

The Course and Anatomical Characteristics of Sciatic and Femoral Nerves in Unilateral Crowe Type-IV Hip Dysplasia

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Background: This study aims to investigate the course and anatomical characteristics of sciatic and femoral nerves in unilateral Crowe type-IV developmental dysplasia of the hip (DDH) patients.

Methods: We conducted a retrospective own-control study of patients with unilateral Crowe type-IV DDH. Bilateral hip computed tomography (CT) of 21 female patients was reviewed in our institute from February 2018 to February 2020. The distances between nerves and bony landmarks were measured in different CT sections (anterior superior iliac spine, acetabular inner wall, teardrop, and ischial tuberosity) to analyze the anatomical position and course of sciatic and femoral nerves between bilateral hips.

Results: In the section of the acetabular inner wall, the distance between the femoral nerve and the acetabular anterior wall in affected hip (13.20 ± 3.59 mm) was significantly smaller than that in the healthy hip (16.58 ± 5.12 mm) ($p < 0.001$). In other sections, the distances between nerves and bony landmarks in affected hips were significantly larger than or equal to those in the healthy hips.

Conclusion: In female patients with unilateral Crowe type-IV DDH, the femoral nerve in the affected hip runs closer to the anterior acetabular wall than that in the healthy hip.

Keywords: developmental dysplasia of the hip, total hip arthroplasty, nerve injury, nerve course, sciatic nerve, femoral nerve

Introduction

Total hip arthroplasty (THA) is an effective and mature treatment for patients with Crowe type-IV developmental dysplasia of the hip (DDH). But the incidence of postoperative nerve injury in Crowe type-IV patients, ranging from 7.35% to 10%, was significantly higher than that in other patients with an incidence of 0.08%-3.7%.¹⁻³ Nerve injury following THA is a disastrous adverse complication which severely affects postoperative functional training, recovery, and quality of life.⁴ Limb Lengthening and poor soft-tissue compliance were considered as important risk factors of nerve injury in hip replacement for Crowe type-IV DDH patients.⁵⁻⁷ However, Egli⁸ and other researchers^{9,10} have found that nerve injury was most caused by direct or indirect mechanical trauma, not by limb lengthening on its own.

THA in adult patients with Crowe type-IV DDH is a technically challenging procedure. Due to the femoral upward dislocation and abnormal pelvic architecture, the course of sciatic and femoral nerves may change accordingly. Thus, the difficult surgery is associated with a higher risk of direct or indirect mechanical nerve trauma. A better understanding of the course and anatomical characteristics of sciatic and femoral nerves in patients with Crowe type-IV DDH may help minimize the risk of mechanical injury after THA.¹¹⁻¹⁴ However, the characteristics of the peripheral nerve course of dysplastic hip have not been well studied.¹⁵ This study aims to investigate the course and anatomical characteristics of sciatic and femoral nerves in unilateral Crowe type-IV DDH patients in computed tomography (CT).

Patients and Methods

Patients with unilateral Crowe type-IV DDH were retrospectively enrolled in our institute from February 2018 to February 2020. Inclusion criteria: 1. One hip is Crowe type-IV DDH and the other hip is normally developed, ie the central-edge angle is greater than 25° ,¹⁶ 2. Female, 3. Age: 18–50 years old, 4. Height: 150–170cm, 5. BMI: 20–30kg/m². Exclusion criteria: 1. History of infection/surgery/trauma in either hip, 2. Lower limb peripheral nerve diseases, such as poliomyelitis sequelae, 3. The angle between femoral longitudinal axis and pelvic median axis is greater than 15° in CT localization image, 4. The angle between inter-teardrop line and horizontal line is greater than 10° in CT localization image. Our study protocol was approved by the Ethics Committee of Chinese PLA General Hospital and informed consent obtained from the study participants prior to study commencement.

CT Scan Protocols and Parameters

CT scan (Brilliance ICT, Philips Healthcare, Netherlands) was completed in the supine position, covering the entire pelvis and proximal femur. The scanning parameters were described as follows, layer thickness: 0.625mm, pitch: 5mm, kVp: 120kVp, mA: 200mA, field of view (FOV): 500mm, image resolution: 512×512 matrix.

Measurements

We selected reference transverse sections through several key points (Figure 1, A: anterior inferior iliac spine, B: most medial part of acetabular inner wall, C: inferior margin of the teardrop, D: ischial tuberosity) in CT soft tissue window of the hip using picture archiving and communication system (PACS, Knowlesys Software Technology Co., Ltd., China) in our institute, and identified sciatic nerve and femoral nerve locations according to anatomical adjacency relationship and nerve CT values (40–60) (Figure 2).

