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FULL PAPER

A new path for ultrasound-guided intra-articular hip puncture in patients without hip joint effusion

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Objective: This study aimed to establish a new path for ultrasound (US)-guided intra-articular hip joint puncture in patients without hip joint effusion.
Methods: In total, 113 consecutive patients were enrolled from August to October 2021. Moreover, 125 hip joint punctures were performed in 113 consecutive patients. All patients were randomly divided into two groups: the new-puncture path (the puncture of the needle along the long axis of the femoral neck from the proximal to the distal side) and classic-puncture path (the puncture of the needle along the long axis of the femoral neck from the distal to the proximal side) groups. Four outcomes, including single-puncture technical success, visual analog scale (VAS) score during puncture, puncture depth, and puncture time, were compared between the groups. Complications were compared between the groups. Correlation analysis was used to evaluate the factors related to the four outcomes.
Results: No significant differences in single-puncture technical success, VAS score during puncture, and complications were observed between the two groups. The puncture depth was shorter in the new-puncture path group than in the classic-puncture path group. The puncture time was shorter in the new-puncture path group than in the classic-puncture path group. The puncture depth was correlated with the puncture path, body mass index, and sex. The puncture time was correlated with the puncture path.
Conclusion: The new-puncture path can be used as a new US-guided hip puncture path for patients without hip joint effusion, with the advantages of shorter puncture path and puncture time.
Advances in knowledge: The current study introduces a new-puncture path that can be added with the classic-puncture path.

INTRODUCTION

Hip pain is common in adults of all ages and activity levels,[1] and is a manifestation of a broad range of intra- and extra-articular pathologies.[2] A definitive diagnosis requires a combination of medical history, physical examination, and imaging (X-ray, computed tomography [CT], ultrasonography, or magnetic resonance imaging [MRI]).[1] Intra-articular hip joint puncture can aid in the diagnosis of an intra-articular cause of pain and can even be involved in the treatment of several hip disorders, including osteoarthritis, femoroacetabular impingement syndrome (FAI), and rheumatoid arthritis (RA).[1–10]

Intra-articular hip joint puncture was first performed using only body markers.[11] However, the deep location of the hip joint and the complexity of the adjacent femoral neurovascular bundle cause a low success rate and a high rate of complications, leading to its gradual abandonment.[2,3] Fluoroscopic examination and CT have been used to guide intra-articular hip joint puncture.[3] However, they cannot visualize the femoral neurovascular bundle and display intra-articular effusion in real time. Meanwhile, expensive and inconvenient equipment, radiation exposure, and contrast agent reactions' risk of the patients limit their application.[3,12–14] US-guided hip joint puncture is a convenient, less costly, radiation-free, and real-time image-guiding technique.[2,15,16]It can identify the femoral neurovascular bundle, show effusion accumulation in and around the joint, and visualize the needle path in real time during puncture.[3,12,17] Thus, US is the preferred method for intra-articular hip joint punctures.

The target of the US-guided hip joint puncture is the anterior synovial recess below the joint capsule at the femoral

head and neck junction.[2,3,12,15,18–20] Studies have shown various paths for US-guided intra-articular hip joint puncture, including the posterior, lateral, and anterior-inferior paths.[9,11,21,22] The posterior path is affected by muscles and is close to the sciatic nerve, inferior gluteal arteries, and veins, with a risk of neurovascular injury.[9] The lateral path is susceptible to variations in the femoral blood vessels and nerves.[21–23] The anterior-inferior path helps prevent damage to the femoral neurovascular bundle and hip articular cartilage. Although it is well recognized and commonly used in clinical practice (thus it is also called the classic-puncture path),[3,11] this path carries the risk of rotary lateral femoral artery injury and femoral head ischemia.[21,24]

Therefore, our study aimed to establish a novel, practical, and clinically useful path for US-guided intra-articular hip joint puncture.

METHODS

Patients

In total, 113 consecutive patients (50 males and 63 females; average age, 39.6 years ± 11.5, range from 17 to 69 years) who underwent US-guided hip puncture in our department from August 2021 to October 2021 were enrolled in this study. This study was approved by the medical ethics committee of our hospital (ethics number: S2021-091-01). All patients (see Appendix A for sample size calculation) provided written informed consent prior to the puncture.

