

An MRI Analysis of the Pelvis to Determine the Ideal Method for Ultrasound-Guided Bone Marrow Aspiration from the Iliac Crest

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Author Affiliation | **Disclosures**

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Take-Home Points

- There is an ideal angle and distance for optimization of a bone marrow harvest from the iliac crest.
- Ultrasound is a reliable technology that allows clinicians to accurately and consistently identify the PSIS and avoid neurovascular structures.
- This safe, reliable bone marrow aspiration technique can lower the risk of serious potential complications.
- The ideal angle does not differ significantly between sexes, but the safe distance a clinician can advance does.
- The PSIS should be considered a “table” as opposed to a protuberance.

The iliac crest is an effective site for harvesting bone marrow stem cells. It allows for easy access and is superficial in most individuals, allowing for a relatively quick and simple procedure. Use of mesenchymal stem cells (MSCs) for treatment of orthopedic injuries has grown recently. Whereas overall use has increased, review of the literature reveals very few techniques for iliac crest aspiration,¹ but these are not based on anatomic relationships or studies. Hernigou and colleagues^{2,3} attempted to quantitatively evaluate potential “sectors” allowing for safe aspiration using cadaver and computed tomographic reconstruction imaging. We used magnetic resonance imaging (MRI) to analyze aspiration parameters. Owing to the ilium’s anatomy, improper positioning or aspiration technique during aspiration can result in serious injury.^{2,4-6} We hypothesized that there is an ideal angle

and positioning for bone marrow aspiration from the posterior superior iliac spine (PSIS) that is safe, consistent, and reproducible. Although most aspiration techniques use landmark palpation, this is unreliable and inaccurate, especially when compared with ultrasound-guided injections⁷⁻¹⁶ and procedures.^{9,12,17-19} We describe our technique using ultrasound to visualize patient anatomy and accurately determine anatomic entry with the trocar.

Methods

MRI scans of 26 patients (13 males, 13 females) were reviewed to determine average angles and distances. Axial T2-weighted views of the lumbar spine were used in all analyses. The sacroiliac (SI) joint angle was defined as the angle formed between the vector through the midline of the pelvis and the vector that is parallel to the SI joint. The approach angle was defined as the angle formed between the vector of the most medial aspect of the PSIS through the ilium to the anterior wall and the vector through the midline of the pelvis (**Figure 1**). The distance, in centimeters, of the PSIS to the anterior ilium wall was measured to determine the maximum distance the trocar can advance without puncturing the anterior ilium wall. The perpendicular distance from the PSIS table to the anterior aspect of the ilium was measured to determine the average depth the trocar could advance if the clinician entered it perpendicular to the patient's coronal plane (**Figure 2**). The PSIS table width was defined as the width, in centimeters, of the PSIS posteriorly. The minimum width, in centimeters, of the ilium was measured at the thinnest region of the ilium to determine the degree of variation if the trocar were entered too far laterally and advanced to the anterior ilium wall (**Figure 3**). Means and standard deviations were calculated by sex and as a total. Student's *t* test was used to determine statistical significance ($P < .05$).

Results

The results are reported in the **Table**. For the 13 males, the mean SI joint angle was $31.22^\circ \pm 7.18^\circ$ (range, 20.20° to 48.50°). The mean approach angle was $24.41^\circ \pm 4.11^\circ$ (range, 19.50° to 31.00°). The mean PSIS table width was $1.20 \text{ cm} \pm 0.26 \text{ cm}$ (range, 0.84 cm to 1.70 cm). The mean distance from the PSIS to the anterior ilium wall was $7.53 \text{ cm} \pm 0.75 \text{ cm}$ (range, 6.43 cm to 8.80 cm). The mean perpendicular distance from the PSIS table to the anterior ilium was $3.40 \text{ cm} \pm 0.56 \text{ cm}$ (range, 2.34 cm to 4.16 cm). The mean minimum width of the ilium to the SI joint was $1.16 \text{ cm} \pm 0.26 \text{ cm}$ (range, 0.65 cm to 1.56 cm).

