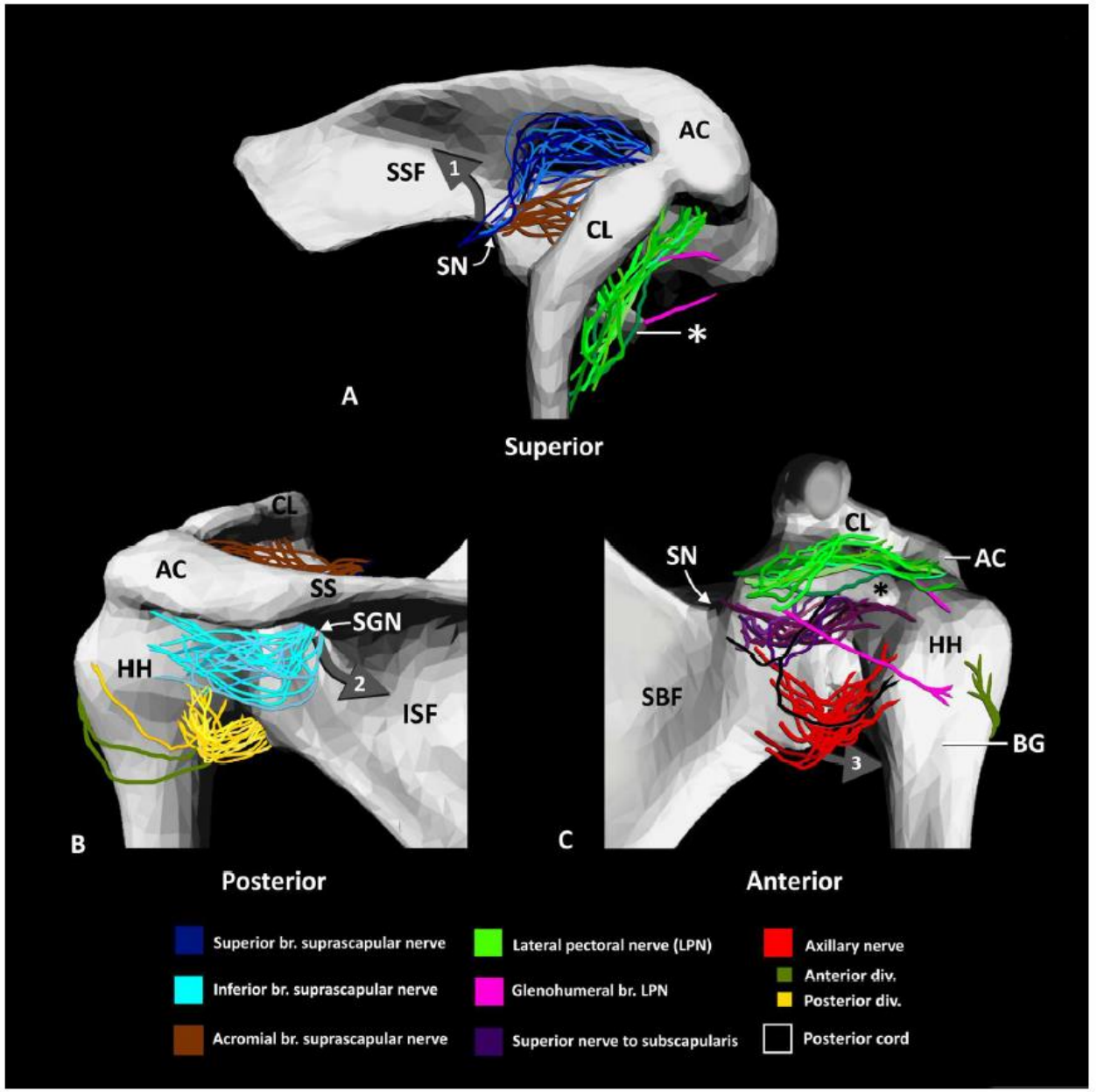
Nerve to Subscapularis innervates the Anterior-Superior GHJ

