ORIGINAL ARTICLE

Anatomic Study of Innervation of the Anterior Hip Capsule
Implication for Image-Guided Intervention

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Background and Objectives: The purpose of this cadaveric study was to determine the pattern of anterior hip capsule innervation and the associated bony landmarks for image-guided radiofrequency denervation.

Methods: Thirteen hemipelvises were dissected to identify innervation of the anterior hip capsule. The femoral (FN), obturator (ON), and accessory obturator (AON) nerves were traced distally, and branches supplying the anterior capsule documented. The relationships of the branches to bony landmarks potentially visible with ultrasound were identified.

Results: The anterior hip capsule received innervation from the FNs and ONs in all specimens and the AON in 7 of 13 specimens. High branches of the FN (originating above the inguinal ligament) were found exclusively in 12 specimens and passed between the anterior inferior iliac spine and the iliopubic eminence. The ONs were innervated exclusively by high branches (proximal to the division), by low branches (from the posterior branch), and by both in 4, 5, and 4 specimens, respectively. The most consistent landmark was the inferomedial acetabulum (radiographic "teardrop"). When present, the AON coursed over the iliopubic eminence before innervating the anterior hip capsule.

Conclusions: Branches of the FNs and ONs consistently provided innervation to the anterior hip capsule. The AON also contributed innervation in many specimens. The relationship of the articular branches from these 3 nerves to the inferomedial acetabulum and the space between the anterior inferior iliac spine and iliopubic eminence may suggest potential sites for radiofrequency ablation.

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Osteoarthritis is a common condition leading to chronic pain and loss of function. An estimated 1 in 4 individuals will develop painful hip OA by the age of 85 years.[1] The management strategies consist of pharmacologic treatments, physical therapy, interventional techniques, and surgery.[2] Total hip arthroplasty is considered for patients with advanced OA and moderate to severe symptoms.[3] New, noninvasive treatment options need to be developed for patients who cannot undergo surgery and for those with severe postoperative pain. Radiofrequency denervation (RFD), known to be effective for facet and sacroiliac joint arthritis,[4] is now emerging as a possible treatment for chronic hip pain. In a review article, Gupta et al[5] described 8 case reports/case series assessing RFD of the hip joint. Patients reported a moderate (30%–80%) reduction in pain at 3 to 6 months. However, the number of subjects was small (total 53 in this review) the denervation methods were heterogeneous, and the inclusion criteria were inconsistent.[5] The target of denervation was the anterior capsule in virtually all studies. Ultimately, the success of RFD relies on precise anatomic knowledge of nerves innervating the hip joint and their relationships to landmarks visible with imaging.

Previous studies investigating innervation of the anterior aspect of the hip joint reported innervation by the obturator (ON), accessory obturator (AON), and/or femoral (FN) nerves.[6–14] Both ON and AON have been investigated in many studies for their contribution to hip innervation, with ON being the most commonly reported source of innervation (83%–98%). In contrast, the frequency of FN innervation was examined in only 2 studies (75% and 95%). In a study investigating the internervous safe zone of the capsule of the hip joint, ON (0–7 branches), AON (0–2 branches), and FN (0–3 branches) were found to innervate the anterior capsule.[14] No anatomic studies to date have related innervation of the anterior hip capsule to bony or soft tissue landmarks visible with ultrasound (US). Clinical studies have used the radiographic "teardrop" to localize the ON[5,15–21] and the anterior inferior iliac spine (AIIS) or superolateral acetabular margin for FN localization.[5,15,16,18,19,21]

In summary, although studies have reported the successful use of RFD for chronic hip pain, there has been a lack of anatomic investigation relating innervation of the anterior hip capsule with bony landmarks that could be used to target these nerves.[5] The purposes of this cadaveric study were to determine the trajectory of nerves innervating the anterior hip capsule and describe the patterns of innervation. Furthermore, this study aimed to determine the relationship between capsular branches and the bony landmarks, visible under US, to propose targets for RFD.

METHODS

Ethics approval was received from the University of Toronto Health Sciences Research Ethics Board. Thirteen hemipelvises (4 from male and 9 from female cadavers) with a mean age of 79.3 ± 11.9 years were used for this study. Twelve specimens were formalin embalmed, and one was lightly embalmed. Specimens with visible signs of pathology or previous surgery were excluded.