The inclusion criteria were as follows: (i) the presence of hip disorders (including osteoarthritis, FAI, RA, labral injury, hip tuberculosis, or ankylosing spondylitis) who required drug injection (including local anesthetics, platelet-rich plasma, and glucocorticoids)[25] and (ii) the absence of hip joint effusion detected in the anterior synovial recess of the hip joint by the US.[25,26]

The exclusion criteria were as follows: (i) US-visible effusion accumulation in the anterior synovial recess of the hip joint, (ii) severe coagulation disorder, (iii) pregnancy, and (vi) hip infection or history of open hip surgery.[3,6,12,27]

All patients were randomly divided into two groups according to the random-number grouping method: the new-puncture path (the anterior–superior path) and classic-puncture path (the anterior–inferior path) groups. This grouping was known only to the sonographer, but not to the patients.

Individual information and clinical data, including sex, age, height, weight, body mass index (BMI), arthroscopic surgery, puncture side (left or right), and injected medication of all patients were recorded before puncture. Pain during injection was recorded using a visual analog scale (VAS).[28]

Ultrasound examination

An Esaote MyLab Twice eHD US instrument (Esaote S.p.A., Geneva, Italy) with a CA541 probe (convex array probe, [center frequency, 4.5 MHz; frequency range,1–8 MHz]) was used in our study. Hip puncture was performed by a sonographer with >10 years of experience using the intraplane puncture technique.[18,22] All patients were placed in the supine position with the hip in a slight external rotation and abduction of the lower limbs.[29,30]

The US probe was placed along the long axis of the femoral neck at the head and neck junction. B-mode US was used to visualize the anterior margins of the acetabulum, femoral head, femoral neck, and anterior recess.[29] Real-time ultrasonic detection can avoid the damage of femoral nerve vascular plexus, especially the application of color Doppler was used to determine the peripheral blood vessels and avoid injury. The anterior–superior path refers to the puncture of the needle along the long axis of the femoral neck from the proximal to the distal side (Figure 1a–1c). The anterior–inferior path refers to the puncture of the needle along the long axis of the femoral neck from the distal to the proximal side (Figure 2a–2c).

The anterior hip and inguinal areas of the patients were routinely disinfected and covered. Subsequently, a 21-gauge PTC needle (Hakko Company, Chikuma-Shi, Nagano, Japan, 200 mm length, outer diameter: 0.8 mm, inner diameter: 0.5 mm) was used for puncture under US guidance either in the anterior–superior or

Figure 1. Operation diagram and US image of the new puncture path (anterior–superior path). (**a**). Operation diagram of the new puncture path: Supine position with the thighs in slight external rotation and abduction; the probe was placed along the long axis of the femoral neck. F: foot side. H: head side. (**b**). Anatomical diagram of the new puncture path operation: The direction of needle entry was from the proximal end to the distal end along the long axis of the femoral head. (**c**). Ultrasonic image of the new puncture path: The red circle represented the anterior synovial recess of the target. The red arrow represented the needle pathway. FH: femoral head; FN: femoral neck.