Tran, John, University of Toronto, Surgery (Division of Anatomy);
Peng, Philip, Toronto Western Hospital, University Health Network, Anesthesia;
Agur, Anne, University of Toronto, Surgery (Division of Anatomy)

Summary and Quantitative Frequency Mapping

Reference	Sp	Suprascapular nerve GHJ	Suprascapular nerve ACJ	Lateral pectoral nerve GHJ	Lateral pectoral nerve ACJ	Axillary nerve GHJ	Nerves to subscapularis GHJ
Gardner[7] (1948)	11	✓	✓	✓	✓	✓***	✓
Wrete[8] (1949)	5	✓	NI	x	NI	5/5**	✓
Aszmann et al[9] (1996)	25	✓	✓	x	✓	✓	✓
Akita et al[10] (2002)	125	NI	2/125	2/125	NI	NI	NI
Gelber et al[11] (2006)	45	NI	NI	NI	NI	8/45 (Abr.) 40/45 (Pbr.)	NI
Vorster et al[12] (2008)	31	23/31	x	NI	NI	NI	NI
Ebraheim et al[13] (2011)	12	NI	12/12	NI	NI	NI	NI
Nasu et al[14] (2015)	20	NI	NI	NI	NI	16/20	NI
Nam et al[15] (2016)	43	NI	NI	29/43	NI	NI	NI
Eckmann et al[16] (2017)	33*	16/16	NI	12/14	NI	16/16	NI

Tran J, Peng PWH, Agur AMR. Anatomical study of the innervation of glenohumeral and acromioclavicular joint capsules: implications for image-guided intervention. Reg Anesth Pain Med. 2019 Jan 11.



Shoulder Nerve Ablation – Emerging Knowledge

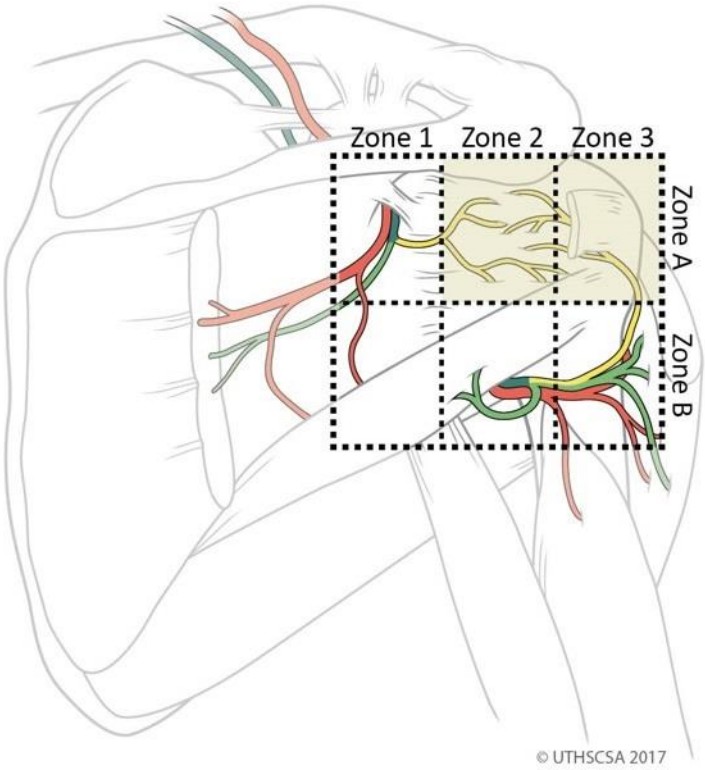
Patient	Pre-treatment NRS score	Post-treatment NRS score (at 5–7 weeks)	Pre-treatment ROM [F/A]	Post-treatment ROM [F/A]	Duration of relief (months)	Repeat procedures (n)
1	7	2	60°/60° (P)	90°/90° (P)	18	1
2	9	4	60°/50° (P)	80°/80° (P)	4	2
3	6	2	20°/20° (P)	45°/90° (P)	4	3
4	6	3	90°/90° (A)	120°/120° (A)	3	1
5	7	3	90°/90° (A)	180°/180° (A)	6	2
6	8	4	40°/40° (A)	80°/80° (A)	6	2

