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Original Research Article

AN ANATOMICAL CADAVERIC STUDY OF VARIATIONS IN THE RELATIONSHIP BETWEEN THE SCIATIC NERVE AND PIRIFORMIS MUSCLE WITH AN ASSOCIATED VARIATION OF THE INFERIOR GLUTEAL NERVE AND VESSELS TRAVERSING THE TIBIAL NERVE IN THE GLUTEAL REGION: EMBRYOLOGICAL BASIS AND CLINICAL IMPLICATIONS

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ABSTRACT

Background: The sciatic nerve is the largest peripheral nerve, innervating mainly the posterior compartment of the thigh and the majority of the lower limb in humans. It leaves the pelvis as a single trunk through the greater sciatic foramen below the piriformis muscle, in the lower third of the thigh the sciatic nerve terminates by dividing into tibial and common peroneal nerves. Embryological alterations during intrauterine life may produce variations in its anatomical relationship. Such variations are of considerable clinical significance, may predispose to piriformis syndrome, increase the risk of failed sciatic nerve blocks, complicate gluteal intramuscular injections, and pose challenges during orthopedic and neurosurgical procedures. The aim is to evaluate the anatomical relationship between the sciatic nerve and the piriformis muscle in adult human cadavers, determine the frequency of anatomical variations, classify the observed patterns, associated neurovascular anomalies and discuss their embryological origin and clinical relevance. **Materials and Methods:** A descriptive observational cadaveric study was carried out in the Department of Anatomy, Government Medical College, Suryapet, for a period of two years. Fifteen embalmed adult cadavers comprising thirty lower limbs were dissected using standard anatomical techniques. The course of the sciatic nerve, its level of division, its relationship to the piriformis muscle and associated neurovascular anomalies were carefully examined and documented. The frequency of anatomical variations was calculated and the findings were compared with previously published studies. **Results:** High division of the sciatic nerve was observed in 2 specimens (6.67%), unilaterally, in one specimen the variation was observed in right lower limb (3.33%) while other was observed in left lower limb. In these specimens, the common peroneal nerve pierced the piriformis muscle while the tibial nerve continued below it. This variation corresponds to Type II of the Beaton and Anson classification. An associated uncommon variation was also observed in both the specimens with inferior gluteal nerve and accompanying inferior gluteal vessels piercing the the tibial nerve. The normal anatomical pattern, in which the sciatic nerve emerged below the piriformis muscle as a single trunk, was observed in 28 of the 30 lower limbs (93.33%). **Conclusion:** Variations in the relationship between the sciatic nerve and the piriformis muscle and associated neurovascular anomalies have significant clinical implications. A thorough knowledge about these variations helpful for surgeons, anesthesiologists, radiologists, surgeons and clinicians to minimize iatrogenic injuries for surgeons, anesthesiologists, radiologists, and clinicians to minimize iatrogenic injuries, improve the accuracy of regional anesthesia, and facilitate the diagnosis and management of sciatic nerve entrapment disorders.

INTRODUCTION

The sciatic nerve is the largest and thickest peripheral nerve in the human body and constitutes the principal nerve supply to the lower extremity. It originates from the lumbosacral plexus, receiving contributions from the anterior rami of the fourth and fifth lumbar nerves together with the first, second, and third sacral spinal nerves (L4–S3). After its formation within the pelvis, the nerve typically exits through the greater sciatic foramen inferior to the piriformis muscle and descends into the gluteal region as a single trunk before dividing into the tibial and common peroneal nerves near the superior angle of the popliteal fossa. Although this arrangement is considered the standard anatomical pattern, numerous studies have demonstrated that variations in its formation, course, and branching are not uncommon [1-3]

The piriformis muscle serves as an important anatomical landmark within the gluteal region because it divides the greater sciatic foramen into suprapiriform and infrapiriform compartments. Under normal circumstances, the sciatic nerve traverses the infrapiriform compartment as a single undivided structure. However, variations may occur in which the nerve divides within the pelvis and one or both of its terminal components follow an altered course in relation to the piriformis muscle. These anatomical variations arise during embryonic development and require considerable attention because of their clinical and surgical importance.[4,5]

