Precision and Accuracy of Identification of Anatomical Surface Landmarks by 30 Expert Hip Arthroscopists

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Abstract

We conducted a study to assess 30 expert hip arthroscopists' ability to identify common surface landmarks used during hip arthroscopy. Thirty hip arthroscopists independently performed a blinded examination of an awake supine human volunteer for identification of 5 surface landmarks: anterior superior iliac spine (ASIS), tip of greater trochanter (GT), rectus origin (RO), superficial inguinal ring (SIR), and psoas tendon (PT). The examiners applied the labels *ASIS*, *GT*, *RO*, *SIR*, and *PT* to the landmarks. An ultrasonographer performed a musculoskeletal ultrasound examination and applied labels as well, and a photographer documented the examiner labels after obtaining overhead and lateral digital images with use of fixed camera mounts. Digital overlay composite images of arthroscopist and ultrasonographer labels were analyzed. Direction and distance of inaccurately placed labels were compared with known values for neurovascular structures previously reported for common arthroscopic portals.

Average distance from examiner-applied labels to ultrasonographer-applied labels was 31 mm for ASIS, 24 mm for GT, 26 mm for RO, 19 mm for SIR, and 35 mm for PT. Interobserver variability of examiner-applied labels was recorded as areas of 95% predictive interval: 65 cm^2 for ASIS, 16 cm^2 for GT, 221 cm^2 for RO, 38 cm^2 for SIR, and 29 cm^2 for PT. Examiner labels demonstrated the highest potential for injury because of anterior portal inaccuracy.

Expert hip arthroscopists varied in their ability to accurately and precisely identify common surface landmarks about the hip, using only manual palpation.

Anatomical surface landmarks about the hip and lower abdomen are often referenced when placing arthroscopic portals and office-based injections.[1-3] However, the degree to which these landmarks can be reproducibly identified using only visual inspection and palpation is unknown.

Safe access to the hip joint and surrounding structures during hip arthroscopy has been a focus in the orthopedic literature. Authors have described anatomical relationships of recommended portals to neurovascular and other anatomical structures.[4-6] This information has been reported in millimeters to centimeters of safety based on cadaver dissection studies.[4-7]

We conducted a study to assess expert hip arthroscopists' ability to identify, using only physical examination techniques, the anatomical structures used for reference when creating safe starting points for arthroscopic access. We hypothesized that variance in examiner-identified points would exceed safe distances from neurovascular structures for the most commonly used hip arthroscopic portals. The volunteer in this study provided written informed consent for print and electronic publication of this article.

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Take-Home Points

- Surface landmarks are routinely used for physical examination and surgical technique.
- Common surface landmarks used in establishing arthroscopic portals may be more difficult to accurately identify than previously thought.
- The greater trochanter was the surface landmark most precisely identified by expert examiners.
- Ultrasound examination identified landmarks varied from landmarks identified by palpation alone.

Methods

In this study, we prospectively assessed 30 expert hip arthroscopic surgeons' ability to identify commonly referenced surface landmarks on the adult male hip, using only inspection and manual palpation. Surgeons were defined as experts on the basis of their status as hip arthroscopy instructors at the Orthopaedic Learning Center (Rosemont, IL) for the Arthroscopy Association of North America and industry-sponsored hip arthroscopy education faculty (Arthrex). Five surface landmarks were selected for their relevance to publications on safe portal placement[2-5]: anterior superior iliac spine (ASIS), tip of greater trochanter (GT), rectus origin (RO), superficial inguinal ring (SIR), and psoas tendon (PT).

A healthy adult male volunteer was placed supine on an examination table and exposed distally from the mid abdomen, with the perineum and the genital area covered bikini-style. An expert musculoskeletal ultrasonographer used a handheld musculoskeletal ultrasound transducer (Sonosite) to identify the 5 landmarks. Short- and long-axis images of each structure were obtained. The examiner applied a round (1 cm in diameter), uniquely colored adhesive label to the skin over each location. A professional photographer using a Canon digital camera and fixed mounts made precise overhead and lateral images. The positional integrity and scale of these images were confirmed with referral to constant anatomical skin features. Images were archived for analysis (**Figure 1A**).