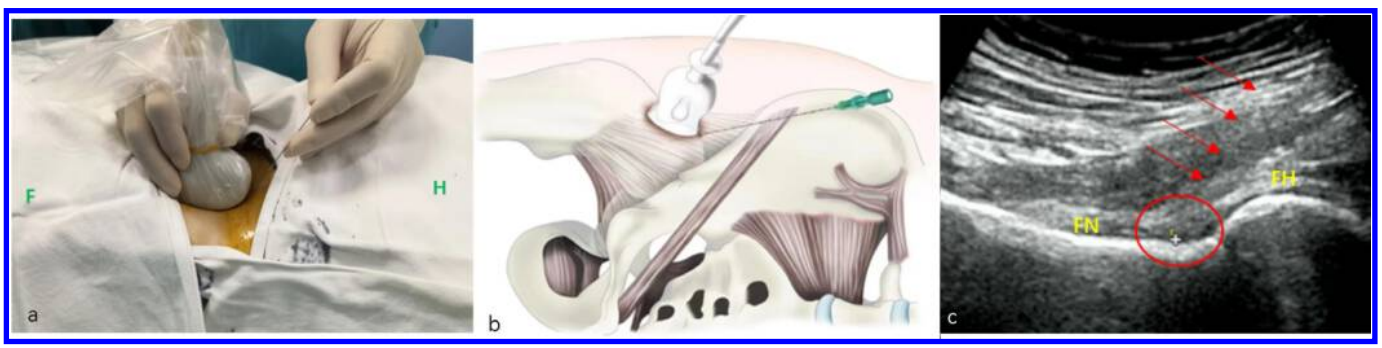
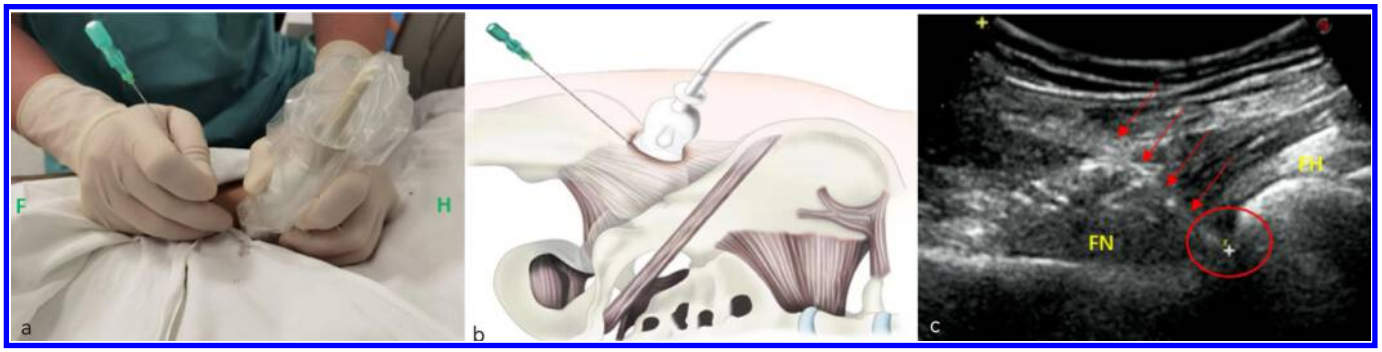


Figure 2. Operation diagram and ultrasound image of the classic puncture path (anterior-inferior path). (**a**). Operation diagram of the classic puncture path: Supine position with the thighs in slight external rotation and abduction; the probe was placed along the long axis of the femoral neck. F: foot side. H: head side. (**b**). Anatomical diagram of the classic puncture path operation: The direction of needle entry was from the distal end to the proximal end along the long axis of the femoral head. (**c**). Ultrasonic image of the classic puncture path: The red circle represented the anterior synovial recess of the target. The red arrow represented the needle pathway. FH: femoral head; FN: femoral neck.



anterior–inferior path into the anterior recess of the hip joint, and 1–2 ml of normal saline was injected.

When there was no resistance during the injection, the liquid was injected. If there was an evident resistance, the needle was adjusted, and even re-punctured,[31] until the needle tip was inserted into the hip joint cavity. Injection without resistance and US showed that expansion of the hip joint cavity was used as the standard for correct hip joint injection.

Measurement parameters

During the puncture, the puncture depth (the distance between the puncture point on the skin surface and the tip of the needle that reached the anterior synovial recess) was measured. The puncture time (the period of time from the needle entering the skin to the needle leaving the skin) was measured. The number of punctures and needle adjustments were recorded. We defined single-puncture technical success as one puncture and zero adjustment. All other procedures (including multiple punctures or adjustments) were considered unsuccessful.

A VAS was used during the puncture period.[28,32] A 100-mm VAS was employed, and the patients rated pain intensity from no pain (0 mm) to unbearable pain (100 mm). Complications (including pain, bleeding, and infection) were recorded within 1 week of follow-up after puncture.

Statistical analyses

SPSS version 26.0 statistical software (SPSS Inc., Chicago, Illinois, USA) was used for the statistical analyses. Mean ± standard deviation was used to describe the normally distributed variable. Median (M) and interquartile range (IQR) were used to describe non-normally distributed data. Qualitative variables were described as numbers (ratios). Fisher's chi-squared test was used to analyze qualitative variables. Normally distributed variables were analyzed using the T-test. Non-normally distributed variables were analyzed using the Mann–Whitney U-test. Correlation analyses (including Pearson correlation analysis, Fisher's Chi-squared test, and point two-column correlation analyses) were used to analyze the correlation between other clinical data characteristics and the four outcomes. A p value < 0.05 was considered statistically significant.