The skin, fascia, and superficial musculature were removed to expose the iliopsoas, pectineus, and adductor longus. Next,

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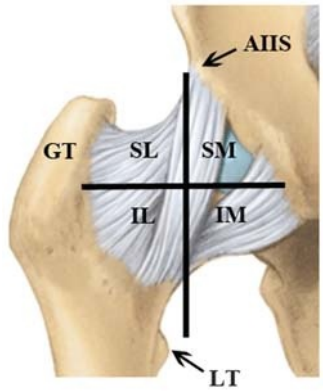

FIGURE 1. Quadrants of the anterior hip capsule: superolateral (SL), superomedial (SM), inferolateral (IL), and inferomedial (IM). GT indicates greater trochanter; LT, lesser tubercle. Anterior view. Reproduced with permission from Philip Peng Educational Series.

the FN, ON, and AON were traced distally to their termination, and if they were found to innervate the anterior hip capsule, the quadrant(s) of innervation were recorded: superomedial, superolateral, inferomedial, and/or inferolateral (Fig. 1).

The FN was identified at the lateral border of the psoas and followed medially to the vertebral column and inferiorly to midthigh. To expose the branches of the FN, fiber bundles of the iliacus and psoas were carefully delineated and then excised without disrupting nerve distribution. The articular branches that innervated the anterior hip capsule were identified, and each branch was classified either as a high branch if it was given off the FN superior to the inguinal ligament or as a low branch if it was given off inferior to the inguinal ligament.

To expose the ON and its branches, adductor longus was removed, and the pectineus, adductor brevis, and obturator externus were dissected at the fiber bundle level. Nerves coursing through these muscles were preserved. As the fiber bundles of these muscles were removed, the ON and its anterior and posterior branches were exposed at the distal end of the obturator canal. Any branches from the ON and its anterior and posterior branches were followed laterally. The articular branches innervating the anterior hip capsule were isolated, and their area of innervation recorded. Each branch was classified as a high branch if given off superior to the bifurcation of the ON (proximal or within the obturator canal) or a low branch if given off from either the anterior or posterior branch of the ON.

The AON was identified during dissection of the FN and its branches within the psoas muscle. If present, AON was followed proximally to the vertebral column and distally to its termination. Any branches innervating the anterior hip capsule were identified and documented.

Upon completion of dissection of the FN, ON, and AON, the relationships of branches innervating the anterior hip capsule to bony landmarks were determined. All specimens were photographed. Patterns of innervation were analyzed, and the frequency of each determined. The innervation patterns were defined by documenting the origin of nerve branches, as well as their termination in respective quadrants of the anterior hip capsule. The branches from each main nerve were counted and compared between specimens.

Ultrasound scanning of other nondissected specimens was performed. The consistency of bony landmarks visible with US that could be used to demarcate the position of nerve branches innervating the anterior hip capsule was analyzed. Based on the innervation patterns and bony landmarks, a US-guided protocol for RFD that targets nerves innervating the anterior hip capsule was proposed.

RESULTS

The anterior hip capsule received innervation from the FN and ON in all specimens and AON in 7 of 13 (Table 1, Fig. 2). However, the frequency and arrangement of articular branches varied between specimens. Each nerve is described in the following sections.

Femoral Nerve

Articular branches from FN were observed in all specimens. The branches were classified as either high or low femoral, corresponding to their origin superior or inferior to the inguinal ligament. High branches were found exclusively in 7 specimens, low branches exclusively in 1, and both in 5 specimens (Table 1).

The number of high branches ranged from 1 to 14 per specimen, with a mean of 5. One to 4 branches were found in 5 specimens, 5 to 7 branches in 4, and 8 to 14 branches in 3 specimens (Fig. 3). The high branches were given off the FN distal to the lateral border of the psoas. The branches then traveled intramuscularly through iliacus, deep to the inguinal ligament, prior to innervating the anterior hip capsule. High branches all passed on the periosteal surface of the pubis between the AIIS and the medial aspect of the iliopubic eminence (Table 2). High femoral branches supplied all 4 quadrants of the anterior hip capsule (Table 3). Most frequently, the superolateral, inferolateral, and superomedial quadrants were supplied, although the inferomedial region was innervated in a smaller number of specimens.

Fewer low femoral branches were present than high femoral. One low branch was found in 2 specimens, 2 branches in 2, 5 branches in 1, and 6 branches in 1 specimen (Fig. 3). Low branches pierced the iliopsoas to supply the anterior hip capsule directly or coursed inferiorly before recurring superiorly to innervate the capsule. Low femoral branches supplied all quadrants, with the inferolateral quadrant having the greatest frequency (Table 3). Low branches could not be related to landmarks visible with US.