For the 13 females, the mean SI joint angle was $29.54^\circ \pm 10.84^\circ$ (range, 17.20° to 48.20°). The mean approach angle was $23.56^\circ \pm 6.88^\circ$ (range, 14.80° to 38.50°). The mean PSIS table width was $0.96 \text{ cm} \pm 0.21 \text{ cm}$ (range, 0.61 cm to 1.54 cm). The mean distance from the PSIS to the anterior ilium wall was $6.74 \text{ cm} \pm 0.85 \text{ cm}$ (range, 5.33 cm to 8.32 cm). The mean perpendicular distance from the PSIS table to the anterior ilium was $3.00 \text{ cm} \pm 0.48 \text{ cm}$ (range, 2.23 cm to 3.76 cm). The mean minimum width of the ilium to the SI joint was $1.04 \text{ cm} \pm 0.25 \text{ cm}$ (range, 0.71 cm to 1.42 cm).

For the 26 total patients, the mean SI joint angle was $30.38^\circ \pm 9.05^\circ$ (range, 17.20° to 48.50°). The mean approach angle was $23.98^\circ \pm 5.57^\circ$ (range, 14.80° to 38.50°). The mean PSIS table width was $1.08 \text{ cm} \pm 0.26 \text{ cm}$ (range, 0.61 cm to 1.70 cm). The mean distance from the PSIS to the anterior ilium wall was $7.14 \text{ cm} \pm 0.88 \text{ cm}$ (range, 5.33 cm to 8.80 cm). The mean perpendicular distance from the PSIS table to the anterior ilium was $3.20 \text{ cm} \pm 0.55 \text{ cm}$ (range, 2.23 cm to 4.16 cm). The mean minimum width of the ilium to the SI joint was $1.10 \text{ cm} \pm 0.26 \text{ cm}$ (range, 0.65 cm to 1.56 cm).

There was a statistically significant difference between the male and female groups for the maximum distance the trocar can be advanced from the PSIS to the anterior ilium wall ($P < .02$), and a statistically significant difference

for the PSIS table width ($P < .02$). There were no significant differences between the male and female groups for the approach angle, the SI joint angle, the perpendicular distance from the PSIS to the anterior ilium, and the minimum width of the ilium to the SI joint.

Technique: Iliac Crest (PSIS) Bone Marrow Aspiration

The patient is brought to the procedure room and placed in a prone position. The donor site is prepared and draped in the usual sterile manner. Ultrasound is used to identify the median sacral crest in a short-axis view. The probe is then moved laterally to identify the PSIS (**Figures 4A, 4B**). The probe can be moved superiorly and inferiorly to determine the most prominent and central portion of the PSIS. The SI joint and ilium can also be visualized if needed.

The crosshairs on the ultrasound probe are used to mark the center lines of each plane. The central point marks the location of the PSIS. Alternatively, an in-plane technique can be used to place a spinal needle on the exact entry point on the PSIS. Once the PSIS and entry point are identified, the site is blocked with 10 mL of 0.5% ropivacaine.

Prior to introduction of the trocar, all instrumentation is primed with heparin and syringes are prepped with anticoagulant citrate dextrose solution, solution A. A stab incision is made at the site. The trocar is placed at the entry point, which should be centered in a superior-inferior plane and at the most medial point of the PSIS. Starting with the trocar vertical, the trocar is angled laterally 24° by dropping the hand medially toward the midline. No angulation cephalad or caudad is necessary, but cephalad must be avoided so as not to skive superiorly. This angle, which is recommended for both males and females, allows for the greatest distance the trocar can travel in bone before hitting the anterior ilium wall. A standard deviation of 5.57° is present, which should be considered. Steady pressure should be applied with a slight twisting motion on the PSIS. If advancement of the trocar is too difficult, a mallet or drill can be used to assist in penetration.