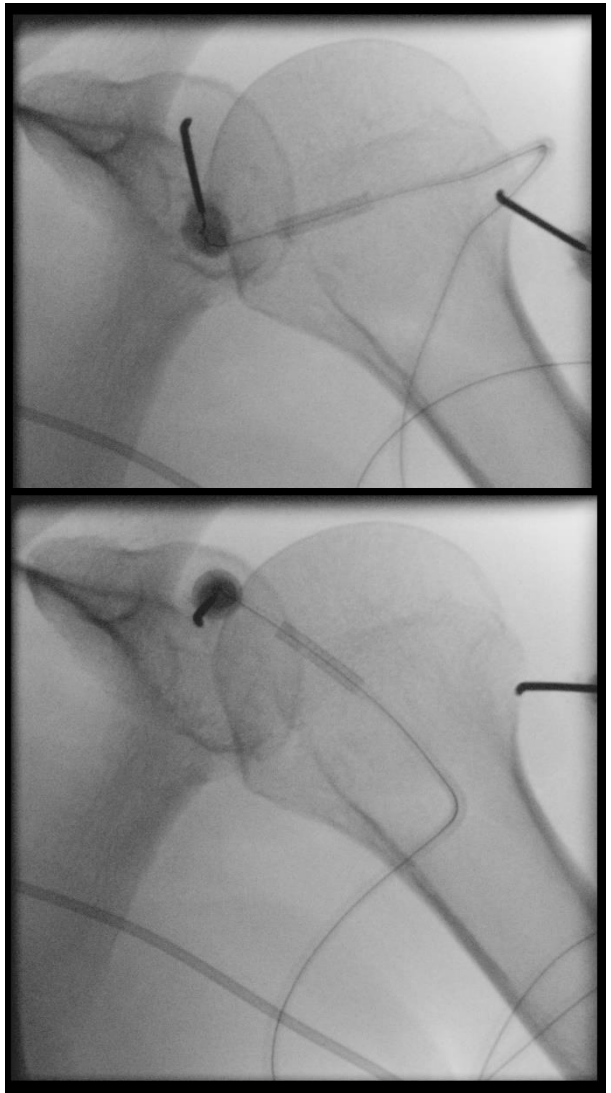
Abbreviations: A, active; F/A, flexion and abduction; NRS, numeric rating scale; P, passive.