The inferior gluteal nerve and inferior gluteal vessels normally emerge below the piriformis muscle through the greater sciatic foramen. The inferior gluteal nerve arise from the dorsal division of the L5,S1 and S2 of the sacral plexus, while the inferior gluteal artery is the largest terminal branch of the anterior division of the internal iliac artery. The inferior gluteal nerve supplies the gluteus maximus muscle and the inferior gluteal vessels gives muscular branches and contribute to the vascular anastomoses around hipjoint. Anatomical variations involving the inferior gluteal nerve and vessels are uncommon but of considerable clinical importance during gluteal and hip surgeries.

Embryologically, the tibial and common peroneal components initially develop as separate nerve bundles before they unite to form the sciatic nerve. Incomplete fusion or persistence of their independent developmental pathways may result in high division of the sciatic nerve or an abnormal relationship with the piriformis muscle. While the sacral plexus and arterial network of the lower limb develop simultaneously within the mesenchyme of the developing limb bud. Altered fusion or separation of the tibial nerve fascicles together with the persistence of primitive vascular channels may result in the inferior gluteal nerve and vessels traversed through the tibial nerve, producing this rare anatomical variation. Such developmental variations account for the diversity of anatomical configurations encountered during cadaveric dissection and radiological evaluation.[4]

A systematic classification of these variations was proposed by Beaton and Anson, who described six distinct anatomical patterns based on the course of the tibial and common peroneal divisions relative to the piriformis muscle. The normal configuration, in which an undivided sciatic nerve passes inferior to the muscle, represents the most frequently observed pattern. Among the remaining types, high division with the common peroneal nerve traversing the piriformis muscle while the tibial nerve passes below it is one of the most commonly reported variants.[5]

Knowledge of these variations has considerable clinical significance. Abnormal relationships between the sciatic nerve and the piriformis muscle may predispose individuals to nerve compression syndromes, particularly piriformis syndrome, which presents with buttock pain radiating along the posterior aspect of the thigh. Such variations may also contribute to unsuccessful sciatic nerve blocks, postoperative neurological deficits, and unexpected complications during hip surgery, acetabular fracture fixation, gluteal flap procedures, and intramuscular injections administered in the gluteal region. Hence awareness of variant anatomy enhances the interpretation of imaging studies, including magnetic resonance imaging, computed tomography, and ultrasonography.[6-12]

The reported incidence of sciatic nerve variations differs considerably among various populations, reflecting differences in ethnicity, sample size, and study methodology. Population-specific cadaveric studies therefore remain valuable in expanding anatomical knowledge and providing clinically relevant information that can improve surgical safety and diagnostic accuracy.[7,8,11,13-20]

Cadaveric dissection remains the most reliable method for evaluating the anatomical relationship between the sciatic nerve and the piriformis muscle because it allows direct visualization of the nerve throughout its course. The present study was undertaken to document the relationship of the sciatic nerve with the piriformis muscle in adult cadavers, determine the frequency of anatomical variations, classify the observed patterns, and discuss their embryological basis and clinical importance.

MATERIALS AND METHODS

A descriptive observational cadaveric study was conducted over a period of two years in the Department of Anatomy, Government Medical College, Suryapet, Telangana, India. The investigation was designed to evaluate the anatomical relationship between the sciatic nerve and the piriformis muscle and to identify variations in the course and division of the sciatic nerve.

The study was performed on fifteen embalmed adult human cadavers, providing a total of thirty lower limbs for examination. The sample size was

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determined based on a convenience sampling method, as the study utilized cadaveric material available for routine undergraduate dissection. The present study was done in accordance with institutional and ethical guidelines. Ethical approval was obtained from the Institutional Ethics Committee. Cadavers with well-preserved gluteal regions and intact lower limbs were included in the study. Specimens demonstrating previous surgical intervention, traumatic injury, congenital anomalies, or extensive tissue damage involving the gluteal region were excluded to avoid distortion of the normal anatomy.

