Composite Anatomical Variations Between the Sciatic Nerve and the Piriformis Muscle

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1 Introduction

Piriformis syndrome (PS) is a debilitating condition characterized by pain, numbness, and tingling sensations in the buttocks and lower extremities resulting from compression or irritation of the sciatic nerve by the piriformis muscle, a small muscle located deep within the gluteal region. The piriformis muscle functions as an external rotator of the hip and is adjacently related to the sciatic nerve. While the anatomy of the piriformis muscle and its relationship with the sciatic nerve is well-known, there are significant variations in their structure and position among individuals. These anatomical variations can contribute to the development and clinical presentation of PS (Hicks et al. 2023). This chapter aims to comprehend the variations of the piriformis muscle and sciatic nerve and their implications in the pathogenesis and management of PS.

Sciatic nerve entrapment along its course results in conditions like sciatica and PS. PS is a painful condition responsible for 6% of low back pain cases (Mitra et al. 2014; Yeoman 1928). It is one of the non-discogenic causes of sciatica resulting due to trauma, inflammation, and degenerative changes to the piriformis muscle. However, rare structural variations can be one of the main causes of this syndrome (Ro and Edmonds 2018; Natsis et al. 2014). Therefore, awareness of the anatomical variation of the sciatic nerve and piriformis muscle is essential for clinical procedures such as hip arthroplasty, sciatic nerve block, and gluteal surgery. Understanding these variations can also minimize the iatrogenic injuries resulting from these procedures (Tomaszewski et al. 2016). The structural variation of the sciatic nerve, piriformis muscle, and their relations was first classified by Beaton and Anson into six categories in 1937 (Table 1).

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Table 1 Beaton and Anson classification (Beaton and Anson 1937)

Type a	Undivided nerve below the undivided muscle
Type b	Divisions of the nerve between and below the undivided muscle
Type c	Divisions above and below the undivided muscle
Type d	Undivided nerve between heads
Type e	Divisions between and above heads
Type f	Undivided nerve above the undivided muscle

Various researchers adopted this classification to categorize their findings. The two common groups of variations are the undivided sciatic nerve passing below the unsplit muscle. At the same time, the other is the unusual appearance of the sciatic nerve exiting the gluteal region and entering through the greater sciatic foramen as an early split into tibial and common peroneal nerves (Tomaszewski et al. 2016). There is a need to provide a compendious and evidence-based evaluation of composite anatomical variations of the sciatic nerve, piriformis muscle, and their relationship during routine dissection of cadavers.

2 Anatomy of the Piriformis Muscle and the Sciatic Nerve

The sciatic nerve is the largest nerve carrying ventral rami of L4-S3 spinal nerves, which lies inferior to the piriformis muscle in the gluteal region and is the longest and thickest nerve in the human body. It courses through the pelvis, passing beneath or through the piriformis muscle in approximately 85% of individuals. The provenance of the anatomical variation in the pelvic region is mostly embryologically influenced. The various sites of origin of the piriformis muscle include the second to fourth sacral segment (pelvic surface), the upper margin of the greater sciatic notch, and the sacrotuberous ligament. Post origin, it tends to exit the pelvis through the greater sciatic foramen along with the ischiadic nerve and inserts into the greater trochanter of the femur (Natsis et al. 2014; Parson 2009).

Its unique position and shape allow it to function as an external hip joint rotator, aiding in walking and running. The piriformis muscle and sciatic nerve are key players in the complex network of the human anatomy. This anatomical relationship poses a potential risk for compression or entrapment of the sciatic nerve by the piriformis muscle, leading to the development of piriformis syndrome (Berihu and Debeb 2015). In some individuals, the sciatic nerve may pass through the muscle belly itself, while in others, it may travel adjacent to or beneath it. This variability contributes to the complexity of diagnosing piriformis syndrome, as the same site and mechanism of nerve impingement may differ from person to person.

Muscular branches of the nerve are distributed to all the hamstrings. Sensory branches supply the whole tibial and foot areas except for the anteromedial tibial region and medial margin of the foot supplied by the saphenous nerve. The Tibial component is formed by a ventral branch of the ventral rami of L4 to S3 spinal nerves, while the dorsal branch of the ventral rami of L4 to S2 spinal nerves forms the common peroneal nerve. There is a high likelihood of variability of the sites of the division of the sciatic nerve into its components, where the commonest site is the junction of the middle and lower third of the thigh, near the popliteal fossa's apex (Amlan et al. 2023).