After the ultrasonographer's labels were removed, each of the 30 expert hip arthroscopic surgeons identified the structures by static physical examination (inspection and palpation only) and applied the same colored labels to the skin. The volunteer was not allowed to communicate about label placement with examiners but was encouraged to report any safety-related concerns. The photographer made the same digital photographs of the labels for each examiner as for the ultrasonographer (**Figure 1B**).

Imaging software (Adobe Photoshop Creative Suite 5.1) was used to superimpose the digital images of the examiner labels on those of the ultrasound-verified anatomical labels (**Figure 1C**). Measurements were then taken with digital calipers to determine average distance from ultrasound label; accuracy within 10 mm of verified ultrasound label; true average location (TAL) determined by 95% confidence interval (CI); and interobserver variability calculated by 95% prediction interval, which determined the probability of where an additional examiner data point would lie.

In the second arm of the study, examiner data were compared with previously published data on arthroscopic portal safety. Distances from surface landmarks have been used to create common arthroscopy portals.[2-4] The risk of neurovascular

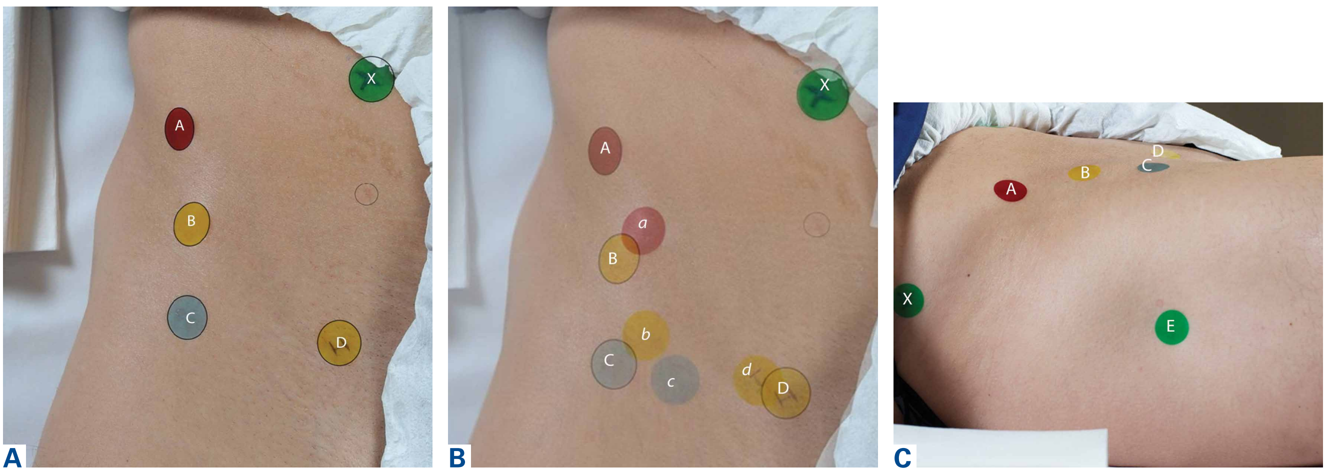

Figure 1. (A) Overhead digital photograph of supine volunteer after placement of ultrasonographer-applied labels for (letter A) anterior superior iliac spine, (letter B) rectus origin, (letter C) psoas tendon, and (letter D) superficial inguinal ring. (B) Overhead digital photograph of supine volunteer after placement of examiner marks (lowercase letters) with digital overlay of ultrasonographer labels (uppercase letters). (C) Lateral digital photograph with central point of labels identified (black dots for digital calipers measurement of distances) and with ultrasonographer-applied label for tip of greater trochanter (letter E).

injury resulting from errors in identifying surface landmarks for creating portals was calculated using the direction and distance of the examiner TAL and the nearest published direction and distance of the nearest neurovascular structure. Increased risk of injury resulting from inaccurate identification of surface landmarks was surmised if the TAL of the anatomical structure fell outside the safe distance and direction to the nearest neurovascular structure for each of 4 common portals: anterolateral portal (ALP), anterior portal (AP), posterolateral portal (PLP), and mid-anterior portal (MAP).

Results

Average absolute distance from examiner labels to ultrasonographer labels was 31 mm for ASIS, 24 mm for GT, 26 mm for RO, 19 mm for SIR, and 35 mm for PT (**Figure 2**).