With the trocar advanced into the bone 1 cm, the trocar needle is removed while the cannula remains in place. The syringe is attached to the top of the cannula. The syringe plunger is pulled back to aspirate 20 mL of bone marrow. The cannula and syringe assembly are advanced 2 cm farther into the bone to allow for aspiration of a new location within the bone marrow cavity, and 20 mL of bone marrow are again aspirated. This is done a final time, advancing the trocar another 2 cm and aspirating a final 20 mL of bone marrow. The entire process should yield roughly 60 mL of bone marrow from one side. If desired, the same process can be repeated for the contralateral PSIS to yield a total of 120 mL of bone marrow from the 2 sites.

Based on our data, the average distance to the anterior ilium wall was 7 cm, but the shortest distance noted in this study was 5 cm. On the basis of the data presented, this technique allows for safe advancement based on even the shortest measured distance, without fear of puncturing the anterior ilium wall. Perforation could damage the femoral nerve and the internal or external iliac artery or vein that lie anterior to the ilium.

Discussion

We hypothesized that there would be an optimal angle of entry and maximal safe distance the trocar could advance through the ilium when aspirating. Because male and female pelvic anatomy differs, we also hypothesized that there would be differences in distance and size measurements for males and females. Our results supported our hypothesis that there is an ideal approach angle. The results also showed that the maximum distance the trocar can advance and the width of the PSIS table differ significantly between males and females.

Although pelvic anatomy differs between males and females, there should be an ideal entry angle that would allow maximum advancement into the ilium without perforating the anterior wall, which we defined as the approach angle. In our comparison of 26 MRI scans, we found that the approach angle did not differ significantly between the 2 groups (13 males, 13 females). This allows clinicians to enter the PSIS at roughly 24° medial to the parasagittal line, maximizing the space before puncturing into the anterior pelvis in either males or females.

If clinicians were to enter perpendicular to the patient's PSIS, they would, on average, be able to advance only 3.20 cm before encountering the SI joint. When entering at 24° as we recommend, the average distance increases to 7.14 cm. Although the angle did not differ significantly, there was a significant difference between males and females in the length from the PSIS to the anterior wall, with males having 7.53 cm distance and females 6.74 cm. This is an important measurement because if the anterior ilium wall is punctured, the femoral nerve and the common, internal and external iliac arteries and veins could be damaged, resulting in retroperitoneal hemorrhage.

A fatality in 2001 in the United Kingdom led to a national audit of bone marrow aspiration and biopsies.^{4,6} Although these procedures were done primarily for patients with cancer, hemorrhagic events were the most frequent and serious events. This audit led to the identification of many risk factors. Bain^{4,6} conducted reviews of bone marrow aspirations and biopsies in the United Kingdom from 2002 to 2004. Of a total of 53,088 procedures conducted during that time frame, 48 (0.09%) adverse events occurred, with 29 (0.05%) being hemorrhagic events. Although infrequent, hemorrhagic adverse events represent significant morbidity. Reviews such as those conducted by Bain^{4,6} highlight the importance of a study that helps determine the optimal parameters for aspiration to ensure safety and reliability.

Hernigou and colleagues^{2,3} conducted studies analyzing different "sectors" in an attempt to develop a safe aspiration technique. They found that obese patients were at higher risk, and some sites of aspiration (sectors 1, 4, 5) had increased risk for perforation and damage to surrounding structures. Their sector 6, which incorporated the entirety of the PSIS table, was considered the safest, most reliable site for trocar introduction.^{2,3} Hernigou and colleagues,² in comparing the bone mass of the sectors, also noted that sector 6 has the greatest bone thickness close to the entry point, making it the most favorable site. The PSIS is not just a point; it is more a "table." The PSIS can be palpated posteriorly, but this is inaccurate and unreliable, particularly in larger individuals. The PSIS table can be identified on ultrasound before introducing the trocar, which is a more reliable method of landmark identification than palpation guidance, just as in ultrasound-guided injections⁷⁻¹⁶ and procedures.^{9,12,17-19}