After confirming the nerves' location, their linear distance to the adjacent pelvic or femoral bony landmarks were measured (Figure 2). All the measurements were carried out by two postgraduate students in orthopedics, then repeated two weeks later. Screenshots of CT images were saved at the time of measurement, and if the results differed significantly or nerve location was controversial, a senior orthopedic surgeon made the determination. The mean measurements were used for comparison.

Statistics

Statistical analysis was performed in SPSS22.0 (IBM Company, NY, USA) and power analysis was performed in PASS15.0 (NCSS, LLC, Kaysville, USA). All indices were subjected to normality test, and those conforming to normal distribution were expressed as mean \pm standard deviation. All the distances in both sides were analyzed by paired-*t* test. Intra-class correlation coefficients (ICC) were adopted to assess consistency in measurements. ICC value ranged between



Figure 1 Transverse sections through selected key points (A: anterior inferior iliac spine, B: acetabular inner wall, C: inferior margin of the teardrop, D: ischial tuberosity).

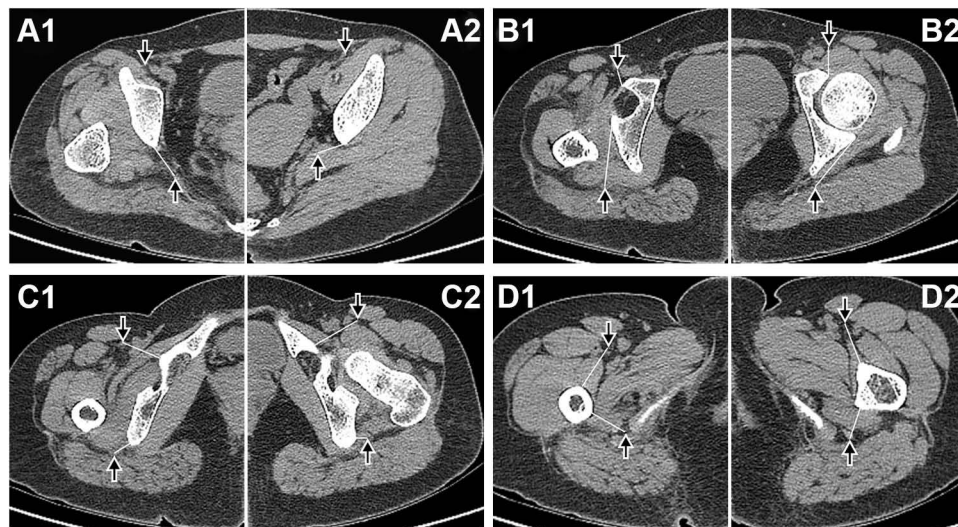


Figure 2 Axial CT scans demonstrating the sections used for evaluation of the femoral nerve (indicated by down arrow) and sciatic nerve (indicated by up arrow) in a cranio-caudal direction. **A1, B1, C1, D1** were affected hip and **A2, B2, C2, D2** were healthy hip. Linear distance (indicated by white line) between nerves and adjacent bony landmarks. **(A)**: distance from sciatic nerve to posterior edge of iliac crest, section **(B)**: distance from sciatic nerve to posterior acetabular wall and distance from femoral nerve to anterior acetabular wall, section **(C)**: distance from sciatic nerve to ischium and distance from femoral nerve to pubis, section **(D)**: distance from sciatic nerve and femoral nerve to femur.

0 and 1, and consistency would be poor ($\kappa=0-0.4$), moderate ($\kappa=0.4-0.6$), substantial ($\kappa=0.6-0.8$) or almost perfect ($\kappa=0.8-1$) agreement. The criterion for a significant statistical difference was $p<0.05$.

Results

Bilateral hips' CTs of 21 female patients with unilateral Crowe type-IV DDH were selected in our study (Figure 3). These patients' basic information showed in Table 1. Consistency in the measurement results was almost perfect, with $ICC>0.81$. Although the power of comparison of distance from femoral nerve to pubis (0.58) and femur (0.74) was relatively low, the power of comparison of distance from femoral nerve to anterior acetabular wall (1.00) and distance from sciatic nerve to posterior acetabular wall (1.00) and femur (0.93) were convincing.