RESULTS

Patient demographics

US-guided intra-articular hip joint puncture was performed in 113 consecutive patients. Six patients underwent two punctures, and three underwent three punctures. No significant differences in clinical information (Including age, sex, BMI, arthroscopic surgery, and types of injection drugs)[33,34] were found between the two groups (Table 1).

Puncture depth

The results showed that the puncture depth was shorter in the anterior–superior path group than in the anterior–inferior path group (Table 2). According to the results of the correlation analysis, our study showed that the puncture depth was correlated with the puncture path, BMI, and sex (Table 3).

Puncture time

The results showed that the puncture time was shorter in the anterior–superior path group than in the anterior–inferior path group (Table 2). According to the results of correlation analysis, our study showed that the puncture time was correlated with the puncture path (Table 3).

Single-puncture technical success

A comparison of the outcomes showed no significant differences in single-puncture technical success between the two groups (Table 2). There was no statistically significant difference in the number of cases of unsuccessful puncture between the new-puncture path and the classic-puncture path groups (p = 0.789).

Single-puncture technical unsuccess

With the new-puncture path, 56.2% (9/16) of unsuccessful puncture cases were punctured once, and needle adjustment was performed once. Of the unsuccessful puncture cases, 31.2% (5/16) were punctured once, and needle adjustment was performed twice. Of the unsuccessful puncture cases, 6.3% (1/16)

Table 1. Patients' Demographic Data for both groups(n = 125)

Parameter	Group A (n = 62)	Group B (n = 63)	Statistical value	P value
Age	41.0 ± 12.4(17–59)	38.2 ± 10.5(19–69)	1.360[a]	0.176
BM	22.9 ± 3.3(17.3–31.6)	23.3 ± 3.3(16.4–31.6)	0.605[a]	0.546
Sex			0.964[b]	0.326
Male	33 (53.2%)	28 (44.4%)		
Female	29 (46.8%)	35 (55.6%)		
Arthroscopic surgery			0.001[b]	0.981
Yes	4 (6.5%)	4 (6.35%)		0.055
No	58 (93.5%)	59 (93.7%)	5.814 [b]	
Types of injection drugs				
Local anesthetics	54 (87.1%)	59 (93.6%)		
Platelet-rich plasma (PRP)	8 (12.9%)	2 (3.2%)		
Glucocorticoid	0 (0%)	2 (3.2%)		

Group A: the new-puncture path.
Group B: the classic-puncture path.
[a]the T value
[b]the $\chi 2$ value

were punctured twice and needle adjustment was not performed, 6.3% (1/16) were punctured twice, and needle adjustment was performed once. With the classic-puncture path, 62.5% (10/16) of the unsuccessful puncture cases were punctured once, and needle adjustment was performed once. Of the unsuccessful puncture cases, 31.2% (5/16) were punctured once, and needle adjustment was performed twice. Of the unsuccessful puncture cases,6.3% (1/16) were punctured twice, and needle adjustment was performed once.

According to the results of the correlation analysis, the single-puncture technical success was not correlated with sex, age, BMI, arthroscopic history, or puncture approach (Table 4).

Visual analog scale score during puncture

No significant differences in the VAS scores during puncture were detected between the two groups (Table 2). According to the results of the correlation analysis, our study showed that the VAS score during puncture did not correlate with sex, age, BMI, arthroscopic history, or puncture path (Table 4).

Complications

At follow-up, no complications were observed in the anterior–superior path. There were two complications (both with more pain) in the anterior–inferior path. Of these two patients, one experienced pain aggravation on the second day and remission

Table 2. Clinical outcome data and complications for both groups

Outcomes data	Group A (n = 62)	Group B (n = 63)	Statistical value	P value
Puncture depth(mm)	54.5 ± 7.8(36.4–72)	59.2 ± 8.8(40.4–77)	3.138 [a]	0.002[d]
Puncture time(s)	48.0 ± 26.3(10–103)	56.7 ± 19.6(17–138)	2.088[a]	0.039[c]
Single puncture clinical success			0.003[b]	0.958
Yes	46 (74.2%)	47 (74.6%)		
No	16 (25.8%)	16 (25.3%)		
VAS score during puncture			0.001[b]	0.971
Painless (0 score)	9 (14.5%)	9 (14.3%)		
Pain (≥1 score)	53 (85.5%)	54 (85.7%)		

Group A: the new-puncture path.
Group B: the classic-puncture path
[a]the T value.
[b]the χ^2 value.
[c]$p < 0.05$
[d]$p < 0.005$. Significant results are highlighted in bold.