If the PSIS is not accurately identified, penetration laterally will result in entering the ilium wing, where it is quite narrow. We found the distance between the posterior ilium wall and the SI joint to be only 1.10 cm wide (Figure 3); we defined this area as the narrow corridor. Superior and lateral entry could damage the superior cluneal nerves coming over the iliac crest, which are located 6 cm lateral to the SI joint. Inferior and lateral entry 6 cm below the PSIS could reach the greater sciatic foramen, damaging the sacral plexus and superior gluteal artery and vein. If the entry slips above the PSIS over the pelvis, the trocar could enter the retroperitoneal space and damage the femoral nerve and common iliac artery and vein, leading to a retroperitoneal hemorrhage.^{4,6,20}

MSCs are found as perivascular cells and lie in the cortices of bones.²¹ Following the approach angle and directed line from the PSIS to the anterior ilium wall described in this study (Figures 1 and 2), the trocar would pass through the narrow corridor as it advances farther into the ilium. The minimum width of this corridor was measured in this study and, on average, was 1.10 cm wide from cortex to cortex (Figure 3). As the bone marrow is aspirated from this narrow corridor, the clinician is gathering MSCs from both the lateral and medial cortices of the ilium. By aspirating from a greater surface area of the cortices, it is believed that this will increase the total collection of MSCs.

Conclusion

Although there are reports in the literature that describe techniques for bone marrow aspiration from the iliac crest, the techniques are very general and vague regarding the ideal angles and methods. Studies have attempted to quantify the safest entry sites for aspiration but have not detailed ideal parameters for collection. Blind aspiration from the iliac crest can have serious implications if adverse events occur, and thus there is a need for a safe and reliable method of aspiration from the iliac crest. Ultrasound guidance to identify anatomy, as opposed to palpation guidance, ensures anatomic placement of the trocar while minimizing the risk of aspiration. Based on the measurements gathered in this study, an optimal angle of entry and safe distance of penetration have been identified. Using our data and relevant literature, we developed a technique for a safe, consistent, and reliable method of bone marrow aspiration out of the iliac crest.

Key Info

Figures/Tables

Figures / Tables:

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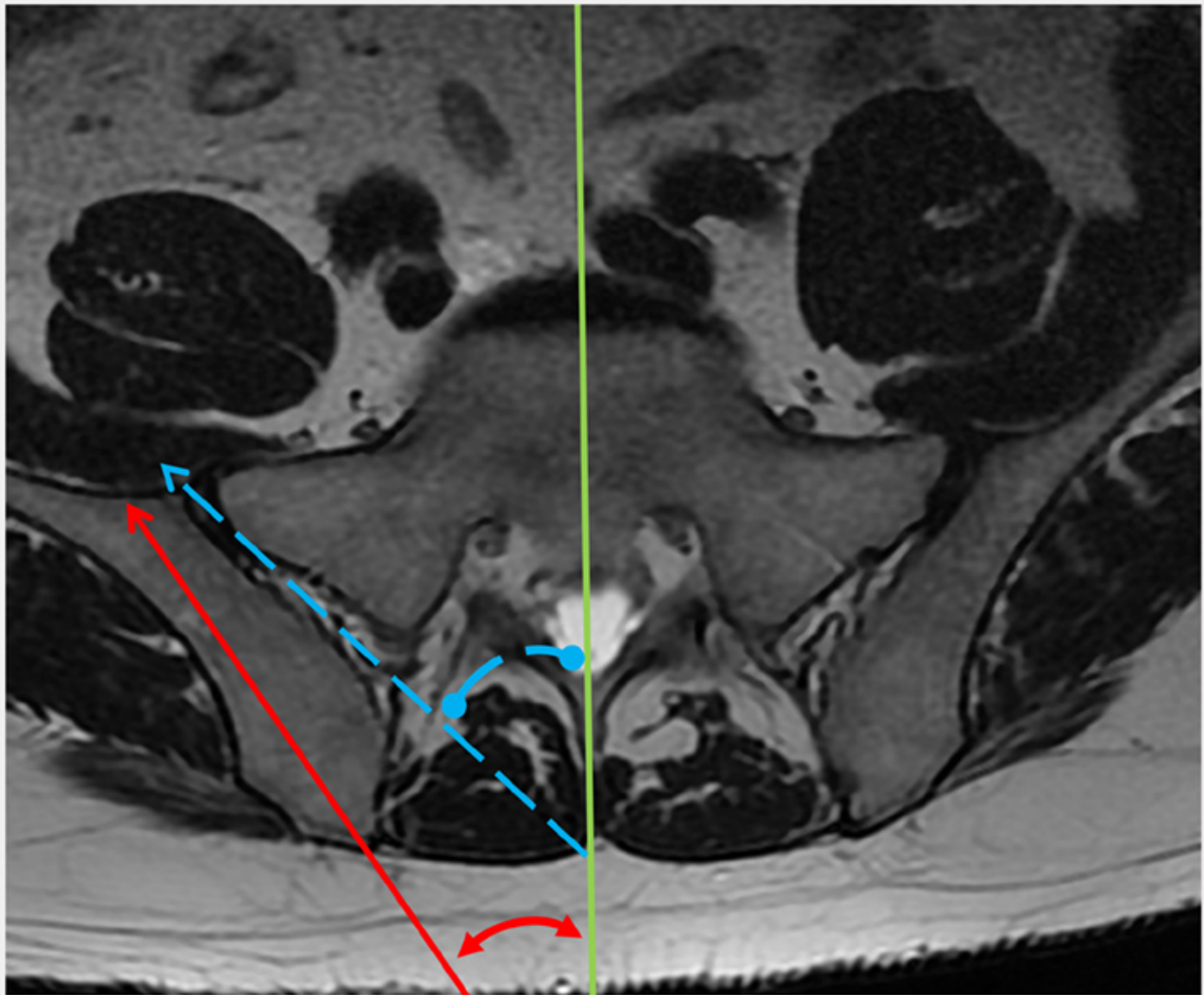