Dissections were carried out according to the standard procedures described in Gray's Anatomy. The skin, superficial fascia, deep fascia of the gluteal region was reflected carefully, followed by exposure of the gluteus maximus muscle. After reflecting the gluteus maximus, the deeper structures of the gluteal region were meticulously dissected to expose the piriformis muscle and the sciatic nerve.

Course of the sciatic nerve after its exit from the pelvis.

Relationship of the sciatic nerve to the piriformis muscle.

Level of division of the sciatic nerve into the tibial and common peroneal nerves.

Presence of any abnormal branching pattern or anatomical variation.

Variations was identified, its morphology was documented in detail and photographed for anatomical records. The observed pattern was classified according to the Beaton and Anson classification.

Data Collection

The observations obtained from each lower limb were entered into a structured data sheet. The number of specimens exhibiting the normal anatomical pattern and those demonstrating variations was recorded separately.

Statistical Analysis

As the objective of the study was to describe anatomical variations, only descriptive statistical methods were employed. Frequencies and percentages were calculated for each anatomical pattern. The findings were subsequently compared with observations.

RESULTS

Thirty lower limbs obtained from fifteen embalmed adult cadavers were carefully dissected and examined.

The normal anatomical relationship between the sciatic nerve and the piriformis muscle was observed in twenty-eight lower limbs (93.33%). In these specimens, the sciatic nerve emerged through the infrapiriform compartment of the greater sciatic foramen as a single undivided trunk and descended through the posterior compartment of the thigh before dividing into the tibial and common peroneal nerves near the popliteal region 9. [Table 1]

An anatomical variation was identified in two lower limbs (6.67%). In both specimens, the sciatic nerve divided within the pelvis before emerging into the gluteal region. The common peroneal nerve pierced the piriformis muscle, whereas the tibial nerve emerged inferior to the muscle and continued its normal course into the thigh. Associated variation was also noted in both specimens, in which the inferior gluteal nerve and vessels pierced the tibial nerve, a rare anatomical finding. [Figure 1,2]

According to the Beatson and Anson classification, both specimens were classified as Type II, representing high division of the sciatic nerve with common peroneal nerve passing through the pyriformis muscle and the tibial nerve passing below it. The overall incidence of sciatic nerve variation observed during the investigation was 6.67%, while the normal anatomical arrangement accounted for 93.33% of the examined specimens.

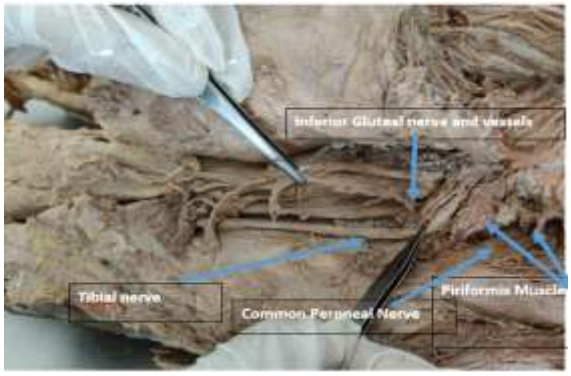

Figure 1: In Right lower limb specimen showing high division of the sciatic nerve demonstrating the common peroneal nerve traversing the piriformis muscle and the tibial nerve passing inferior to it (Beaton and Anson Type II) with inferior gluteal nerve and vessels piercing the tibial nerve in gluteal region.

Figure 2: High division of the sciatic nerve of left lower limb. demonstrating the common peroneal nerve traversing the piriformis muscle and the tibial nerve passing inferior to it (Beaton and Anson Type II) with inferior gluteal nerve and vessels piercing the tibial nerve in gluteal region.