Obturator Nerve

The ON innervated the anterior hip capsule in all specimens (Table 1). The ON provided articular branches that were categorized as high or low according to their point of origin. High branches originated just proximal to or within the obturator canal and low branches from the posterior branch of ON (Fig. 4). Four specimens were innervated exclusively by high branches, 5 specimens exclusively by low branches, and 4 specimens by both.

Most high branches descended inferiorly from the obturator canal, just distal to the inferior aspect of the hip joint and then recurred to supply only the inferomedial quadrant (Table 3). If a high branch was present, it usually consisted of a single nerve branch. The low branches, when present, were more numerous and traveled either directly to the hip joint or formed a fine

TABLE 1. Frequency of Innervation of the Anterior Hip Capsule by FN, ON, and AON

Nerve	Innervation (n = 13)	Distribution		
		High	Low	High and Low
FN	100% (13/13)	53.8% (7/13)	7.7% (1/13)	38.5% (5/13)
ON	100% (13/13)	30.8% (4/13)	38.4% (5/13)	30.8% (4/13)
AON	53.8% (7/13)			

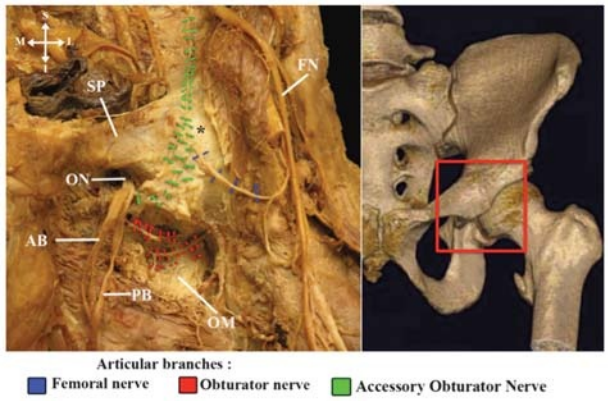

FIGURE 2. Anterior view of the hip shows the innervation of the hip joint capsule by articular branches of the FN (blue), ON (red), and AON (green). The location of this anterior view is indicated by the red square on the right figure. AB indicates anterior branch of ON; I, inferior; L, lateral; M, medial; OM, obturator membrane; PB, posterior branch of ON; S, superior; SP, superior ramus of pubis. Reproduced with permission from Philip Peng Educational Series.

plexus that innervated the capsule. Low branches supplied both the inferomedial and the inferolateral aspects of the anterior hip capsule. The most consistent landmark for both high and low ON branches was the bone thickening of the inferomedial acetabulum that correlates to the previously described radiographic teardrop (Table 2).

Accessory Obturator Nerve

The AON was found in 7 of 13 specimens as a single nerve formed by branches from the lumbar plexus (L2–L5) (Fig. 5).

TABLE 2. Innervation of the Anterior Hip Joint Capsule and Related Landmarks

Nerve	Specimens (n = 13)	Landmark(s)
Femoral high	92.3% (12/13)	Iliopubic eminence AIIS
Femoral low	33.3 % (4/13)	None
Obturator high	61.5% (8/13)	Inferomedial acetabulum (teardrop)
Obturator low	74.0% (9/13)	Inferomedial acetabulum (teardrop)
AON	53.8% (7/13)	Iliopubic eminence

The nerve coursed deep to the psoas along its medial margin and in all specimens passed over the iliopubic eminence to terminate on the capsule (Table 2). In 2 specimens, a branch of AON anastomosed with the ON. The AON innervated the medial aspect of the capsule, supplying the inferomedial quadrant in all 7 specimens and the superomedial quadrant in 5 (Table 3).

DISCUSSION

The results of this anatomic study suggest that branches of both the FN and ON provide innervation to the anterior hip capsule. High and low branches of FN provided the majority of innervation to the lateral and superomedial hip capsule. High branches of the FN were found to play a much greater role than reported in the literature.[6,12] High and low ON branches provided focused innervation to the inferomedial aspect of the capsule. The AON was found to innervate the medial capsule with higher frequency than previously reported.[10,12,22,23]

