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The Importance of Learning Anatomical Variation in Dissection Anatomy: Sciatic Nerve and The Piriformis Muscle

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1. Abstract

Human variation is a cornerstone of biomedical science and patient care. In a first-year anatomy course, medical students at one dissection table had difficulty finding the piriformis muscle in the gluteal region of their Donor. Once the deep fascias were carefully cleared away and the muscles, vessels, and nerves exposed, an atypical sciatic nerve and diminutive piriformis muscle were identified. The discovery of variants in human dissection is a primary, and often under-appreciated, benefit of the dissection laboratory. In clinical practice, understanding natural diversity can improve diagnosis, treatment and patient safety. This brief paper reviews the importance of observing anatomical variability in dissection laboratory, focusing on the gluteal region and its significance with respect to sciatic pain in patients.

2. Introduction

“Variability is the law of life”, William Osler [1]. Even in a world of digital anatomy, the human dissection laboratory is an educational model for active, team-based learning and the development of professional skills. Human anatomy remains the educational foundation for most medical professionals [2-5]. Evidence-based practices continue to support the notion that anatomy is best learned in the dissection laboratory. While approaches vary, a general framework involves a team of students working in concert to make important observations in human structure that provides a foundation for understanding clinical presentations [6, 7]. Among the most important observations are anatomical variations that contribute to clinical treatment and patient safety [8-10]. Variation in human anatomy introduces students to key components of clinical medicine: 1) each human is unique, and a “textbook” description or diagram may not be applicable to each patient; 2) even common pathologies can have variable presentations that confound clinical diagnosis and treatment [11-13]. Estimates of misdiagnosis in the US are as high as 12 million per year in primary care, resulting in nearly 1.7 million deaths and disabilities [13-15]. Understanding how anatomical variation can contribute to a diagnosis helps students appreciate patient uniqueness and instills a precedent for being objective and thorough in clinical examination. An archetype of anatomic variation is the course of the sciatic nerve in relation to the piriformis muscle [16]. The prevalence of sciatic nerve variants is relevant to clinicians performing procedures such image-guided injections, surgery to relieve pain in the gluteal region, and total hip arthroplasty [17, 18]. Variation in the sciatic nerve can contribute to clinical syndromes involving the sciatic nerve, including the speculative “piriformis syndrome”, where the sciatic nerve is theoretically constricted by the piriformis muscle. Sciatic pain can be quite debilitating, with numbness and/or pain in the gluteal and posterior lower limb. Specifically, there are multiple variants of the relationship between the sciatic nerve and the piriformis muscle, and some of these variants, while being endogenous (i.e. not from trauma), may predispose an individual to sciatic pain [19]. Human anatomical dissection integrates biomedical sciences in ways that clinicians and their patients can appreciate and introduces students to variants they may observe in the clinic. Dissection is an important foundation for clinical training [6, 9, 20, 21]. In an anatomy laboratory, body Donors are often former patients who generously gift their bodies to programs with the expectation their donation will enhance fundamental education in human anatomy and advance research in biomedical sciences and clinical care. Viewed from this perspective, the dissection laboratory becomes an effective method for introduction of variable relationships and diversity in the unique anatomy of patients relevant to individualized health care [6, 7, 9, 22, 23]. Learning about diversity in human body Donors in first-year anatomy can improve objectivity, and reduce the risks of misdiagnosis to improve effectiveness of patient care.