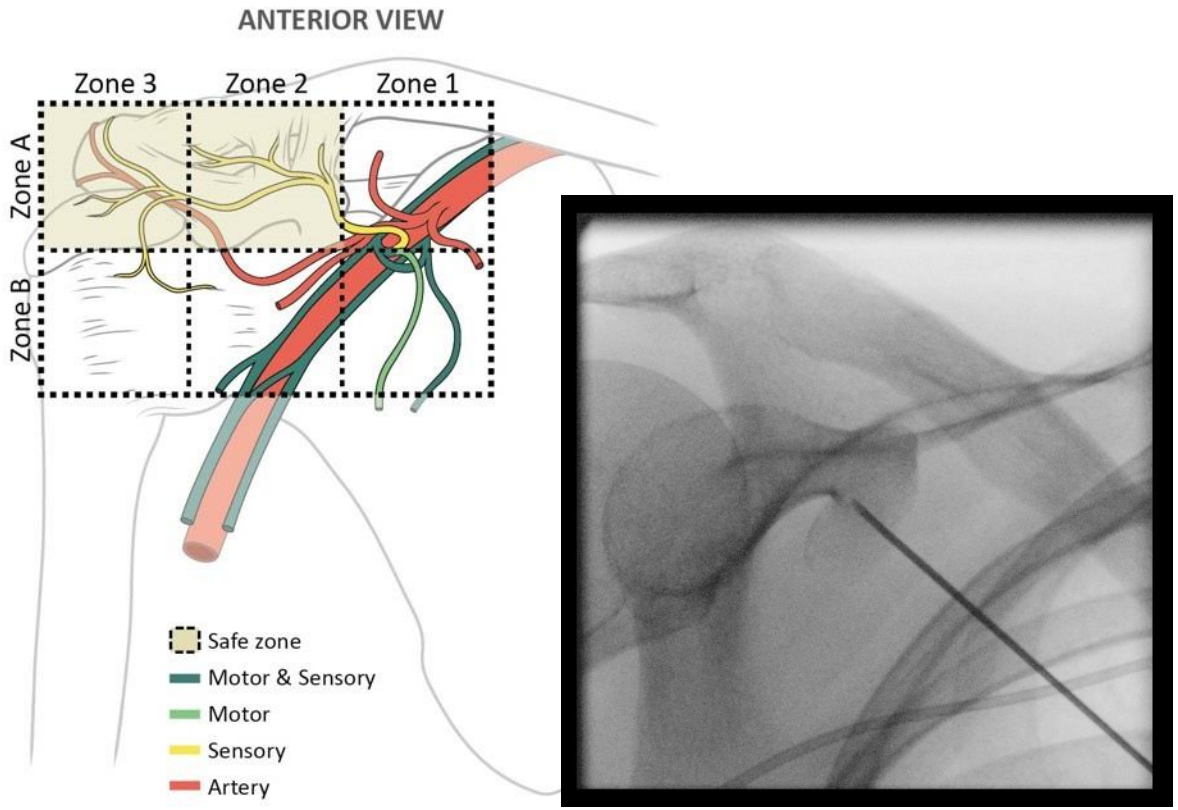
- Case series exist of main suprascapular nerve ablation to palliate shoulder pain in patients with limited functional use of the shoulder (Simopoulos 2012).
  - *Patients can retain or improve function due to reduced pain and compensation.*

Simopoulos TT, Nagda J, Aner MM. Percutaneous radiofrequency lesioning of the suprascapular nerve for the management of chronic shoulder pain: a case series. J Pain Res. 2012;5:91-7.

Locations With Complete Motor Sparing Potential







OXFORD UNIVERSITY PRESS

Pain Medicine

In press Oct 2019

Terminal Sensory Articular Nerve Radiofrequency Ablation for the Treatment of Chronic Intractable Shoulder Pain: A Novel Technique and Case Series

Eckmann, Maxim; UT Health Science Center, Anesthesiology
Johal, Justin; University of Texas Health Science Center at San Antonio
Bickelhaupt, Brittany; University of Texas Health Science Center at San Antonio
McCormick, Zachary; University of Utah Hospital, Physical Medicine and Rehabilitation
Abdallah, Rany; Lewis Katz School of Medicine at Temple University
Menzies, Robert; JPS Orthopedic and Sports Medicine
Soliman, Sameer; Sigma Pain Clinic
Nagpal, Ameet; University of Texas Health Science Center at San Antonio, Department of Anesthesiology