Table 3. Analysis the correlation between each of the other clinical data characteristics and the puncture depth and puncture time (n = 125)

Clinical data characteristics	Puncture depth(mm)			Puncture time(s)		
		Value	*P* value		Statistical value	*P* value
Arthroscopic surgery		0.082[b]	0.366	0.069[b]	0.447	
Yes	59.5 ± 7.8			46.3 ± 27.4		
No	56.7 ± 8.6			52.8 ± 23.3		
Sex		0.269[b]	**0.002**[d]		0.103[b]	0.251
Male	59.2 ± 8.8			49.2 ± 24.7		
Female	54.6 ± 7.8			54.8 ± 22.3		
puncture path		2.72[b]	**0.002**[d]		0.185[b]	**0.039**[c]
Group A	54.5 ± 7.8			48.0 ± 26.3		
Group B	59.2 ± 8.8			56.7 ± 19.6		
BMI		0.492[a]	**<0.001**[e]		0.006[a]	0.944
Age		0.014[a]	0.881		0.003[a]	0.971

Group A: the new-puncture path.
Group B: the classic-puncture path.
[a]the Pearson correlation coefficient R value.
[b]the Point two column correlation coefficient.
[c]p < 0.05.
[d]p < 0.005.
[e]p < 0.001.

on the third day, and the other reported worsening on the second day and remission on the fourth day.

DISCUSSION

Our study aimed to establish a new US-guided path for intra-articular hip joint puncture that is particularly applicable to patients without hip joint effusion. The results showed that the anterior–superior path had a shorter puncture depth and shorter puncture time than the classic–puncture path, with no significant difference in single puncture technical success, complication rate, and VAS score during puncture.

Various US-guided hip puncture methods have been reported in the literature. The posterior path starts with insertion at the junction of the medial third of the line between the midpoint of the great bulge and the posterior–inferior iliac spine.[35] Therefore, it is affected by the hip muscles and prone to injuring the sciatic nerve and inferior gluteal arteries and veins, which poses a risk of neurovascular damage.[9] The lateral path is susceptible to the influence of the femoral neck trunk angle and hip shape,[22,23] and the needle can easily enter the posterior margin of the hip joint.[36] Other studies have reported that when there is variation in blood vessels and nerves, serious complications, such as bleeding and inevitably occur.[21,22]

The anterior–inferior path is more popular among clinicians than the lateral and posterior paths.[29]In addition, the anterior–inferior path is suitable in the presence of a large amount of effusion in the hip cavity.[11] When there is a large amount of effusion in the anterior synovial recess, it is favorable to form a strong contrast interface, display the puncture needle head, and approach more clearly. However, hip joint puncture is more difficult when the hip joint without effusion, which increases puncture risk.[3,25] In our hospital, there are more patients with hip pain without effusion, accounting for approximately 70% of the patients. In these patients, the needle point may be unclear when effusion is absent.[3,25] Smith et al reported an inaccurate puncture in a young patient with a BMI of 28 kg/cm^2 with no hip joint effusion.[3] Our results suggest that showed that the anterior–superior path may provide a new and shorter puncture path for patients, even for patients without hip joint effusion.