Figure 1. Lumbar spine T2-weighted magnetic resonance imaging axillary view of the sacrum, sacroiliac (SI) joint, and ilium. The green line represents the midline of the patient. The angle formed between the red arrow vector and the midline represents the approach angle. The approach angle is defined as the angle formed between the vector of the most medial aspect of the posterior superior iliac spine through the ilium to the anterior wall and the vector through the midline of the pelvis. The blue dashed vector and the midline form the SI joint angle, defined as the angle formed between the 2 vectors.

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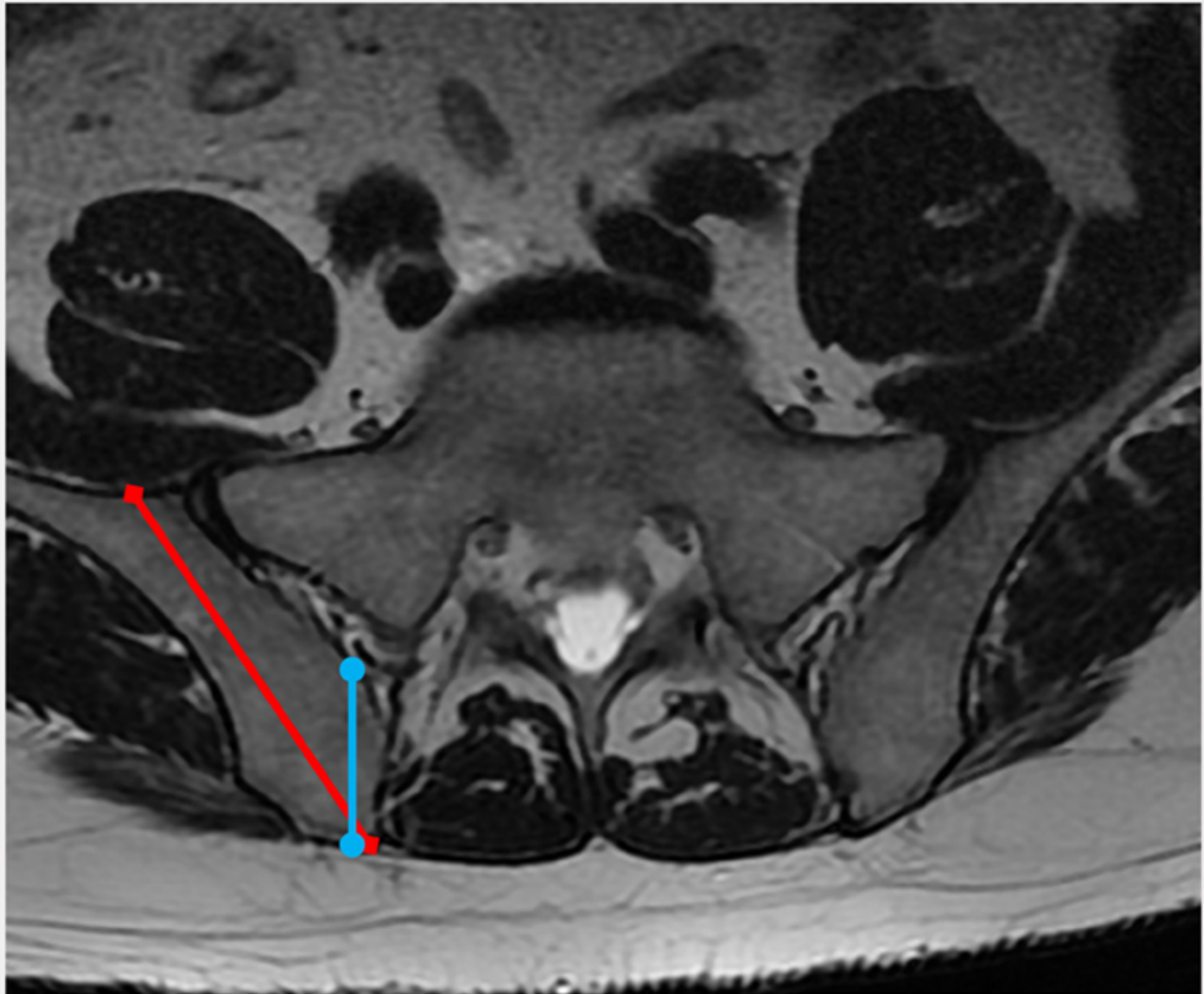


Figure 2. Lumbar spine T2-weighted magnetic resonance imaging axillary view of the sacrum, sacroiliac joint, and ilium. The red vector with diamond ends represents the maximum length from the posterior superior iliac spine (PSIS) to the anterior ilium wall. This measurement helps determine the maximum distance a trocar can be advanced during aspiration without perforating the anterior ilium wall. The blue vector with circular ends represents the maximum distance from the PSIS table to the anterior aspect of the ilium if the clinician entered the PSIS directly perpendicular to the coronal plane of the patient.