When the piriformis muscle becomes tight, inflamed, or hypertrophic, it can compress or irritate the sciatic nerve, resulting in a cascade of symptoms. The classic symptoms associated with piriformis syndrome include deep gluteal pain, radiating pain down the back of the thigh and leg, numbness, tingling, and even weakness in the affected limb. However, due to the shared pathways and overlapping symptoms with other conditions like lumbar disc herniation or spinal stenosis, accurately pinpointing the source of these symptoms becomes a diagnostic challenge. Therefore, understanding the intricate anatomy and relationship between the piriformis muscle and the sciatic nerve is crucial in unraveling the complexities of piriformis syndrome. By comprehending the potential sites of nerve entrapment and the mechanisms by which the piriformis muscle can impinge upon the sciatic nerve, healthcare professionals can navigate the diagnostic process more effectively and provide targeted treatment for those suffering from this enigmatic condition.

3 Diagnostic Challenges of Piriformis Syndrome

Piriformis syndrome presents a diagnostic challenge due to its complex nature and elusive symptoms. The condition involves dysfunction of the piriformis muscle, located deep in the gluteal region, which plays a crucial role in hip function. However, diagnosing piriformis syndrome proves difficult due to its overlap with sciatica, as the piriformis muscle and sciatic nerve are closely intertwined. The absence of definitive diagnostic tests, such as X-rays and MRIs, further complicates the process, as these imaging techniques may fail to capture the subtle changes in muscle morphology or detect nerve entrapment. As a result, patients often endure inconclusive examinations and trials, leading to uncertainty and frustration. Another challenge stems from the lack of universally accepted diagnostic criteria for piriformis syndrome. Clinicians rely on clinical signs, symptomatology, and physical examination findings to reach a diagnosis, but the subjective nature of pain, diverse symptom presentation, and overlap with other conditions often lead to misdiagnosis or delayed recognition. The complexity of piriformis syndrome is evident in its varied symptom manifestations. Some individuals experience localized buttock pain, while others endure radiating discomfort down the leg or numbness and tingling sensations. This diversity further complicates the identification and confirmation of the syndrome (Siddiq 2018; Chang et al. 2023).

4 Variations of the Piriformis Muscle, Sciatic Nerve and Piriformis Syndrome

Variations in the piriformis muscle, sciatic nerve, and the manifestations of piriformis syndrome further contribute to the diagnostic challenges associated with this condition. Anatomical variations of the piriformis muscle are not uncommon, with reports suggesting that the muscle may have different origins, insertions, or even absence in some individuals. These variations can alter the spatial relationship between the piriformis muscle and the sciatic nerve, potentially increasing the likelihood of nerve compression or entrapment.

Similarly, the sciatic nerve can exhibit variations in its course and relationship with the piriformis muscle. For example, in some individuals, the sciatic nerve may split into two distinct branches, passing either above or below the piriformis muscle. Alternatively, the nerve may have multiple divisions or communicate with other regional nerves. Such anatomical variations make it challenging to predict the precise location and mechanism of nerve compression, further complicating the diagnosis of piriformis syndrome.

Moreover, PS can manifest in diverse ways, with individual symptom presentation variations. For example, while the classic symptoms of deep gluteal pain and radiating leg pain are often reported, some patients may experience predominantly buttock pain without leg involvement. Others may present with symptoms mimicking lumbar radiculopathy, making it difficult to differentiate between piriformis syndrome and other conditions affecting the lower back and lower limb.

These variations in the piriformis muscle, sciatic nerve, and the clinical presentation of piriformis syndrome highlight the need for a comprehensive and individualized approach to diagnosis and management. Healthcare professionals must be aware of these anatomical variations and consider them when evaluating patients with suspected piriformis syndrome. In addition, a thorough history, physical examination, and diagnostic tests, such as electromyography and dynamic imaging, may be necessary to confirm the diagnosis and rule out other potential causes of similar symptoms.

In summary, the variations in the piriformis muscle, sciatic nerve, and the manifestations of piriformis syndrome contribute to the complexity of diagnosing this condition. Therefore, understanding and recognizing these variations is crucial for accurate diagnosis and effective treatment, ensuring that individuals suffering from piriformis syndrome receive the appropriate care tailored to their unique anatomical and symptomatic presentation.

5 Review of Literature

PS is considered an atypical, contentious neuromuscular disorder resulting from compression of the sciatic nerve at the level of the piriformis muscle. The diagnosis has been a major challenge due to difficulties finding the exact cause of the pain and a paucity of confirmed clinical and definitive diagnostic criteria like radio imaging or electrodiagnostic testing (Ro and Edmonds 2018; Miller et al. 2012). The anomalous variation of the sciatic nerve, piriformis muscle, and their variable relationship can lead to entrapment and nerve compression, resulting in piriformis syndrome (Adibatti and Sangeetha 2014). Such variations must be emphasized as they play a crucial role in the basis of sciatica and the pain etiology (Erdewyk 2017). Studies have explored various cadavers to provide awareness and strengthen the findings of the sciatic nerve variation and its relation to the piriformis as a probable cause for non-discogenic sciatica and other pain etiologies.