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Table 1: Distribution of Sciatic Nerve Patterns in Relation to the Piriformis Muscle and associated variations

Anatomical Pattern	High division with common peroneal nerve piercing the piriformis and the tibial nerve passing below the muscle	Associated variations including inferior gluteal nerve and vessels traversing through the tibial nerve	Right Lower limb	Left lower limb
No. of Lower limbs	2(6.67%)	2 (6.677%)	Observed (3.33%)	Observed(3.33%)

Table 2: Comparision of the Present study with the Previous Literature

Author	Year	Sample size	Incidence (%)	Type of Variation	Key Findings
Beaton and Anson	1937	120 Lower limbs	11.7%	Type II	Proposed the six type of classification
Chiba et al	1992	514 lower limbs	16.2%	Multiple types	Reported diverse sacral plexus relationships
Babinskin et al	2003	50 lower limbs	8%	Type II	Unilateral high division
Machado et al	2003	100 lower limbs	13%	Type II	Higher incidence than the present study
Ugrnovic et al	2005	100 lower limbs	4%	Type II	Lower incidence than the present study
Pokorny et al	2006	182 Lower limbs	7.1%	Type II	Incidence comparable to the present study
Guvencer et al	2009	50 lower limbs	6.4%	Type II	Similar findings
Adibatti & Prasanna	2014	50 lower limbs	8%	Type II	Slightly higher incidence
Natis et al	2014	294 Lower limbs	6.8%	Type II	Comparable findings
Present study	2026	30 lower limbs	6.67%	Type II	Asssociated rae variation of the inferior gluteal nerve and accompanying Inferior gluteal vessels piercing the tibial nerve in both specimens

DISCUSSION

The sciatic nerve is the largest terminal branch of the sacral plexus and represents one of the most important landmark of the gluteal region and posterior compartment of the lower limb. Typically, the sciatic nerve course beneath the piriformis muscle, anatomical variations involving its terminal division and relationship with the piriformis muscle have been documented in different populations. Such variations are clinically relevant because they influence surgical approaches, regional anesthesia, radiological interpretation, and the diagnosis of sciatic nerve entrapment syndromes.[5,6]

In the present cadaveric study, the normal anatomical arrangement was observed in 93.33% of the examined lower limbs, whereas anatomical variation was identified in 6.67% of the specimens. The variation involves a high division of the sciatic nerve, with the common peroneal nerve passing through the piriformis muscle and the tibial nerve emerging below the muscle. This anatomical configuration corresponds to Type II of the Beaton and Anson classification, one of the most frequently observed variants reported in anatomical literature.[5]

The incidence observed in the present study is comparable with the findings of several previous cadaveric studies [Table 2]. Although the reported prevalence of sciatic nerve variations differs considerably among studies, most authors have documented an incidence ranging from approximately 4% to 20%. These differences may be attributed to variations in ethnicity, geographical distribution, sample size, methods of specimen selection, and classification criteria. The present findings therefore contribute valuable regional anatomical data and support previous observations that the normal infra-piriform course remains the predominant anatomical pattern.[7,8,11,13]

An associated rare variation observed in the present study includes, piercing of the tibial nerve by the inferior gluteal nerve and inferior gluteal vessels in both specimens presenting a high division of sciatic nerve. Recognition of such rare variation is clinically important during posterior approaches to the hip, gluteal surgeries and sciatic nerve blocks as unanticipated neurovascular anatomy may increase the risk of iatrogenic injury. The embryological basis of this variation provides an explanation for the observed morphology. During early fetal development, the tibial and common peroneal components arise independently from the sacral plexus before they unite to form the sciatic nerve. Disturbances in this developmental process, particularly incomplete fusion or persistence of separate nerve pathways, may result in early division of the sciatic nerve and an altered relationship with the piriformis muscle. These developmental mechanisms account for the anatomical diversity observed in cadaveric and imaging studies. The associated variation may result from abnormal separation of the sciatic nerve components and persistence of primitive neurovascular relationships during the development of lumbosacral plexus and gluteal vasculature.[4,19]

From a clinical perspective, the identified variation has considerable practical importance. When the common peroneal nerve traverses the piriformis