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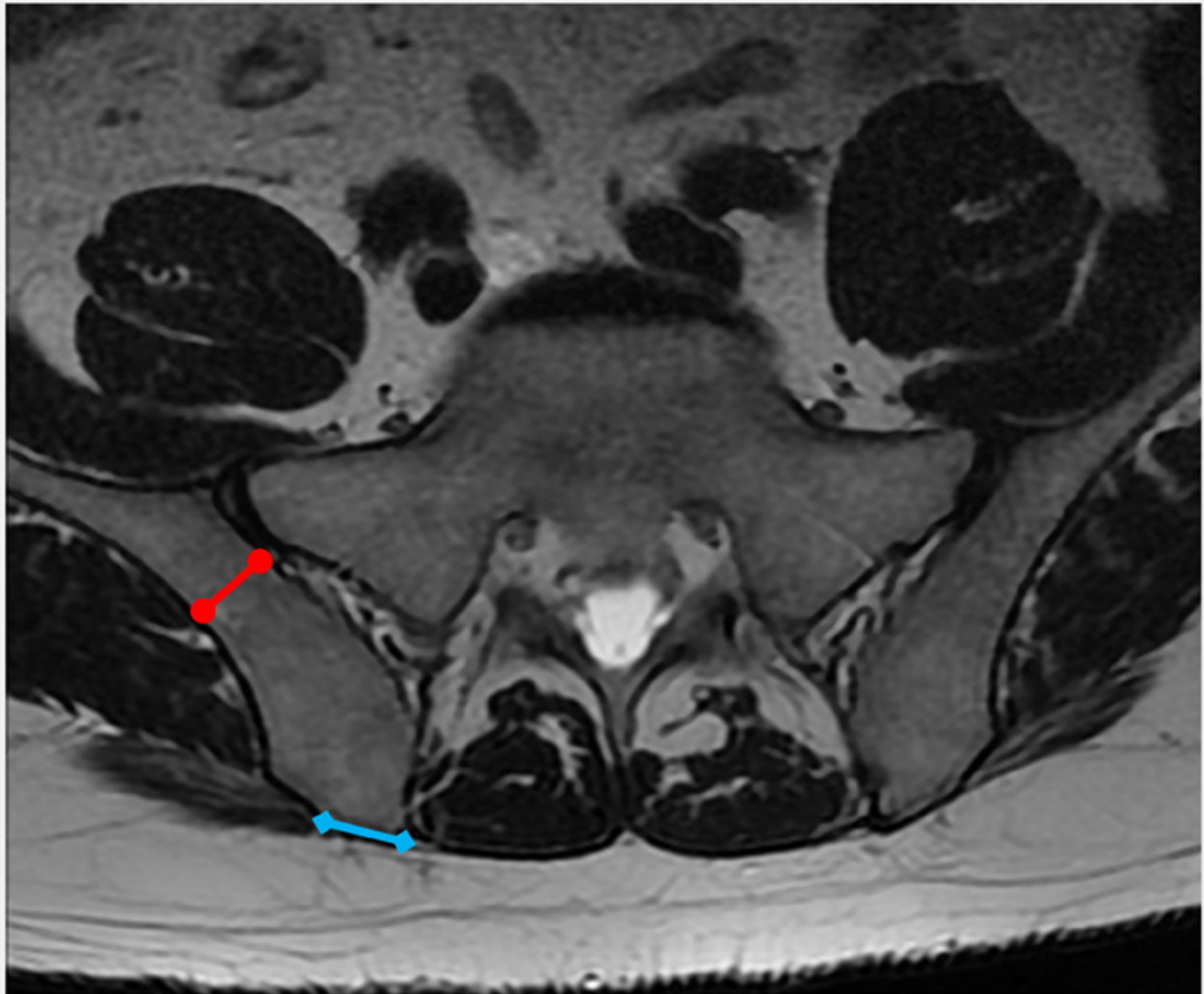


Figure 3. Lumbar spine T2-weighted magnetic resonance imaging axillary view of the sacrum, sacroiliac joint, and ilium. The blue vector with diamond ends represents the posterior superior iliac spine table width. The