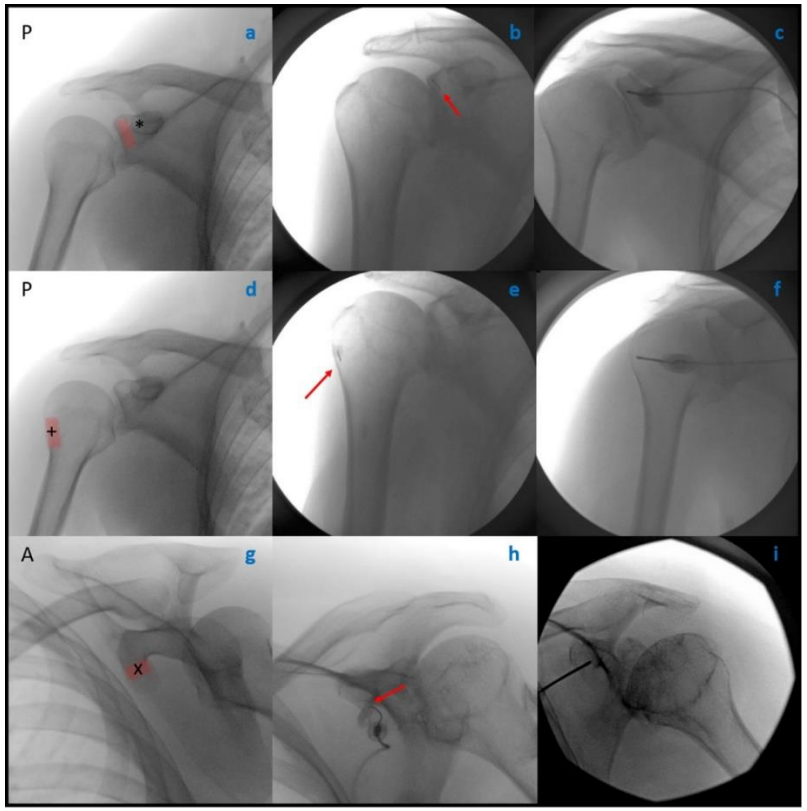


Figure 1. Fluoroscopically guided nerve blocks and ablations. *a:* Posterior (P) view of motor sparing ablation zone (red) for the articular branches of the Suprascapular nerve (abSN). Ablation zone is lateral to the Spinoglenoid Notch (*) on the neck of the glenoid for the abSN. Optimal AP view of the shoulder is a modified Grashey's (ipsilateral oblique) view with caudal tilt to expose this region. *b:* Position for diagnostic nerve block of the abSN (red arrow). *c:* Radiofrequency lesion targeting abSN after motor testing. *d:* Posterior (P) view of motor sparing ablation zone (red) for the articular branches of the Axillary nerve (abAN). Ablation zone is at the posterior-inferior portion of the greater tubercle (+) or epiphysis-diaphysis junction of the humerus for the abAN. *e:* Position for diagnostic nerve block of the abAN (red arrow). *f:* Radiofrequency lesion targeting abAN after motor testing. *g:* Anterior (A) view of motor sparing ablation zone (red) for the articular branches of the Lateral Pectoral Nerve (abLPN). Ablation zone is overlying the dorsal aspect of the coracoid process (X) proximal to the tip. *h:* Position for diagnostic nerve block of the abLPN. *i:* Radiofrequency lesion targeting the abLPN after motor testing.

- 6/10 (60% [CI 29.7%-90.4%]) CRFA patients were responders, >50% pain relief of 6.6 [CI 4.6-8.6] mo
- 3/9(33% [CI 2.3%-63.4%]) TRFA were responders, >50% pain relief for 5.3 [CI 0.9-9.7] mo
- Three CRFA responders and one TRFA responder still had significant pain relief at conclusion of retrospective review
- Shoulder osteoarthritis was the most common primary diagnosis in patients receiving RFA (11/19, 57.9% [CI 35.7%-80.1%]).