Of the 30 surgeons, 1 (3%) came within 10 mm of the ultrasound for ASIS, 1 (3%) for GT, 4 (13%) for RO, 5 (17%) for SIR, and 1 (3%) for PT (**Table 1**).

TAL as determined by CI was 16 mm medial and 29 mm inferior for ASIS; 8 mm anterior and 22 mm superior for GT; 10 mm medial and 25 mm inferior for RO; 5 mm lateral and 5 mm inferior for SIR; and 28 mm medial and 16 mm inferior for PT (**Figure 3, Table 2**). Interobserver variability determined by prediction interval had a range of 18 mm medial to lateral × 36 mm proximal to distal for ASIS; 33 mm anterior to posterior × 48 mm superior to inferior for GT; 41 mm medial to distal × 54 mm proximal to distal for RO; 51 mm medial to lateral × 74 mm proximal to distal for SIR; and 49 mm medial to distal × 61 mm proximal to distal for PT.

Given the difference between examiner data (direction and distance from ultrasound labels) and published data (distance to significant neurovascular structures), inaccurate identification of surface landmarks has the potential to lead to AP and MAP damage (**Table 3**). The examiner GT and ASIS surface landmarks used for AP overlapped directly with the safe distances for the lateral femoral cutaneous nerve and the terminal branch of the lateral circumflex femoral artery.

Discussion

Others have investigated examiners' use of palpation, compared with ultrasound, to identify common shoulder and knee structures.[8-10] In a 2011 systematic review, Gilliland and colleagues[11] confirmed that accuracy was improved with use of ultrasound (vs palpation) for injections in the shoulder, hip, knee, wrist, and ankle. Given the scarcity of data in this setting, we conducted the present study to assess the precision and accuracy of expert arthroscopists in identifying common surface landmarks. We hypothesized that physical examination and ultrasound examination would differ significantly in precisely and accurately identifying these landmarks.

Working with a standard awake volunteer, our test group of examiners was consistently inaccurate when they accepted ultrasonographer-placed labels as the ideal. Precision within the group, however, trended toward close agreement; examiners consistently placed labels in the same direction

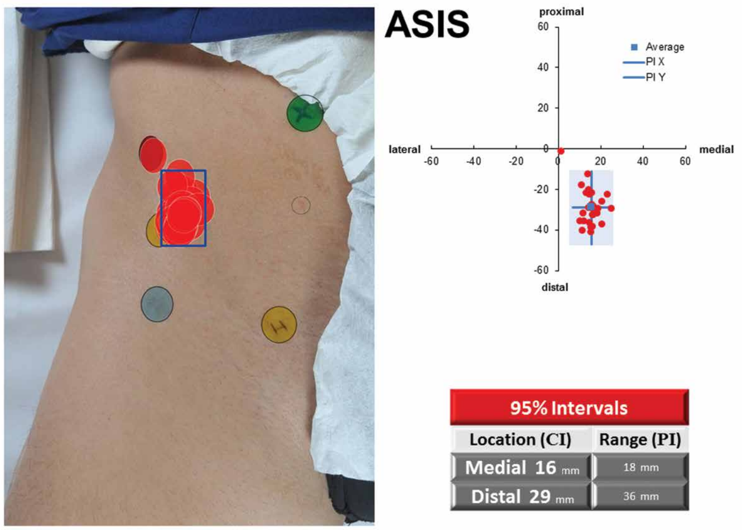

Figure 2. Sample of all-examiner overlay image for anterior superior iliac spine (ASIS). Blue rectangle represents area within which 95% of examiner labels were applied (precision of expert examiners). Cartesian plane centered on ultrasonographer-applied label allows for characterization of direction and magnitude of 95% confidence interval (CI) from ultrasonographer-established point (accuracy of expert examiners).
Abbreviation: PI, prediction interval.