A study on 40 dissected gluteal regions in the Nepalese cadavers encountered 92.5% type-a, 2.5% type-b, and 5% type-c nerve-muscle relations (Jha and Baral 2020). This study also observed an altered anatomical variation where a higher sciatic nerve division occurs, and the common peroneal component passes between the two heads of the piriformis muscle (Fig. 1).

Another study from India revealed similar findings with 92% of type-a, 2% of type-b, and 6% of type-c with dissection on gluteal regions (Adibatti and Sangeetha 2014). Desalegn et al. found 92% of type-a, 3% of type-b, and 5.5% of type-c while dissecting 36 gluteal regions of the northern Ethiopian population (Desalegn and Tesfay 2014). Another study revealed 77% of type-a, 20% of type-b, and 3% of type-c from Polish cadavers (Haladaj et al. 2015). Berihu et al. research on 56 Ethiopian cadavers marked 89% of type-a, 9% of type-b and 2% of type-c relations (Berihu and Debeb 2015). Various studies on Turkish, Brazilian, and Kenyan cadavers reported 76%, 90%, and 90% type a relation and 24%, 10%, and 10% of type b-f relations, respectively (Guvencer et al. 2008; Brooks et al. 2011; Ogeng'o et al. 2011). Another substantial research resulted in 79% type-a, 14% type-b, 4% type-c, and 2% type-d relationship between the sciatic nerve and piriformis muscle in the Czech Republican cadavers (Pokorny et al. 2006). There was a similarity in a finding of research conducted on 100 Indian cadavers, which showed 85% type-a, 9% type-b, 3% type-c, and 3% type-d relations (Sinha et al. 2014). Studies have also revealed 2.2%, 10%, 0.35%, and 3% type-d relations, respectively (Natsis et al. 2014; Brooks et al. 2011; Pokorny et al. 2006; Sinha et al. 2014). Greek research on 290 cadavers revealed 0.35% extremely rare type-f relation (Natsis et al. 2014). Some studies on 24 Malaysian and 102 American cadavers have reported 83.4% and 88.2% type-a relations and 16.6% and 11.8% type b-f relations, respectively; however, type-d, type-e, and type-f relations were absent (Khan et al. 2016; Lewis et al. 2016). Another research on 120 American cadavers detected 97.5% type-a and 2.5% type-b relations (Erdewyk 2017).

Fetal cadaver research in the Turkish population revealed 98% type-a 1% type b, and 1% type c relations (Sulak et al. 2014). The probability of anatomical variation

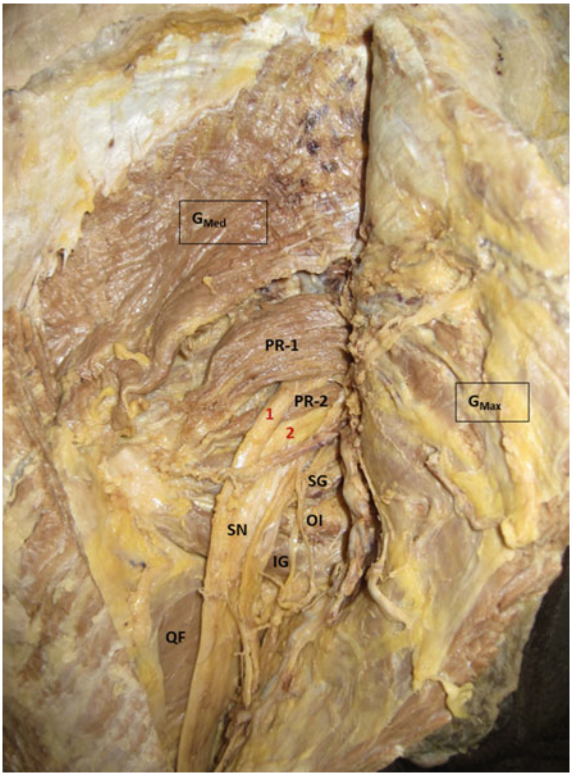

Fig. 1 Higher division of sciatic nerve and split piriformis muscle with two heads. 1: common peroneal superior head of piriformis; 2: tibial component; PR-1: inferior component; PR-2: head of piriformis; GMax: gluteus maximus; GMed: gluteus medius; SN: sciatic nerve; SG: superior gemellus. Figure from open access article: Original work: Jha AK, Baral P. Composite Anatomical Variations between the Sciatic Nerve and the Piriformis Muscle: A Nepalese Cadaveric Study. Case Rep Neurol Med. 2020 Mar 31;2020