red vector with circular ends represents the minimum width of the ilium. This was measured at the thinnest region of the ilium to determine the degree of variation if the trocar were advanced to anterior ilium wall.

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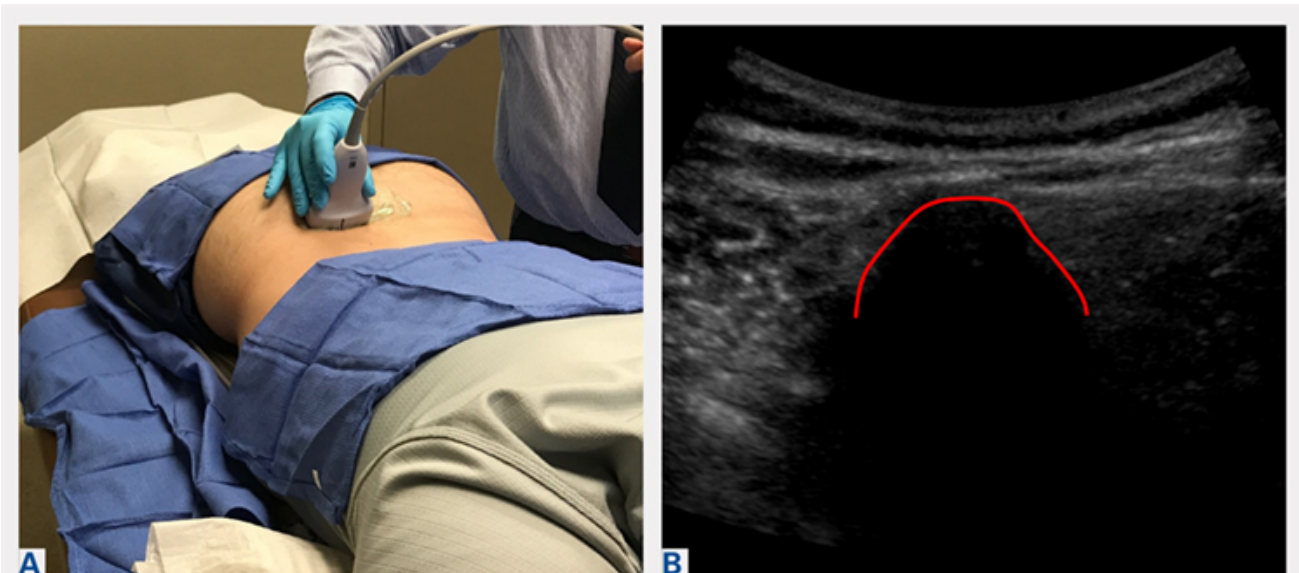