3. Dissection Method

A team of four first-year medical students completed a dissection of the gluteal region as part of the University of Washington's foundational medical school curriculum. The Donor for this dissection is an 88 year-old female, whose pain status is unknown, and the cause of death is listed as dementia. With the Donor in the prone position, the skin over the gluteal region is reflected laterally from the iliac crest and sacrum to expose the entire posterior thigh, the gluteus maximus, and the gluteus medius [24]. A space (pocket) is created between the gluteus maximus and medius by pushing fingers between the deep fascia. The gluteus maximus is cut away from its origins along the sacrum and sacrotuberous ligament and reflected laterally, carefully exposing the underlying superior and inferior gluteal neurovascular bundles, the gluteus medius, and the superior attachment of the gluteus minimus to the external surface of the ilium, just inferior to the iliac crest, the piriformis, obturator internus, and gemelli muscles (Figure 1). As the student dissection followed standard instructions, the students observed an unusually small piriformis muscle and an atypical sciatic nerve (Figure 2). The piriformis muscle originates on the anterior aspect of the sacrum at the second, third, and fourth sacral foramina, the superior margin of the greater sciatic notch and the sacrotuberous ligament. The muscle exits the pelvis through the greater sciatic foramen to form a tendinous insertion on the superior border of the greater trochanter (Figure 2). It was observed that the piriformis muscle separated two parts of the sciatic nerve on its path to the superior border of the greater trochanter. The insertion of the piriformis is just superior to the attachment of the fused tendons of the superior and inferior gemelli, with the obturator internus muscle on the medial surface of the greater trochanter. Functionally, the position of these attachments accounts for their collective actions as external/lateral rotators and abductors of the femur.

4. Formation of The Sciatic Nerve

The anterior divisions of the ventral rami of L4-5 form the lumbosacral trunk that then descends into the pelvis, uniting with ventral rami of S1-S3 emerging from the sacral foramina to form the sciatic nerve, the largest nerve in the human body. The sciatic nerve includes components of the common fibular (peroneal) nerve (CFN, L4-S2) and the tibial nerve (TBN, L4-S3). It descends on the ventral surface of the piriformis muscle in the posterior pelvis, passes through the greater sciatic foramen deep to the piriformis muscle (viewed from posterior) to enter the posterior thigh, distal to the greater trochanter and ischial tuberosity [25] (Figure 1). In the most common variant, the united components (CFN and TBN) continue as a single sciatic nerve descending between and innervating the hamstring muscles until the superior boundary of the popliteal fossa where the sciatic nerve separates into distinct functional components, CFN and TBN. As one of the two major branches of the sciatic nerve, the CFN supplies the short head of the biceps femoris in the posterior thigh, as well as becoming the major nerve of the lower leg where it innervates the anterior and lateral muscular compartments. The anterior compartment includes the tibialis anterior muscle, extensor hallucis longus muscle, and the extensor digitorum longus muscle, primarily responsible for extension of the ankle. The lateral muscular compartment of the lower extremity includes the fibularis longus and the fibularis brevis muscles responsible for stabilization of the ankle and eversion of the foot [26]. As the sciatic nerve descends through the posterior thigh, the TBN component gives off branches to the hamstring muscles (long head of the biceps femoris, the semitendinosus, semimembranosus and the vertical fibers of the adductor magnus). These muscles are powerful flexors of the knee and extensors of the hip that are commonly injured in athletes. In the lower limb, the TBN supplies the superficial and deep muscles of the posterior compartment. The gastrocnemius, plantaris, soleus, and popliteus are superficial. The tibialis posterior, flexor hallucis longus, and flexor digitorum longus are deep in the posterior compartment. The tibial nerve exits the posterior compartment of the leg through the tarsal tunnel behind the medial malleolus in the ankle, to supply intrinsic muscles of the sole of the foot and sensation. In humans the sciatic nerve leaves the gluteal region as a single structure. The Class A variant is the most common (Figure 3), far more common than Class B, with Class C, D, E and F being relatively rare [17, 18, 21, 22, 27-31]. In (Figure 3), the six classes of sciatic nerves are diagrammed with their relationships to the piriformis muscle and labeled with their approximate frequencies.