In section A, the mean distance from sciatic nerve to posterior edge of iliac crest was $10.89\pm 0.50\text{mm}$ in healthy hip and $11.03\pm 0.65\text{mm}$ in affected hip, with no significant difference bilaterally ($p=0.487$). The femoral nerve was far from the operating area and no measurement was performed.

In section B, the distance from sciatic nerve to posterior acetabular wall in affected hip ($30.70\pm 6.68\text{mm}$) was significantly larger ($p<0.001$) than that in healthy hip ($20.07\pm 2.08\text{mm}$); the distance from femoral nerve to anterior acetabular wall in affected hip ($13.20\pm 3.59\text{mm}$) was significantly smaller ($p<0.001$) than that in healthy hip ($16.58\pm 5.12\text{mm}$).

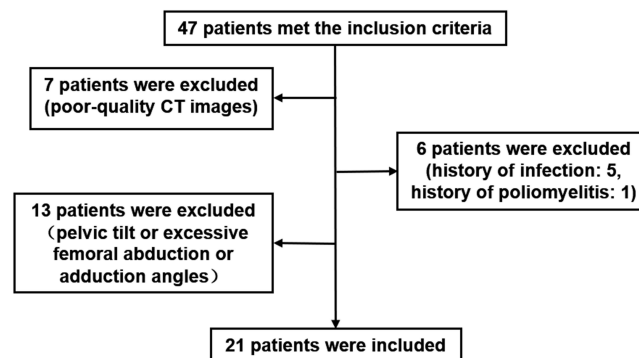


Figure 3 Patient flow diagram.

Table 1 Demographic Data

	Means \pm SD (95%IC)
Age (years)	38.29 \pm 7.73 (24–48)
Height (cm)	160.00 \pm 4.87 (153–170)
Weight (kg)	58.57 \pm 4.76 (52–69)
BMI (kg/m ²)	22.89 \pm 1.70 (20.45–27.12)

Abbreviations: BMI, body mass index; SD, standard deviation.

In section C, the distance from sciatic nerve to ischium was 13.98 \pm 3.24mm in healthy hip and 13.30 \pm 2.90mm in affected hip, no significant difference was detected bilaterally ($p=0.429$); the distance from femoral nerve to pubis in affected hip (26.2 \pm 6.90mm) was significantly larger ($p=0.036$) than that in healthy hip (21.70 \pm 2.17mm).

In section D, the distance from sciatic nerve to femur in affected hip (15.62 \pm 1.11mm) was significantly larger ($p=0.001$) than that in healthy hip (14.52 \pm 0.86mm). The distance from femoral nerve to femur in affected hip (30.40 \pm 5.67mm) was significantly larger ($p=0.013$) than that in healthy hip (34.36 \pm 5.33mm). The detailed values are shown in Tables 2 and 3.

Discussion

Comparing to healthy hips, the femoral nerve in affected hips moved away from the femur while it got closer to anterior acetabular wall. The distances from the sciatic nerve to posterior acetabular wall and femur in affected hips were larger than those in healthy hips.

Understanding the anatomic adjacency of sciatic and femoral nerves in hip region could help reduce nerve injury during THA.^{17–19} Previous studies on peripheral nerve anatomy and course were mainly based on magnetic resonance imaging (MRI) or cadaveric specimens. However, CT might be a better choice of evaluating nerve course for DDH.^{20–25} On the one hand, MRI was not a routine examination for DDH patients and cannot clearly show bony landmarks; it would increase patients' medical costs purely for the purpose of observing nerve course. On the other hand, it was very difficult to find cadaveric donors with DDH. Several researchers have confirmed that CT, as a routine preoperative examination for Crowe type-IV DDH patients, can accurately identify sciatic and femoral nerve.^{21,26,27}

To date, there was only one study done in the subject of nerve course in patients with DDH. In 2015, Wang et al¹⁵ used CT to observe the nerve course in DDH patients and summarized the anatomical characteristics of sciatic nerve.