Figure 4. (A) External view of a clinician using ultrasound to identify the posterior superior iliac spine (PSIS). (B) Correlative short-axis view of the PSIS on ultrasound. The red curve outlines the PSIS.

Table. Measurements of Patients Taken on Axial T2-Weighted Views of Lumbosacral MRI Scans^a

Patient	SI Joint Angle (°)	Approach Angle (°)	PSIS Table Width (cm)	PSIS to Anterior Ilium Wall (cm)	Perpendicular Distance PSIS to Anterior Joint (cm)	Post Ilium Wall to SI Joint Width (cm)
Males						
1	28.80	19.50	1.24	8.80	4.16	1.52
2	31.80	27.60	1.70	7.89	3.49	1.02
3	33.70	27.70	1.12	8.14	3.15	1.28
4	23.70	26.40	0.95	6.66	3.22	0.65
5	35.90	28.40	0.84	7.60	2.57	0.95
6	33.80	29.30	1.20	7.73	2.34	0.90
7	30.30	21.20	1.36	8.44	3.95	1.18
8	34.50	20.40	1.53	7.08	3.98	1.56
9	28.70	24.00	1.34	8.19	3.51	1.31
10	22.40	20.10	1.37	7.30	3.87	1.28
11	33.60	20.80	0.88	6.43	3.26	0.94
12	48.50	31.00	1.15	6.69	2.97	1.38
13	20.20	20.90	0.94	6.95	3.79	1.05
Averages	31.22	24.41	1.20	7.53	3.40	1.16
Standard Deviation	7.18	4.11	0.26	0.75	0.56	0.26
Females						

14	22.80	23.20	1.54	7.21	3.45	1.39
15	33.30	21.40	1.09	7.26	3.57	0.98
16	19.70	15.60	0.78	8.32	3.76	0.86
17	17.50	15.60	0.61	7.57	3.37	1.03
18	48.20	26.60	0.94	6.62	3.16	0.71
19	38.20	28.30	0.90	6.32	2.23	0.91
20	44.50	31.70	0.99	6.19	3.06	0.76
21	24.10	18.00	0.92	6.99	3.23	0.71
22	17.20	14.80	0.81	6.00	2.81	1.13
23	42.00	38.50	1.00	5.33	2.47	1.42
24	32.00	25.50	0.98	6.01	2.79	1.21
25	24.70	24.80	0.87	6.09	2.79	1.02
26	19.80	22.30	1.04	7.71	2.37	1.36
Averages	29.54	23.56	0.96	6.74	3.00	1.04
Standard Deviation	10.84	6.88	0.21	0.85	0.48	0.25
All patients Averages	30.38	23.98	1.08	7.14	3.20	1.10
Standard Deviation	9.05	5.57	0.26	0.88	0.55	0.26

^aStatistical significance is denoted as $P < .02$.

Abbreviations: MRI, magnetic resonance imaging; PSIS, posterior iliac spine; SI, sacroiliac.

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