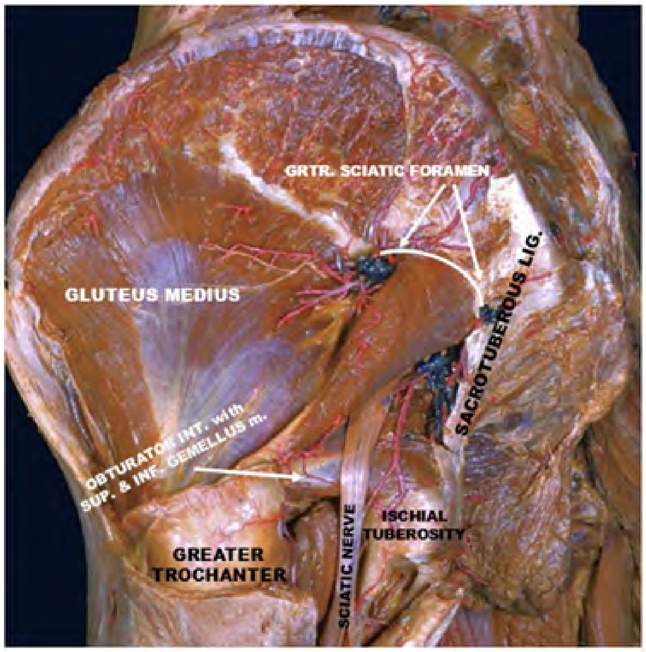

Figure 1: LEFT GLUTEAL DISSECTION in the PRONE POSITION (from the Bassett Collection [42]: In a standard dissection of the hip, reflection of the gluteal skin, superficial fascia and gluteus maximus exposes the gluteus medius, piriformis muscles and the sciatic nerve [42]. The piriformis muscle emerges from the greater sciatic foramen, runs laterally to form a tendinous attachment at the apex of the greater trochanter. The large sciatic nerve (L4-S3), almost 2 cm in diameter, exits the greater sciatic foramen, deep to the piriformis muscle. As it descends between the ischial tuberosity and the greater trochanter, the sciatic nerve passes over the obturator internus and the sup. & inf. gemellus muscles to enter the posterior thigh where branches supply the biceps femoris, semitendinous, semimembranosus and the ischial part of the adductor magnus muscles.

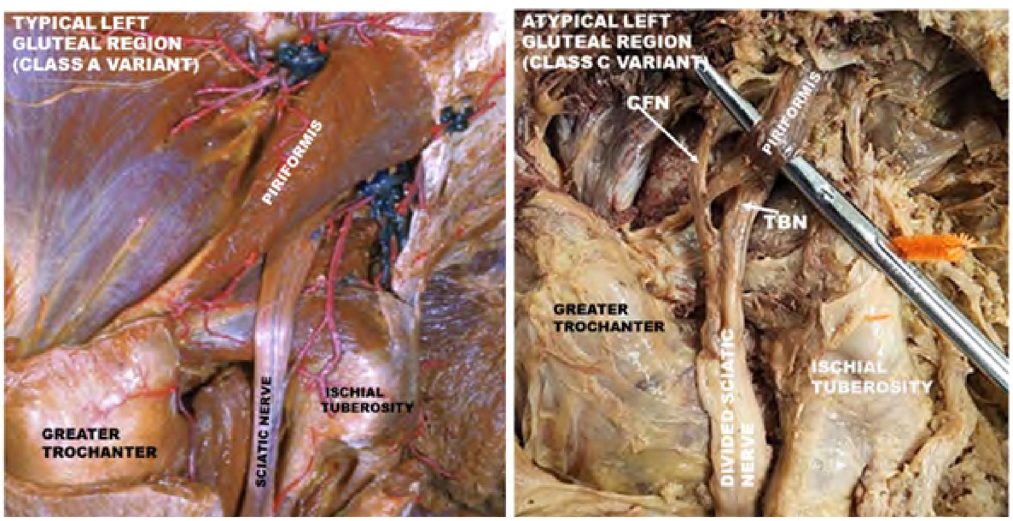

Figure 2: COMPARISON of DISSECTIONS of a TYPICAL and ATYPICAL PIRIFORMIS MUSCLE and SCIATIC NERVE. In a dissection, the piriformis muscle is most commonly observed to pass through the greater sciatic foramen, and cross laterally, superficial to the sciatic nerve to attach to the superior border of the greater trochanter. An undivided sciatic nerve is hidden deep to the piriformis as it passes through the greater sciatic foramen, descends over the sup. & inf. gemelli muscles and the obturator internus as they cross laterally to attach on the medial side of the greater trochanter. The relationship of the sciatic nerve as it descends into the posterior leg is observed. In this Donor, the tendon of a diminished piriformis muscle passes between the separated common fibular component (CFN) and tibial component (TBN) of the atypical sciatic nerve, to attach to the upper surface of the greater trochanter. The atypical sciatic nerve descends into the posterior leg as two nerve trunks. The classification variants is based on Beaton & Anson [27] (Fig 3). While the frequency of Class A is ~84%, values as high as 94% are reported [21].