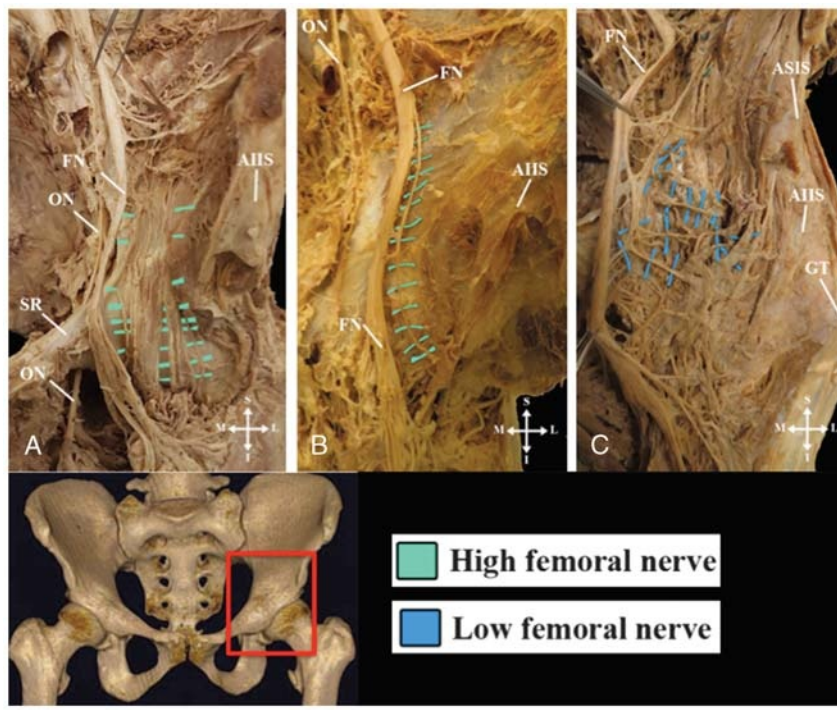

FIGURE 3. Innervation of the anterior hip capsule by articular branches of the FN, anterior views. A and B, High femoral branches. C, Low femoral branches. The red rectangle in the pelvis skeleton (lower figure) shows the area of interest in A to C. ASIS indicates anterior superior iliac spine; GT, greater trochanter; I, inferior; L, lateral; M, medial; S, superior; SR, superior ramus of pubis. Reproduced with permission from Philip Peng Educational Series.

TABLE 3. Innervation of Quadrants of the Anterior Hip Capsule

	Innervation of Quadrants of the Anterior Hip Capsule (n = 13 Specimens)			
Nerve	**Superolateral**	**Superomedial**	**Inferolateral**	**Inferomedial**
FN	10/13	9/13	12/13	7/13
Femoral high	9/13	8/13	8/13	5/13
Femoral low	1/13	1/13	4/13	2/13
ON	None	None	4/13	11/13
Obturator high	None	None	1/13	7/13
Obturator low	None	None	3/13	4/13
AON	None	5/13	None	7/13

Several branches of FN have previously been shown to innervate the anterior hip capsule.[6–14,22,24,25] However, the contribution of high transmuscular branches has received limited attention.[13] An important finding of this study was the number and consistency of the high branches of FN, all of which passed between 2 bony landmarks identifiable with US, the AIIS, and the iliopubic eminence. Low femoral branches were found in a smaller number of specimens than previously reported.[6–10,12–14,24,25] These branches innervated the capsule exclusively or provided mixed sensory and muscular innervation.

In line with previous anatomic studies, ON consistently innervated the inferomedial hip capsule.[6,8–10,12–14,24–29] Our findings are similar to those described by Locher et al,[26] who detailed the anatomic course of articular branches of the ON and their relationship to bony landmarks. They described articular branches located lateral to the obturator foramen, just below the acetabulum. This correlated with the teardrop, which is a radiographic silhouette formed by a thickening of bone at the inferomedial acetabulum.[30]

The AON has been described in previous studies.[23,31,32] Our study suggests a much higher incidence (54%) than the estimated occurrence reported in previous studies (8%–29%).[33] Anatomic landmarks for AON denervation have not been well described in the literature. In this study, the AON presented as a single nerve coursing over the iliopubic eminence before splitting into capsular branches. The iliopubic eminence was a consistent landmark.