Table 1. Characteristics and Outcomes of Patients

Subject number	Age (yrs)	Sex	Weight (kg)	Primary diagnosis	Duration of Shoulder Pain	Procedure	Nerves involved	Relief Duration (Month)	Percent relief
Responders									
1◊	64	M	136.1	Painful Rotator cuff tendinopathy	>6 months	TRFA	abAN, abSN, abLPN	3	80%
2†	70	M	61.2	Osteoarthritis of the shoulder	>6 months	TRFA	abAN, abSN, abLPN	3	60%
3‡	90	M	61.2	Osteoarthritis of the shoulder	>6 months	TRFA	abLPN	10	>50%
4‡	85	M	108.9	Osteoarthritis of the shoulder	>6 months	CRFA	abAN, abSN	10	100%
5	77	M	Unk	Painful Rotator cuff tendinopathy	>1 year	CRFA	abAN, abSN, abLPN	5	70%
6◊	89	F	72.9	Osteoarthritis of the shoulder	>6 months	CRFA	abAN, abSN, abLPN	5	>50%
7†▪	66	F	103.4	Painful Rotator cuff tendinopathy	>6 months	CRFA	abAN, abSN, abLPN	9	100%
8†	71	F	81.7	Osteoarthritis of the shoulder	>6 months	CRFA	abAN, abSN, abLPN	4	50%
9†	57	F	72.9	Osteoarthritis of the shoulder	>6 months	CRFA	abAN, abSN, abLPN	8	80%
Subject number	Age (yrs)	Sex	Weight (kg)	Primary diagnosis	Duration of Shoulder Pain	Procedure	Nerves Involved	**Follow-up Duration (Months)**	**Percent relief**
Non-Responders									
10	85	F	55.3	Osteoarthritis of the shoulder	>6 months	TRFA	abAN, abSN, abLPN	3	0%
11◊	53	F	98.9	Complex regional pain syndrome, type 1	4 years	TRFA	abAN, abSN, abLPN	1	30%
12*	47	F	81.6	Adhesive capsulitis of both shoulders	>1 year	TRFA	abAN, abSN, abLPN	4	0%
13*	47	F	81.6	Adhesive capsulitis of both shoulders	>1 year	TRFA	abAN, abSN, abLPN	3	0%
14	61	M	109.3	Osteoarthritis of the shoulder	>6 months	TRFA	abAN, abSN, abLPN	3	0%
15	75	F	76	Osteoarthritis of the shoulder	>6 months	TRFA	abAN, abSN, abLPN	2	40%
16◊	52	F	127	Sprengel deformity	3 years	CRFA	abAN, abSN, abLPN	2	20%
17	63	F	79.4	Osteoarthritis of the shoulder	>6 months	CRFA	abAN, abSN, abLPN	1	0%
18◊	88	M	Unk	Osteoarthritis of the shoulder	4 years	CRFA	abAN, abSN, abLPN	1	10%
19‡▪	34	M	83.9	Painful Rotator cuff tendinopathy	3 years	CRFA	abSN	10	0%

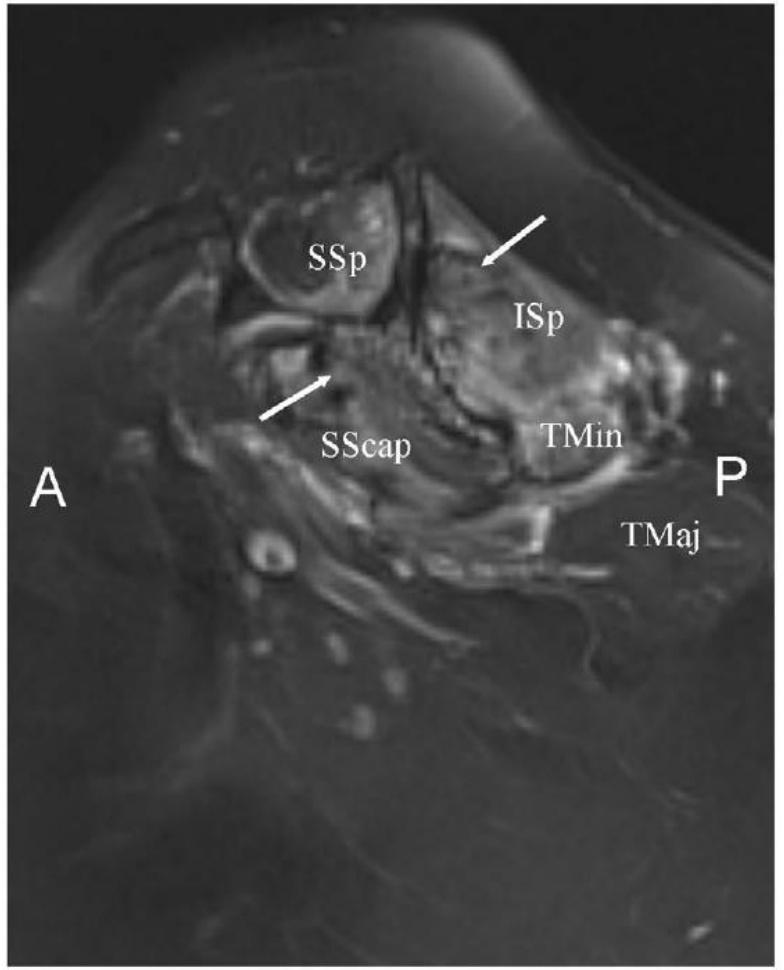
*More than one ablative procedure; †On going relief at time at last follow-up; ‡Less than 3 terminal nerve branches were ablated; ◊History of shoulder surgery; ▪History of arthroplasty surgery