5. Sciatic Variant Discovery

The sciatic nerve dissected by the students is an uncommon Class C variant (Figures 2 & 3). The CFN of the sciatic nerve separates from the TBN as it exits the greater sciatic foramen, deep to the gluteus maximus, and passes over the superior border of the piriformis muscle. The TBN follows the normal path of the sciatic nerve deep to the piriformis to enter the leg below the lower boundary of the piriformis (Figures 2 & 3). The variations are proposed to result from the embryology of the two primary components of the sciatic nerve.

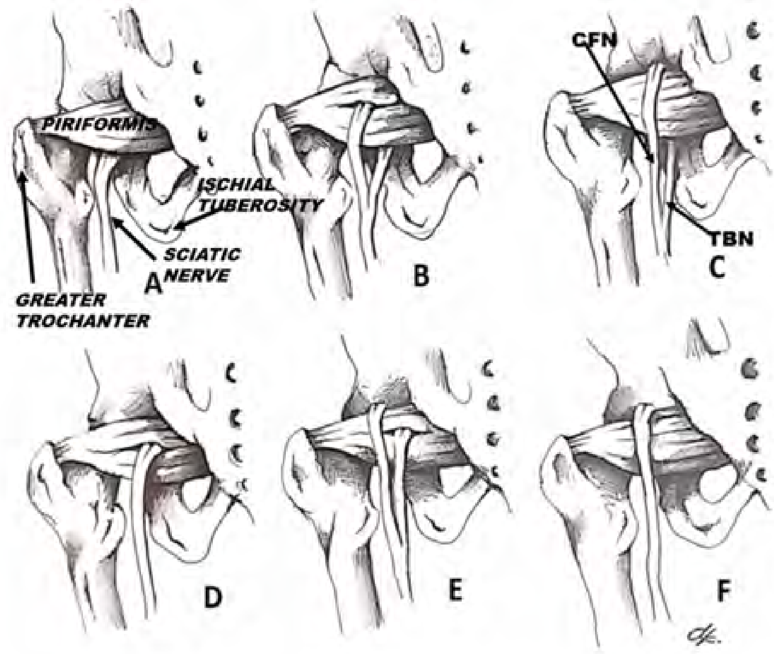

Figure 3: CLASSES of SCIATIC NERVE VARIATION [27] with APPROXIMATE FREQUENCIES (%).
A: typical anatomical pattern, the SN passes beneath the PM undivided. (~84%)
B: the CFN exits through the PM and the TBN exits below the PM. (~12%)
C: the CFN exits above the PM and the TBN and below the PM. (~1%)
D: the SN exits through the PM, as a single trunk. (<1%)
E: the CFN exits above the PM and the TBN through the PM. (<1%)
F: the SN passes undivided superficial the PM (<1%)
SN: Sciatic Nerve; PM: Piriformis Muscle; CFN: Common Fibular (peroneal) Nerve; TBN:Tibial Nerve

6. Mechanism

While the dissection of the left gluteal region in this Donor identified an uncommon Class C variant in the relationship between the sciatic nerve and piriformis muscle, the relationship on the contralateral right gluteal region is a typical Class A variant. Variation is not linked to genetics, and no reports indicate hereditary factors are involved. No signs of pathology or past surgical procedures are noted. The exact mechanism(s) for sciatic nerve variation remain unknown (Figure 3) [27].