Knowledge of detailed topographic anatomy of hip joint innervation is a mandatory requirement to achieve clinically effective denervation. Clinical evidence for RFD is limited to case reports and series. No prospective studies have been published. Fourteen articles have reported intervention on branches of the ON.[5,15–21,34–39] In 11 reports, FN branches were ablated in all patients,[5,16–21,36–39] and in 2 studies, only some of the patients were treated by addressing the femoral contribution.[15,34] Other reportedly targeted nerves were the lateral femoral cutaneous nerve of the thigh,[20] the superior gluteal, and the articular branches of the sciatic nerve.[34] The teardrop silhouette, identified by fluoroscopy, was used as the landmark for ON in most reports. The radiographic targets for branches of the FN were either the superolateral acetabular margin or the AIIS. While the anatomic relationship between the radiographic target and the neural innervation from ON has been examined,[26] the relationship between FN and AON articular branches to the bony landmarks remains unconfirmed.

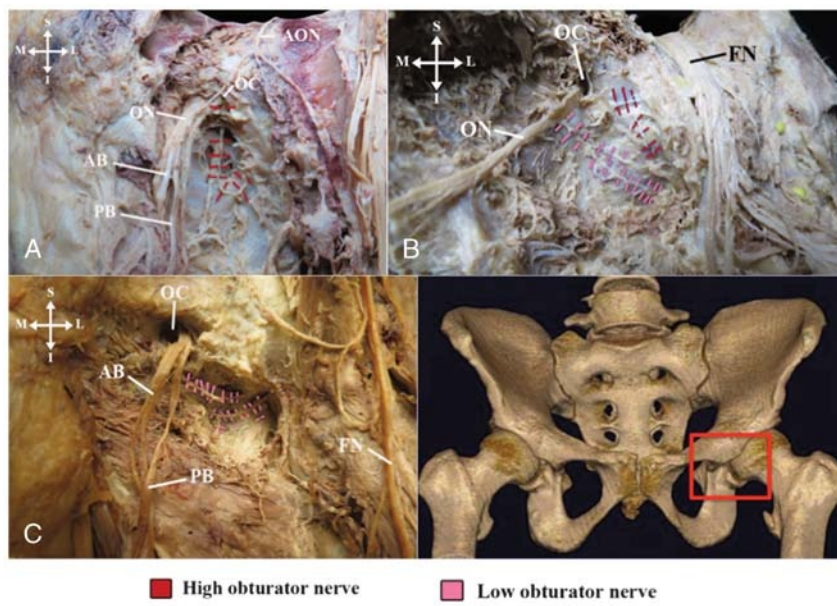

FIGURE 4. Innervation of the anterior hip capsule by articular branches of the ON, anterior views. A, High obturator branches. B, High and low obturator branches. C, Low obturator branches. The red rectangle in the pelvis skeleton in the right lower corner shows the area of interest for A to C. AB indicates anterior branch of ON; I, inferior; L, lateral; M, medial; OC, obturator canal; PB, posterior branch of ON; S, superior. Reproduced with permission from Philip Peng Educational Series.

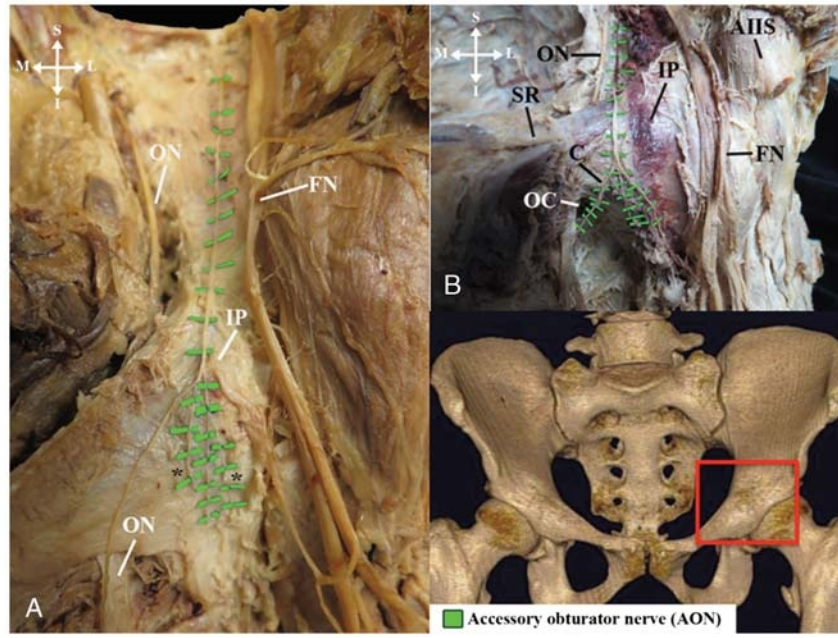

FIGURE 5. Innervation of the anterior hip capsule by articular branches of the AON, anterior views. The red rectangle in the pelvis skeleton in the right lower corner shows the area of interest for A and B. A, Accessory obturator nerve. B, Accessory obturator nerve with branch communicating with the ON. C indicates branch communicating with ON; I, inferior; IP, iliopubic eminence; L, lateral; M, medial; OC, obturator canal; S, superior; SR, superior ramus of pubis. Reproduced with permission from Philip Peng Educational Series.