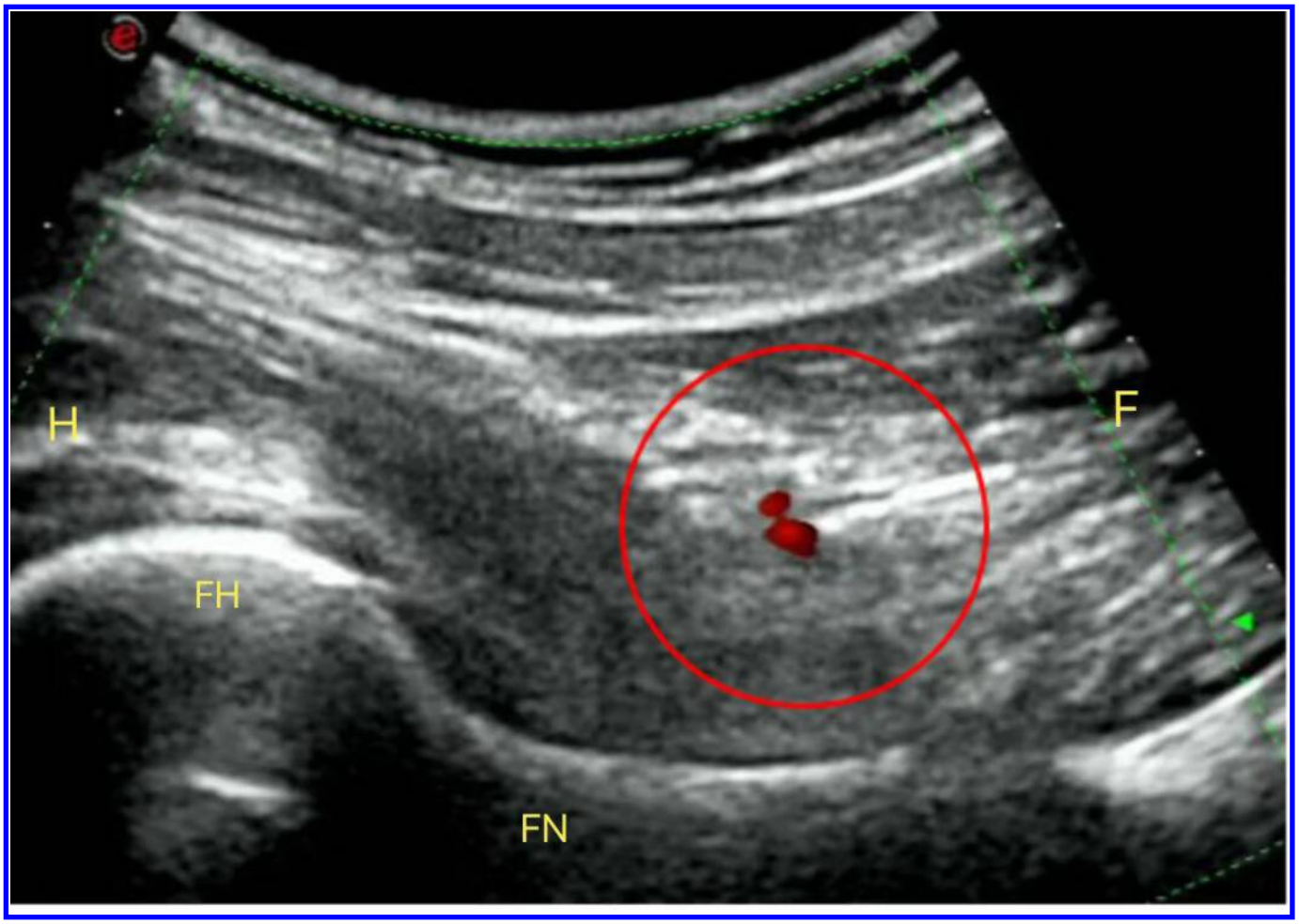
Additionally, the anterior–inferior path is close to the lateral femoral circumflex artery (LCFA) and its branches (Figure 3). The LCFA is a branch of the profunda artery that runs laterally to the femoral triangle near the acetabular femoral joint and reaches the deep surface of the sartorius and rectus femoris.[21,22] The mean distance between the classic-puncture path and ascending branch of the LCFA is 14.2 mm, which may be more likely to cause blood vessel injury and femoral head ischemia.[21,24]Zhang et al reported that four US-guided anterior–inferior approach hip punctures were performed on human cadavers in which the needle made direct contact with the LCFA, and 16% (10 of 62) of the cases involved hip injection-related vascular complications in procedures performed by another provider.[21] In our study, there were no complications such as bleeding and infection, there were two cases of pain aggravation in the classic-puncture path. There was no statistically significant difference in the types of injected drugs between the two groups, and both patients with complications were injected with local anesthetics. Therefore, we conclude that pain complications are not caused by the type of injection drug or the puncture path. We suggest that the

Table 4. Analysis the correlation between each of the other clinical data characteristics and the VAS score during puncture and the successful outcomes (n = 125)