7. Clinical Implications

In sciatica, pain is commonly caused by spinal pathologies including disc herniation, degeneration, rupture, or spinal stenosis where the nerve or its roots are compressed within or near the vertebral column [22]. In contrast, pain in "piriformis syndrome" is thought to be caused by entrapment and/or compression of the sciatic nerve by the piriformis muscle which, in theory, can be linked to sciatic nerve anomalies [19, 32]. At most, piriformis syndrome accounts for <6% of hip and lower back pain [33]. That said, a thorough retrospective, MRI correlative study of 1039 patients found no relationship between the anatomical variants of the proximal sciatic nerve and pain of piriformis syndrome [22]. In a separate study of 27 patients, three were identified with intense unilateral pain on one side and without pain on the other side. However, in these three individuals, an anomalous relationship between the sciatic nerve and the piriformis muscle was observed only on the contralateral, asymptomatic side [34]. Together, these findings suggest the need for more research to determine how the relationship between the sciatic nerve and piriformis muscle leads to "piriformis syndrome". Nonetheless, because variations in sciatic nerve anatomy may contribute to back and hip pain, a leading cause of disability, knowledge of the variability in the relationships between the sciatic nerve and the piriformis is necessary for accurate diagnosis and, most importantly, optimized clinical management [19, 35].

8. Conclusions

Finding a simple variation, like an anomalous sciatic nerve in a routine dissection assignment, emphasizes an important advantage of the human anatomy laboratory where variability can be understood as it is observed in patients. Significant anatomical variations often occur in the urinary system, lungs, the gastro-intestinal tract, vasculature to the brain and heart, and amongst other organ systems where they can cause pathology or complicate surgical repair when unrecognized [13, 36]. Anatomical variations can arise from human genetics, embryology, injury, aging, nutrition, or exercise and may or may not have functional effects. When human variation is not emphasized in traditional/classical textbooks, digital representations and atlases, students may lose confidence in their clinical knowledge and be inadequately prepared to help their patients [8, 9, 37, 38]. While the emphasis in introductory anatomy is normal structure, Donors represent the general patient population where variations are often encountered. There is no better place than a dissection laboratory to begin to educate future clinicians by teaching the significance of anatomical variation for improved in healthcare and patient safety [2, 39, 40]. Hip dissection can be more than a routine exercise in an anatomy laboratory. Here we present an experience in identification of a striking variation in the well-known neuro-muscular structure of hip. It can serve as a direct experience in cooperative learning, and the development of professional communication around an actual observation in a patient. The dissection experience deserves to be a valuable opportunity for talking through original observations in the dissection lab and development of professional skills that will be valuable in the clinic [23, 38]. For many students, anatomy laboratory may be their first experience with professional communication in a clinical setting. Team-based reasoning about phenotypic variations, including a scholarly interpretation of their observations, mirrors the experience in clinical presentations where communication is key to a differential workup. Each dissection table is a small group that works collaboratively to help other students understand their observations. In the dissection lab, verbal presentations simulate discussions with patients, as well as clinical colleagues [6, 7]. Recognition of diversity in the 3-D relationships between human structure and function, combined with an awareness of professional issues involving human dissection laboratory, is necessary for improving clinical care [13, 39, 41]. For most students, the anatomy laboratory is their first experience with patient variation represented by the generous body Donors who make an extraordinary gift to the education of healthcare professionals. The anatomy laboratory is an environment where students need to carefully consider the human body to which they are assigned. It is a time for students to reflect on death and dying of patients and the thoughtfulness that leads Donors to make such an unselfish gift. This brief report summarizes the value of dissection anatomy in the context of first-year medical education with an emphasis on anatomical variation, interactive teamwork, problem solving and professionalism [2, 3, 20, 23, 40, 41].

9. Lessons Learned

What causes the pain experienced in sciatica?

How does sciatica present in a patient and differ from piriformis syndrome?

Does piriformis syndrome exist or is it a diagnosis of convenience based on the close association of the sciatic nerve and piriformis muscle, when other explanations seem not to explain sciatica?

The hypothesis that sciatic pain correlates with sciatic nerve variants needs be tested to establish the correlation between variant imaging in patients with a quantitative evaluation of sciatic pain, if one exists.

Please consider the evidence and decide.

10. Acknowledgements

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11. Conflict of Interest

The authors have no conflicts to disclose.

12. Ethical Considerations

Results in this manuscript are unpublished and original. The co-authors meet criteria for authorship. Information and statements from other sources are accurately referenced. Methods are consistent with policies on best practices as described by the Committee on Publication Ethics (COPE).

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