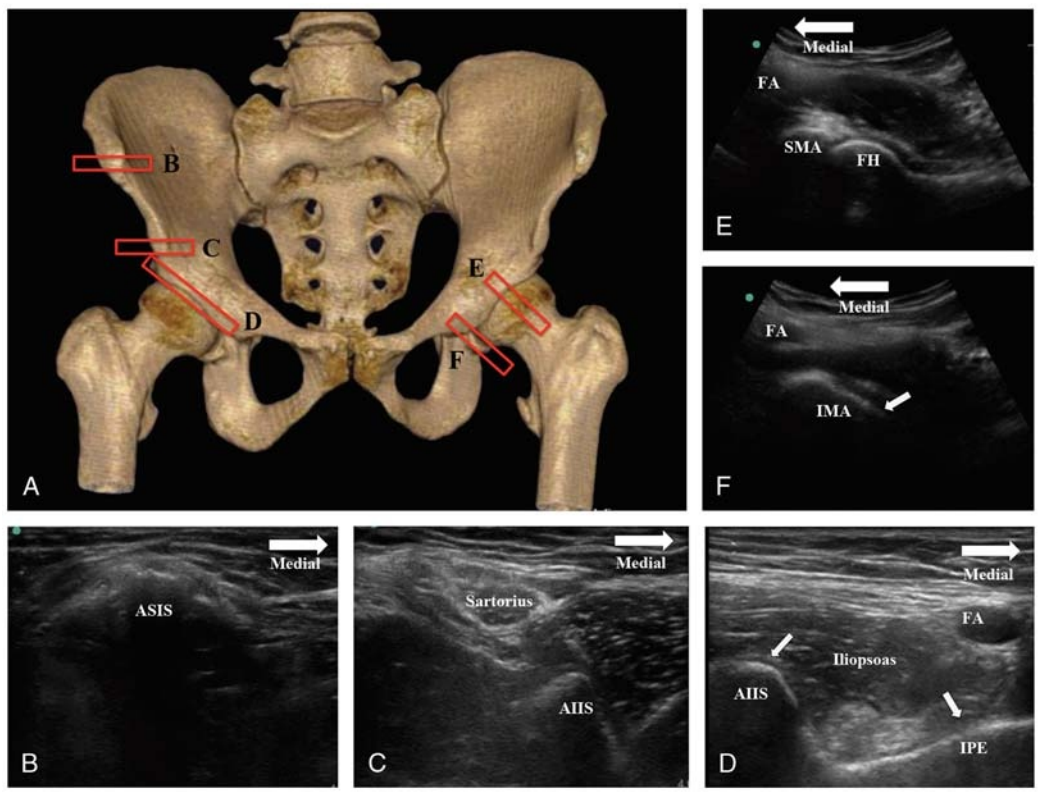

FIGURE 6. Ultrasound landmarks for image-guided injections of articular branches innervating the anterior hip capsule. A, Skeletal model showing US probe positions (red rectangles). B, Ultrasound image at the level of anterior superior iliac spine (ASIS). C, Ultrasound image at the level of AIIS. D, Ultrasound image aligning the AIIS and iliopubic eminence (IPE). The tendon of iliopsoas muscle is shown as hyperechoic structure at the deep end of the muscle. Femoral artery (FA) is on the medial side of the muscle. E, Ultrasound image aligning the femoral head (FH) and neck with superomedial acetabulum (SMA). F, Moving the US probe medially reveals the inferomedial acetabulum (IMA). Reproduced with permission from Philip Peng Educational Series.

The anatomic course of ON branches in this study was consistent with previously reported findings. Therefore, the radiographic teardrop as a landmark for obturator branch denervation appears anatomically sound. Furthermore, we found that the FN provides most innervation to the inferolateral, superolateral, and superomedial anterior hip capsule. High branches were found to pass close to the periosteum between the iliopubic eminence and AIIS, both of which can be seen with US (Fig. 6). These sites can be potential bony landmarks for RFD. Cadaveric injection studies would be useful to establish the accuracy of landmarks we have reported. In addition, the reliability and safety of these landmarks require further validation in clinical trials. For instance, the high branches of FN pass beneath the iliopsoas muscle, and the effect of applying lesion close to this muscle requires further examination. Because of the variability of the course and number of branches of the articular nerves, multiple/palisade lesions or a single large-size lesion delivered using an internally cooled electrode or a cannula with expandable tines is likely required to maximal capture of the articular branches. Further clinical study is required to examine the optimal type and configuration of the lesion.