TRFA= Traditional radiofrequency ablation; CRFA= Cooled radiofrequency ablation; abAN=Axillary nerve; abSN= Suprascapular nerve; abLPN= Lateral pectoral nerve; Unk= Unknown

Ablation associated injuries

Percutaneous Cryoablation of Scapular Metastasis Associated with Iatrogenic Injury to the Suprascapular, Subscapular, and Axillary Nerves

From: Patrick L. Adams, BS
Alda L. Tam, MD
Behrang Amini, MD
Quoc B. Hoang, MD
Valerae O. Lewis, MD
Steven Y. Huang, MD
School of Medicine (P.L.A.)
Baylor College of Medicine
Houston, Texas
Departments of Diagnostic Radiology (B.A.)
Orthopedic Oncology (V.O.L.) and
Interventional Radiology (A.L.T., S.Y.H.)
The University of Texas MD Anderson Cancer Center



MRI, 2 months after lesion

Shoulder Nerve Ablation – Summary

- The shoulder is a complex major joint with emerging neuroanatomic understanding
- Chronic shoulder pain may include: rotator cuff disease, osteoarthritis of the glenohumeral joint (GHJ), nerve injuries, capsulitis, and others.
- The suprascapular, axillary, lateral pectoral, subscapular nerves, are known to innervate the GHJ[1,2,3]. (and possibly others)
- Articular branch nerves have been described and may be future clinical targets[1,2,4,5].
- Case series exist of main suprascapular nerve ablation to palliate shoulder pain in patients with limited functional use of the shoulder[4].
  - While weakness of the shoulder is a logical complication, compensation possible.
- Case series of articular shoulder ablation shows promise in patients with OA[5].

1. Eckmann MS, Bickelhaupt B, Fehl J, Benfield JA, Curley J, Rahimi O, Nagpal AS. Cadaveric Study of the Articular Branches of the Shoulder Joint. Reg Anesth Pain Med. 2017 Sep/Oct;42(5):564-570.
2. Tran J, Peng PWH, Agur AMR. Anatomical study of the innervation of glenohumeral and acromioclavicular joint capsules: implications for image-guided intervention. Reg Anesth Pain Med. 2019 Jan 11.
3. Hébert-Blouin MN, et al. Clin Anat. 2014 May;27(4):548-55.
4. Simopoulos TT, Nagda J, Aner MM. Percutaneous radiofrequency lesioning of the suprascapular nerve for the management of chronic shoulder pain: a case series. J Pain Res. 2012;5:91-7.
5. Eckmann MS, et al. Pain Medicine in Press October 2019.

Summary: Technical Advances in RFA

- Quantitative Anatomy – Improving Targets
  - Spine / SI Joint
  - New body regions: Knee, Hip, Shoulder

- RFA and Versatility
  - Variable success in proving long term outcomes
    - **Cervical Spine > Lumbar Spine > Sacroiliac Joint**
  - Emerging data for Major Joints
    - **Knee > Hip > Shoulder**

- Technical Advancement - Larger Lesion Sizes
  - Possibly improved outcomes
  - New complications
  - Safe trajectories are needed

Thank you!