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muscle, it may be subjected to compression during muscle hypertrophy, inflammation, fibrosis, or spasm. Such compression can produce symptoms characteristic of piriformis syndrome, including pain in the gluteal region radiating along the posterior aspect of the thigh, which may closely resemble lumbar radiculopathy. Failure to recognize these anatomical variations can delay diagnosis and result in inappropriate treatment.[10,20]

Knowledge of sciatic nerve variations is also essential during orthopedic procedures involving the hip and pelvis. Posterior approaches for total hip arthroplasty, acetabular fracture fixation, hip arthroscopy, and gluteal reconstructive procedures require precise identification of the sciatic nerve to avoid iatrogenic injury. An unexpected anatomical course may increase the risk of nerve damage, postoperative neurological deficits, prolonged rehabilitation, and medico-legal complications. Therefore, surgeons should always consider the possibility of variant anatomy during operative planning.[7-11]

Regional anesthesia is another area in which these variations have significant implications. Conventional techniques for sciatic nerve block are based on predictable anatomical landmarks. High division of the sciatic nerve may lead to incomplete blockade if only one component of the nerve is anesthetized. Consequently, awareness of possible anatomical variations enables anesthesiologists to modify needle placement or utilize ultrasound guidance to improve the success rate of nerve blocks and reduce procedure-related complications.[6,8]

Radiological evaluation of the gluteal region also benefits from an understanding of these anatomical patterns. Modern imaging techniques such as magnetic resonance imaging, computed tomography, and high-resolution ultrasonography are increasingly employed in the assessment of patients presenting with unexplained sciatic pain. Recognition of variant nerve pathways facilitates accurate interpretation of imaging findings, aids in the diagnosis of entrapment neuropathies, and supports appropriate preoperative planning.[12,20]

The present study contributes additional evidence regarding the anatomical relationship between the sciatic nerve and the piriformis muscle in the studied population. Direct cadaveric dissection permitted careful visualization of the nerve throughout its course and allowed accurate classification of the observed variation. Such studies remain indispensable because they provide detailed anatomical information that may not always be evident through imaging techniques alone.

Overall, the findings of the present investigation emphasize that anatomical variations of the sciatic nerve are uncommon but clinically important. Comprehensive knowledge of these variations is essential for anatomists, orthopedic surgeons, neurosurgeons, plastic surgeons, anesthesiologists, radiologists, and clinicians involved in the diagnosis and management of disorders affecting the gluteal region and lower limb.

CONCLUSION

The present cadaveric investigation demonstrated that the normal course of the sciatic nerve beneath the piriformis muscle was present in the majority of specimens (93.33%). Anatomical variation was identified in 6.67% of the lower limbs, in which the sciatic nerve divided proximal to its usual level, with the common peroneal nerve traversing the piriformis muscle while the tibial nerve emerged inferior to the muscle. This configuration corresponds to Type II of the Beaton and Anson classification.

Although encountered infrequently, this variation has considerable clinical importance. Alterations in the anatomical relationship between the sciatic nerve and piriformis muscle may predispose individuals to nerve entrapment, contribute to piriformis syndrome, interfere with successful sciatic nerve blockade, and increase the likelihood of iatrogenic injury during surgical procedures involving the gluteal region and hip. Recognition of these variations is therefore essential for anatomists and clinicians involved in diagnostic, anesthetic, and surgical practice.

The findings of the present study provide additional anatomical information for the regional population and reinforce the importance of detailed anatomical knowledge during clinical and surgical interventions. Knowledge about the variations in the relationship between the sciatic nerve and the piriformis muscle and associated rare variation of inferior gluteal nerve and inferior gluteal vessels traversing through the tibial nerve, are essential in clinical practice. Awareness of these anatomical patterns can reduce the risk of sciatic nerve injury during orthopedic, neurosurgical, and reconstructive procedures, improve the success of sciatic nerve block by guiding appropriate anesthetic techniques. Assist clinicians in the diagnosis and management of piriformis syndrome and unexplained sciatic, facilitate accurate interpretation of MRI, CT, and ultrasonographic examinations of the gluteal region, improve preoperative planning and minimize postoperative neurological complications.

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