Table 2 Distance from Sciatic Nerve to Bony Landmarks on Each Section

Sections	Distance (mm)		
	Healthy Hip	Affected Hip	P-value
A (posterior edge of iliac crest)	10.89 \pm 0.50	11.03 \pm 0.65	0.487
B (posterior acetabular wall)	20.07 \pm 2.08	30.70 \pm 6.68	<0.001
C (ischium)	13.98 \pm 3.24	13.30 \pm 2.90	0.429
D (femur)	14.52 \pm 0.86	15.62 \pm 1.11	0.001

Table 3 Distance from Femoral Nerve to Bony Landmarks on Each Section

Sections	Distance (mm)		
	Healthy Hip	Affected Hip	P-value
B (anterior acetabular wall)	16.58 \pm 5.12	13.20 \pm 3.59	<0.001
C (pubis)	21.70 \pm 2.17	26.27 \pm 6.90	0.036
D (femur)	30.40 \pm 5.67	34.36 \pm 5.33	0.013

They found that the sciatic nerve was located near the ischium and ilium but relatively far from the femur of the affected hip, compared to its location on the healthy hip for patients with unilateral DDH.¹⁵ Their finding was important to help surgeons improve their understanding of soft tissue developmental abnormalities around the hip joint in patients with DDH, thereby reducing the risk of nerve injury. However, there were still some flaws in their study. Firstly, the study did not include Crowe type-IV DDH, who was at the highest danger of nerve injury. Secondly, the reference section for all measurements were femur-based, and the femoral landmarks varied with the dislocation level, which reduced the comparability of bilateral nerves anatomical position. Thirdly, their measurement region excluded the area above acetabulum and the area below lesser trochanter, which were often the operating region for Crowe type-IV DDH patients. Fourthly, only the sciatic nerve, but not the femoral nerve was analyzed.

The femoral nerve injury accounted for 27.78% (5/18) of all nerve injuries after surgery in Crowe type-IV DDH.⁵ However, previous studies reported that femoral nerve was more resistant to distraction than sciatic nerve; limb lengthening may not be the main cause of femoral nerve injury.^{11,12} Our findings provided a new explanation for femoral nerve injury in Crowe type-IV DDH from the nerve course viewpoint. Firstly, the femoral nerve was only 1.3 cm on average away from the anterior acetabular wall, improperly positioned the retractor anterior to acetabulum, or prolonged traction may injure the femoral nerve. Secondly, overhanging acetabular cup was a common sacrifice for cup stability in Crowe type-IV DDH hip replacement. The femoral nerve, originating from lumbar plexus, arced around anterior aspect of acetabulum into femoral triangle. When femoral nerve was stretched and tensed with less arc, nerve injury happened with touching the anterior edge of overhanging acetabular cup and cause.

Some studies have also confirmed that the placement of retractor anterior to acetabulum was a high-risk step of femoral nerve injury. Shubert et al²⁶ investigated the position of acetabular retractor in relation to adjacent neurovascular structures in CT scans and cadavers. They found that the anterior inferior iliac spine is the safest anterior acetabular retractor position, with inferior progression along the anterior wall, the distance to the femoral neurovascular bundle decreases.²⁶ In our study, the distance between femoral nerve and anterior acetabular wall was smaller in Crowe type-IV DDH compared to normally developed hip, which might increase the risk of intraoperative femoral nerve injury.

The advantages of this study are reflected in the following aspects. Firstly, only unilateral Crowe type-IV DDH cases were included, eliminating the effect of factors such as body size on the data via an own-control design. Then, demographics such as gender, age, height, and weight were qualified, and previous history and neurological autoimmune diseases were excluded from interfering with the results. Finally, it's the bony landmarks of the pelvis not of the femur that were chosen as references, which was not affected by the height of femoral dislocation.

This study, however, also has several limitations. First, these criteria were very restrictive and excluded nearly 70% of Crowe-IV DDH cases, making the sample size of this study relatively small. Second, the postoperative neurological complications of the cases were not studied, and it was not possible to correlate anatomical characteristic with clinical outcomes. So, we failed to evaluate the true impact of nerve coursing abnormalities on postoperative neurological function. Third, CT measurements in the supine position do not truly reflect the neurological status in the lateral position. Fourth, the morphological study of linear distances through different CT sections can be influenced by several factors, including height of patients, the scanning posture, the selected CT section etc. Although we have set the strict inclusion and exclusion criteria to minimize their influence, there may still have certain degree error in this method. Accordingly, a more comprehensive morphometric geometrical analysis via 3D reconstruction may receive more interesting results and benefit the clinical application better.

Conclusion

In female patients with unilateral Crowe type-IV DDH, the femoral nerve in affected hip runs closer to anterior acetabular wall than that in healthy hip.

Data Sharing Statement

The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

Our study protocol was approved by the Ethics Committee of Chinese PLA General Hospital and informed consent obtained from the study participants prior to study commencement. All procedures were conducted in compliance with the guidelines of the Declaration of Helsinki. We have obtained consent for publication. Ping Song and Xiangpeng Kong are co-first authors for this study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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