A limitation of this study was the small sample size, which makes inference of findings to the general population more uncertain. However, the sample size is comparable with previous studies.[10,13,14,26] Also, postmortem changes and tissue trauma caused by dissection may have resulted in some distortion, albeit this is applicable to any cadaveric experiments. Notwithstanding these limitations, this is a novel cadaveric study that examined US landmarks for articular branches from the FN, ON, and AON. We also did not examine the innervation to the posterior capsule. However, virtually all the clinical studies discussed previously applied radiofrequency lesion to the anterior capsule. Posterior hip innervation needs further investigation to determine the frequency of nerve branches and their trajectories in relation to bony landmarks.

In conclusion, the FN and ON consistently provided innervation to the anterior hip capsule, whereas the AON was found to be a less consistent but still important contributor. For image-guided intervention of the anterior hip capsule, the key bony landmarks for articular branches are the teardrop (ON), the AIIS, and the iliopubic eminence (FN and AON).

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REFERENCES

1. Murphy LB, Helmick CG, Schwartz TA, et al. One in four people may develop symptomatic hip osteoarthritis in his or her lifetime. *Osteoarthritis Cartilage*. 2010;18:1372–1379.
2. Nelson AE, Allen KD, Golightly YM, Goode AP, Jordan JM. A systematic review of recommendations and guidelines for the management of osteoarthritis: the Chronic Osteoarthritis Management Initiative of the U.S. Bone and Joint Initiative. *Semin Arthritis Rheum*. 2014;43:701–712.
3. Dowsey MM, Gunn J, Choong PF. Selecting those to refer for joint replacement: who will likely benefit and who will not? *Best Pract Res Clin Rheumatol*. 2014;28:157–171.
4. Roberts SL, Burnham RS, Agur AM, Loh EY. A cadaveric study evaluating the feasibility of an ultrasound-guided diagnostic block and radiofrequency ablation technique for sacroiliac joint pain. *Reg Anesth Pain Med*. 2017;42:69–74.
5. Gupta G, Radhakrishna M, Etheridge P, Besemann M, Finlayson RJ. Radiofrequency denervation of the hip joint for pain management: case report and literature review. *US Army Med Dep J*. 2014:41–51.
6. Rüdinger N. *Die Gelenknerven Des Menschlichen Körpers: Mit Sechs Lithographischen Tafeln*. Verlag von Ferdinand Enke: Erlangen, Germany; 1857.
7. Chandelux A. Note sur les nerfs de l'articulation coxo-fèmorale. *Lyon Med*. 1886;51:551–554.
8. Duzèa R. Note sur les nerfs de l'articulation coxo-fèmorale. *Lyon Med*. 1886;52:35–38.
9. Billet H, Vincent G, Gaudefroy M. Les nerfs de la hanche. *CR Ass Anat*. 1947;34:42–47.
10. Gardner E. The innervation of the hip joint. *Anat Rec*. 1948;101:353–371.
11. Tavernier L, Pellanda C. Les nerfs articulaires de la hanche. *CR Ass Anat*. 1949;36:662–671.
12. Wertheimer LG. The sensory nerves of the hip joint. *J Bone Joint Surg Am*. 1952;34-A:477–487.
13. Birnbaum K, Prescher A, Hessler S, Heller KD. The sensory innervation of the hip joint—an anatomical study. *Surg Radiol Anat*. 1997;19:371–375.
14. Kampa RJ, Prasthofer A, Lawrence-Watt DJ, Pattison RM. The internervous safe zone for incision of the capsule of the hip. A cadaver study. *J Bone Joint Surg Br*. 2007;89:971–976.
15. Kawaguchi M, Hashizume K, Iwata T, Furuya H. Percutaneous radiofrequency lesioning of sensory branches of the obturator and femoral nerves for the treatment of hip joint pain. *Reg Anesth Pain Med*. 2001;26:576–581.
16. Malik A, Simopolous T, Elkersh M, Aner M, Bajwa ZH. Percutaneous radiofrequency lesioning of sensory branches of the obturator and femoral nerves for the treatment of non-operable hip pain. *Pain Physician*. 2003;6:499–502.
17. Shin KM, Nam SK, Yang MJ, Hong SJ, Lim SY, Choi YR. Radiofrequency lesion generation of the articular branches of the obturator and femoral nerve for hip joint pain - a case report. *Korean J Pain*. 2006;19:282–284.
18. Rivera F, Mariconda C, Annaratone G. Percutaneous radiofrequency denervation in patients with contraindications for total hip arthroplasty. *Orthopedics*. 2012;35:e302–e305.
19. Chaiban G, Paradis T, Atallah J. Use of ultrasound and fluoroscopy guidance in percutaneous radiofrequency lesioning of the sensory branches of the femoral and obturator nerves. *Pain Pract*. 2014;14:343–345.
20. Stone J, Matchett G. Combined ultrasound and fluoroscopic guidance for radiofrequency ablation of the obturator nerve for intractable cancer-associated hip pain. *Pain Physician*. 2014;17:E83–E87.
21. Cortiñas-Sáenz M, Salmerón-Velez G, Holgado-Macho IA. Joint and sensory branch block of the obturator and femoral nerves in a case of femoral head osteonecrosis and arthritis. *Rev Esp Cir Ortop Traumatol*. 2014;58:319–324.
22. Polacek P. The nerve supply of the hip joint and the knee joint and its features. *Anat Anz*. 1963;112:243–256.
23. Woodburne RT. The accessory obturator nerve and the innervation of the pectineus muscle. *Anat Rec*. 1960;136:367–369.
24. Sadovsky DM. Innervation of the capsule of the hip joint. *Vestn Khir*. 1933;31:100–103.
25. Geselevich AM. Types of innervation of the coxo-femoral articulation. *Trans Acad Mil Med Kiroff*. 1935;12:222–232.
26. Locher S, Burmeister H, Böhlen T, et al. Radiological anatomy of the obturator nerve and its articular branches: basis to develop a method of radiofrequency denervation for hip joint pain. *Pain Med*. 2008;9:291–298.
27. Kaplan EB. Resection of the obturator nerve for relief of pain in arthritis of the hip joint. *J Bone Joint Surg Am*. 1948;30A:213–216.