Clinical data characteristics	Pain or painless				Single puncture clinical success or unsuccess			
	Painless(n = 18)	Pain (n = 107)	Statistical value	P value	Success(n = 93)	Unsuccess (n = 32)	Statistical value	P value
Age	40.2 ± 11.5	39.5 ± 11.56	0.001[b]	0.989	39.6 ± 11.2	39.7 ± 12.6	0.019[b]	0.832
BMI	22.5 ± 2.9	23.2 ± 3.4	0.048[b]	0.593	23.0 ± 3.3	23.4 ± 3.3	0.083[b]	0.357
Arthroscopic surgery		1.438[a]	0.230			0.002[a]	0.968	
Yes	0 (0%)		8 (7.5%)		6 (6.5%)	2 (6.3%)		
No	18 (100%)		99 (92.5%)		87 (93.5%)	30 (93.7%)		
Sex		0.012[a]	0.912		0.955[a]	0.328		
Male	9 (50%)	52 (48.6%)			43 (46.2%)	18 (56.25%)		
Female	9 (50%)	55 (51.4%)			50 (53.8%)	14 (43.75%)		
Puncture path		0.001[a]	0.971		0.003[a]	0.958		
Group A	9 (50%)	53 (49.2%)			46 (49.5%)	16 (50%)		
Group B	9 (50%)	54 (50.8%)			47 (50.5%)	16 (50%)		

Group A: the new-puncture path.
Group B: the classic-puncture path.
[a]the χ^2 value
[b]the Point two column correlation coefficient.

Figure 3. Ultrasound image of the anterior hip joint. The circles represent the LCFA and its branches. FH: femoral head; FN: femoral neck. F: foot side. H: head side.



pain complications may be due to hip joint pain and discomfort, internal structural adhesion, high injection resistance, swelling, and pain caused by injection drugs entering the joint capsule or ligament.

Our study proposes a new-puncture path: the anterior–superior path. The results demonstrated that the anterior–superior and anterior–inferior paths had no significant difference in the technical puncture success rate, and the VAS score during puncture in patients with the hip joint indicated the absence of effusion. Therefore, the anterior–superior path can be a new path in addition to the anterior–inferior path. Although the hip puncture technical success rate was 100% in both groups, there were cases of unsuccessful single puncture in both the new-puncture path and classic-puncture path groups (74.2% *vs* 74.6%, $p = 0.958$). According to the results of this study, the success rate of a single puncture was not correlated with age, BMI, sex, arthroscopic surgery, and puncture path. Therefore, we concluded that the causes of single puncture failure maybe as follows: (i) previous myofascial lesions around the hip or muscle atrophy, which may result in hyper-echogenicity or heterogeneous echogenicity, attenuation, or sound shadows on US images and (ii) excessive BMI, which may increase the puncture depth of the hip joint. These results may reduce the clarity and imaging quality of the US images and lead to puncture failure.

Compared with the classic-puncture path, the new-puncture path also has the advantages of shorter puncture depth and puncture time. Our correlation analysis showed that BMI and sex were associated with the puncture depth. These results suggest a shorter puncture depth in the female sex and smaller BMI group, which may have fewer subcutaneous soft tissues and muscles. A shorter puncture depth reduces the distance between the soft tissue and muscles being punctured. Our correlation analysis results showed that compared with the classic-puncture path group, the new-puncture path group had shorter puncture depth and puncture time, which reduced patient discomfort during the puncture.

In addition, our study made full use of the advantages of a 21G PTC needle with a length of 200 mm and inner diameter of 0.5 mm. Its length was sufficiently long enough to be suitable for patients with a high BMI, and its inner diameter was remarkably fine and could minimize damage to the soft tissues and muscles.

Our study has some limitations. First, this was a single-center study; a multicenter clinical study is required to verify the accuracy of this investigation. Second, only one sonographer performed the surgery. In the future, we may study the differences between sonographers with different experience levels and their learning curves. Third, there were ultrasonic beam attenuation in obese patients and surgical areas, such as scar, calcification and so on, and ultrasound display may be impaired. Fourth, the sample can be further expanded to study patients of different ages and weight groups, making this new-puncture path widely applicable.

CONCLUSIONS

The anterior–superior path can be used as a novel, practical, and clinically useful US-guided hip puncture path for patients without hip joint effusion, with the advantages of shorter puncture path and puncture time.

FUNDING

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CLINICAL TRIAL REGISTRATION

This study was registered and approved by The Chinese Clinical Trial Registry (Registration Number: ChiCTR2100049867).

ETHICS APPROVAL

This study was approved by the Medical Ethics Committee of our Hospital (ethics number: S2021-091-01).

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