in cadavers makes it essential for medical professionals to be aware of the potential complications during medical or surgical interventions (Smoll 2010). Jonathan et al. focused on the anatomical variation that plays a significant role in causing PS; however, the unassociated variations were ruled out due to the difficulty in their identification (Erdewyk 2017). The source of refractory sciatic pain due to anatomic variations is rare. Despite the recognition of these variations in the early twentieth century, these findings are uncommon both clinically and radiologically. This historical diagnostic difficulty arises due to the inability to localize the source of pain in PS. Therefore, it is usually a diagnosis of exclusion made by clinical findings (Cassidy et al. 2012).

Neuroimaging techniques are emerging and gaining popularity, and therefore, researchers and neuro physicians will benefit more precisely in recognizing, diagnosing, treating, and managing the pain associated with nerve entrapment due to composite piriformis-sciatic nerve anomalies. As a future implication, it is important to emphasize the study of the embryological basis of these structural variations and their origins.

Variations in the anatomical division of the sciatic nerve are commonly reported. An unusual variation of the sciatic nerve in relation to the superior gemellus and the presence of anomalous muscle has also been reported. The anomalous communicating branches of the posterior cutaneous femoral nerve with tibial and common peroneal nerve and the presence of an anomalous muscle originating from the greater sciatic notch and inserted at ischial tuberosity have been encountered during cadaveric dissections. A newer term, 'Sciaticotuberosus,' has been applied based on muscular attachments. Such variations hold clinical significance as they may contribute to piriformis syndrome, coccydynia, non-discogenic sciatica, and popliteal fossa block failure leading to local anesthesia toxicity and blood vessel traumatization (Amlan et al. 2023).

6 Conclusion

In this chapter, we have embarked on a journey into the intricate and perplexing world of piriformis syndrome, focusing on the composite anatomical variations between the sciatic nerve and the piriformis muscle that contribute to the diagnostic challenges associated with this condition. The piriformis muscle and the sciatic nerve, intimately intertwined within the gluteal region, have a delicate relationship that can become the root cause of piriformis syndrome. However, the complexity arises from the variations in their anatomical configuration, which significantly impact the likelihood and site of nerve impingement or compression.

Anatomical variations in the piriformis muscle can include differences in origin, insertion, or absence in some individuals. In addition, such variations alter the spatial relationship between the muscle and the sciatic nerve, creating a dynamic landscape where nerve compression may occur uniquely and unpredictably. These composite anatomical variations form the foundation of healthcare professionals' diagnostic challenges when differentiating piriformis syndrome from other conditions. The sciatic nerve itself is not exempt from variations. It can exhibit divergent courses and relationships with the piriformis muscle. For instance, the sciatic nerve may split into distinct branches, passing either above or below the piriformis muscle. Multiple divisions or communication with other nearby nerves can further complicate the situation. The resulting anatomical variations affect the mechanics of nerve impingement, making diagnosing piriformis syndrome a complex puzzle to solve.

When confronted with piriformis syndrome, clinicians must decipher this intricate interplay between the sciatic nerve and the piriformis muscle. The variability in their anatomy necessitates meticulously evaluating each patient's unique configuration, ensuring that no two cases are treated the same. In addition, it demands a comprehensive understanding of the variations and their potential impact on the manifestation of symptoms. Furthermore, the clinical presentation of piriformis syndrome varies from person to person, adding another layer of complexity. For example, some individuals may experience localized gluteal pain, while others may suffer from radiating pain down the leg or accompanying sensory disturbances. This diversity in symptomatology further emphasizes the significance of understanding the composite anatomical variations and their potential role in producing distinct patterns of pain and discomfort.

Despite the challenges posed by these composite anatomical variations, advances in diagnostic techniques offer hope for improved accuracy and efficiency. For example, dynamic imaging modalities, such as dynamic ultrasound, provide real-time visualization of the interaction between the piriformis muscle and the sciatic nerve, enabling healthcare professionals to identify abnormalities and better correlate them with clinical symptoms. These advancements pave the way for a more personalized and targeted approach to diagnosis and treatment.

In conclusion, the composite anatomical variations between the sciatic nerve and the piriformis muscle lie at the heart of the diagnostic challenges in piriformis syndrome. Understanding these variations and their impact on symptomatology is crucial for healthcare professionals striving to unravel the complexities of this condition. By embracing the nuances of anatomy, harnessing innovative diagnostic technologies, and tailoring treatment to individual presentations, we can navigate the intricate terrain of piriformis syndrome, ultimately providing relief and improved quality of life for those afflicted by this condition.

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