28. Kaiser RA. Obturator neurectomy for coxalgia; an anatomical study of the obturator and the accessory obturator nerves. *J Bone Joint Surg Am*. 1949;31:815–819.
29. Larochelle JL, Jobin P. Anatomical research on the innervation of the hip joint. *Anat Rec*. 1949;103:480–481.
30. Meschen I. *An Atlas of Anatomy Basic to Radiology*. Philadelphia, PA: WB Saunders Company; 1975.
31. Polacek P. Accessory femoral nerve, accessory obturator nerve, and their practical significance in hip joint surgery. *Acta Chir Orthop Traumatol Cech*. 1958;25:150–155.
32. Katritsis E, Anagnostopoulou S, Papadopoulos N. Anatomical observations on the accessory obturator nerve (based on 1000 specimens). *Anat Anz*. 1980;148:440–445.
33. Archana BJ, Nagaraj DN, Pradeep P, Lakshmi Prabha S. Anatomical variations of accessory obturator nerve: a cadaveric study with proposed clinical implications. *Int J Anat Res*. 2016;4: 2158–2161.
34. Okada K. New approach to the pain of the hip joint. *Pain Res*. 1993;8:125–135.
35. Akatov OV, Dreval ON. Percutaneous radiofrequency destruction of the obturator nerve for treatment of pain caused by coxarthrosis. *Stereotact Funct Neurosurg*. 1997;69:278–280.
36. Fukui S, Nosaka S. Successful relief of hip joint pain by percutaneous radiofrequency nerve thermocoagulation in a patient with contraindications for hip arthroplasty. *J Anesth*. 2001;15:173–175.
37. Wu H, Groner J. Pulsed radiofrequency treatment of articular branches of the obturator and femoral nerves for management of hip joint pain. *Pain Pract*. 2007;7:341–344.
38. Kasliwal P, Iyer V, Kasliwal S. Percutaneous radio frequency ablation for relief of pain in a patient of hip joint avascular necrosis. *Indian J Pain*. 2014;28:121.
39. Chye CL, Liang CL, Lu K, Chen YW, Liliang PC. Pulsed radiofrequency treatment of articular branches of femoral and obturator nerves for chronic hip pain. *Clin Interv Aging*. 2015;10:569–574.