Table 1. **Accuracy of Examiner-Applied Marks from Ultrasound-Validated Mark**

Tag	Anterior Superior Iliac Spine	Rectus Origin	Psoas Tendon	Superficial Inguinal Ring	Tip of Greater Trochanter
Distance from ultrasound	31 mm	26 mm	35 mm	19 mm	24 mm
Surgeons within 10 mm of ultrasound	3% (1/30)	13% (4/30)	3% (1/30)	17% (5/30)	3% (1/30)

Table 2. **Interobserver Variability of Examiner-Applied Mark**

Mark	Anterior Superior Iliac Spine	Tip of Greater Trochanter	Rectus Origin	Superficial Inguinal Ring	Psoas Tendon
Location from ultrasound (95% CI)	16 mm medial 29 mm inferior	8 mm anterior 22 mm superior	10 mm medial 25 mm inferior	5 mm lateral 5 mm inferior	28 mm medial 16 mm inferior
Range of examiner marks (95% PI)	18 mm × 36 mm	33 mm × 48 mm	41 mm × 54 mm	51 mm × 74 mm	49 mm × 61 mm

Abbreviation: CI, confidence interval; PI, prediction interval.

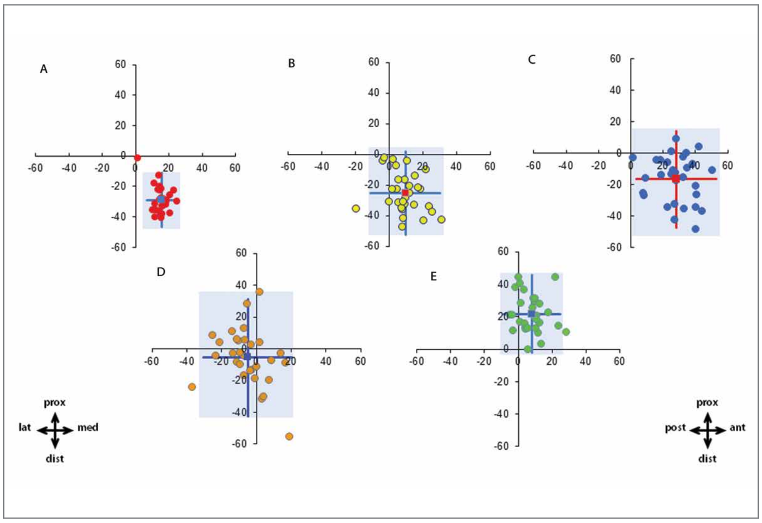

Figure 3. Cartesian planes applied to digital overlay image for each ultrasonographer-identified structure and direction, magnitude, and area of 95% of examiner labels for (A) anterior superior iliac spine, (B) rectus origin, (C) psoas tendon, (D) superficial inguinal ring, and (E) tip of greater trochanter.

and approximate magnitude away from ultrasonographer labels. This suggests that a discrepancy between the ultrasonographic surface structure definitions taught to ultrasonographers and the manually identified definitions taught to surgeons for arthroscopy (training bias) can generate differences in landmark identification.

Given reported low rates of complications in the creation of standard surface anatomy portals, more data is needed to correlate whether safe distance guidelines best apply to the points identified by hip experts or the points identified by ultrasonographers. In a 2013 systematic review, Harris and colleagues[8] found a 7.5% overall complication rate, with temporary neuropraxia 1 of the 2 most common complications. Whether adding ultrasound to physical examination for the creation of some or all portals will reduce the incidence of these problems is unknown. Regardless of the anatomical area referenced by experts for portal creation, the tight grouping of examiner marks in our study supports a consensus regarding the location of the landmarks studied.

In our study of the use of surface anatomical landmarks for the creation of portals, we analyzed 4 previously described locations: ALP, AP, PLP, and MAP. ALP, AP, and PLP directly reference at least 1 surface anatomical structure; AP references 2 anatomical structures (ASIS, GT); and MAP indirectly references ASIS and GT and directly references ALP and AP. In cadaveric and radiographic studies, 7 neurovascular structures have been described in proximity to ALP, AP, MAP, and PLP: superior gluteal nerve, sciatic nerve, femoral nerve, lateral femoral cutaneous nerve, lateral circumflex femoral artery, and medial circumflex femoral artery.[5,6] Our results showed that use of surface anatomy in AP and MAP creation most likely places structures at risk, given the overlap of examiner CIs and the previously published cadaveric[5,6] and radiographic[7] data.

Hua and colleagues[12] confirmed the feasibility of using ultrasound for the creation of hip arthroscopy portals. More data is needed to assess how the standard palpation-and-fluoroscopy method described by Byrd[3] compares with an ultrasound-guided technique in safety and cost. However, data from our study should not be used to justify a demand for ultrasound during arthroscopy portal establishment, as limitations do not permit such a recommendation.

With diagnostic injection remaining a mainstay of differential diagnosis and treatment about the hip,[1] the data presented here suggest a potential for ultrasound in enhancing outcomes. There is evidence supporting the role of image guidance in improving palpation accuracy in the area of the biceps tendon in the forearm.[10] Potentially, identification and treatment of specific extra-articular structures surrounding the hip could be made safer with more routine use of ultrasound.

Limitations

This study had several limitations. The surgeons were limited to palpation and static examination of

Table 3. **Comparison of Cadaveric Distances From Neurovascular Studies and Distances of Examiner Group From Ultrasound Tags**[a]

Central Compartment		Average Distance and Location of Neurovascular Structures From Portals						
Portal	Portal Location	Superior Gluteal Nerve	Sciatic Nerve	Femoral Nerve	Lateral Femoral Cutaneous Nerve	LCFA Ascending Branch	LCFA Terminal Branch	MCFA Deep Branch
ALP	10 mm superior, 10 mm anterior to tip of greater trochanter[5,6] Penetrates gluteus medius muscle before entering lateral aspect of capsule at its anterior margin[7]	44-64 mm superior[5,6]	40 mm posterior[5]	N/A	N/A	N/A	N/A	N/A
PLP	10 mm superior, 10 mm posterior to tip of greater trochanter[5,6] Penetrates both gluteus medius and minimus coursing superior and anterior to piriformis tendon before entering lateral capsule at its posterior margin[7]	N/A	22-29 mm posterior[4-6]	N/A	N/A	N/A	N/A	10 mm inferior[6]
AP	Intersection of line from ASIS and greater trochanter or 10 mm lateral to ASIS in line with ALP (40-60 mm inferior to ASIS)[5,6] Penetrates sartorius and rectus femoris before entering anterior capsule[6]	N/A	N/A	32-45 mm medial[5,6]	3-15 mm medial[4,5] 3 or more branches at this level[4,5]	31-37 mm inferior[5-7]	3-15 mm inferior[5-7]	N/A
MAP	About 20 mm distal at apex of equilateral triangle connecting AP and ALP[4-6] Penetrates tensor fascia lata before passing through gluteus minimus–rectus femoris interval[5]	N/A	N/A	52 mm medial[5]	25 mm medial[5]	19 mm inferior[5]	10 mm inferior[5]	N/A

Abbreviations: ALP, anterolateral portal; AP, anterior portal; ASIS, anterior superior iliac spine; CI, confidence interval; LCFA, lateral circumflex femoral artery; MAP, mid-anterior portal; MCFA, medial circumflex femoral artery; N/A, not applicable; PLP, posterolateral portal.

[a]Red table cells indicate portals and structures within 95% CI of examiners in their respective study; green cells indicate portals formed using landmarks studied, but examiner 95% CI did not exceed safe distances; yellow cells indicate areas in which 95% CI of examiner-applied tags partially exceed safe distances.

a body in its natural state. Hip arthroscopic portals typically are created under traction and after a standard perineal post is placed for hip arthroscopy. In addition, in an awake injection setting, the clinician may receive patient feedback in the form of limb movement or speech. To what degree palpation or ultrasound will be affected in these scenarios is unknown.

Another limitation is the lack of serial examination by each examiner—intrarater variability could not be gauged. In addition, with only 1 ultrasonographic examination performed, there is the potential that adding ultrasonographic examinations, or having an examiner perform serial physical examinations, could better define the precision of each component. Given the practical limitations of our volunteer's time and the schedules of 30 expert arthroscopists, we kept the chosen study design for its single setting.

Conclusion

Visual inspection and manual palpation are standard means of identifying common surface anatomical landmarks for the creation of arthroscopy portals and the placement of injections. Our study results showed variance in landmark identification between expert examiners and an ultrasonographer. The degree of variance exceeded established neurovascular safe zones, particularly for AP and MAP. This new evidence calls for further investigation into the best, safest means of performing hip arthroscopic techniques and injection-based interventions.

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