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ORIGINAL PAPER

Redefining Sciatic Nerve Division Patterns: Cadaveric Study Introducing a Novel Index-Based Classification for Enhanced Clinical Precision

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ABSTRACT

Background: *Increasing anatomical studies reveal considerable variability in sciatic nerve (SN) division, posing challenges in orthopaedic, neurosurgical and anaesthetic procedures. To address limitations in current classification models, this study introduces a novel sciatic nerve division index (SNDI) for precise sub-classification of SN bifurcation levels.*

Methods: *Fifty-eight lower limbs from 29 formalin-fixed adult cadavers were dissected to trace SN bifurcation beyond the lower border of piriformis (Beaton and Anson Type A). These were further subtyped as Type AI (proximal), AII (mid-thigh) and AIII (distal) based on the vertical bifurcation level using SNDI-a reproducible morphometric tool.*

Results: *Among the 58 limbs, 42 (72.41%) showed extra-pelvic (Type A) bifurcation. Of these, mid-thigh (Type AII) was most common (44.8%), followed by proximal (Type AI) in 29.3% and distal (Type AIII) in 25.9%. Non-Type A variants constituted 27.58%. Although more variations were seen in males, differences between male and female and left and right sides of the same cadaver were statistically insignificant.*

Conclusion: *This study underscores the high variability in SN division and the inadequacy of conventional models. The SNDI system improved consistency and anatomical localization of extra pelvic bifurcation of SN, improving procedural safety and guiding future research and education.*

Keywords: anatomical variation, classification, piriformis syndrome, tibial nerve, common peroneal nerve.

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INTRODUCTION

The sciatic nerve (SN), also known as nervus ischiadicus, exits the pelvis through the greater sciatic foramen, usually passing inferior to the piriformis muscle (PM), and courses through the gluteal region and posterior thigh before bifurcating into its terminal branches: the tibial nerve (TN) and common peroneal nerve (CPN) (1, 2). These branches provide motor and sensory innervation to the majority of the lower limb. Anatomical variations in the relationship between the SN and PM are well established and have significant clinical implications. Aberrant courses or high bifurcation of the SN may lead to piriformis syndrome, failed or incomplete sciatic nerve blocks and increased risk of iatrogenic nerve injury during posterior hip surgeries or gluteal interventions (3). Therefore, precise knowledge of the course and branching pattern of the SN is essential for surgeons, anaesthesiologists and radiologists.

The classical Beaton and Anson classification (Types A-G) remains the most widely referenced system for describing SN-PM relationships. In this scheme, Type A, where the undivided SN exits below the PM, is the most common. Other types describe partial or complete division of the SN that passes above, through, or around the PM belly (4). However, this classification focuses solely on SN-PM positional relationships and does not consider the level of SN bifurcation. This variation is particularly relevant in procedures requiring targeted nerve blocks or posterior surgical approaches (5-7).

Many recently identified patterns of SN division fall outside the classical model, especially with the increased use of high-resolution imaging (magnetic resonance imaging – MRI) and meticulous cadaveric dissection (4, 8). While MRI provides in-situ visualization, the cadaveric study remains the gold standard because it allows direct, precise observation and measurement of the sciatic nerve and its division pattern. Comprehensive literature search revealed limited prior work addressing the specific morphometric parameters required for an index-based classification of SN division.

The current study proposes a new morphometrically driven framework: the SN division classification (SNDC). Central to this system is the sciatic division index (SNDI) – a quantitative tool that expresses the level of SN bifurcation as a percentage of the nerve's total length, measured from the greater sciatic foramen to the apex of the popliteal fossa. This allows for a normalized and reproducible description of bifurcation levels across individuals and populations.

By integrating both positional and morphometric criteria, the SNDC intends to provide a more comprehensive and clinically relevant classification system.

MATERIAL AND METHODS

This cadaveric study was conducted over a six-year period (2019–2024) in the dissection hall of the Department of Anatomy, All India Institute of Medical Sciences, Bathinda, Punjab, India. The study was ethically approved by the Institutional Ethics Committee vide letter number IEC/AIIMS/BTI/2026/04/08.

A total of 58 lower limbs from 29 formalin-fixed cadavers (18 males and 11 females), aged between 45 and 92 years, were included. All cadavers were obtained through the institution’s voluntary body donation program, with documented informed consent specifying their use for educational and research purposes. The specimens were preserved in 10% formalin solution.

Inclusion criteria comprised intact lower limbs with preserved musculature and bony landmarks in the gluteal and posterior thigh regions. Exclusion criteria included specimens with any evidence of pathological changes, trauma, surgical intervention, or deformities affecting the anatomy of the gluteal region or lower limb.

The initial dissection of each cadaver was performed in the prone position following standard anatomical protocols. The skin, superficial fascia and gluteus maximus muscle were incised vertically, and the reflected muscle flaps provided exposure of the PM and SN. The SN was traced distally along its course until its bifurcation into the TN and CPN. While dissecting, complete removal of all fat and fascia was intentionally avoided because over-cleaning can distort the natural anatomical relationships. Excessive stripping may shift or stretch the SN, potentially altering the accuracy of morphometric measurements.

For each specimen, the type of SN division was recorded bilaterally using a tabular format in

Microsoft Excel. Photographic documentation was obtained using an iPhone 14 Pro (13 MP resolution). To ensure classification accuracy and reduce observer bias, two independent anatomists verified each observation.

The level of bifurcation was documented using the inferior border of the PM as a fixed anatomical reference point. Measurements were taken using standard tools, ruler, yarn and pins and recorded in millimeters. Each measurement was taken twice and the average value was used for analysis. Data entry was done in Microsoft Excel.

To evaluate intra-observer reliability, all measurements were repeated by the principal investigator after a one-month interval. These were compared with initial values to assess consistency and reproducibility.

Proposed classification system: sciatic nerve division index (SNDI)

Based on observed variation in extra-pelvic SN bifurcation (Type A, *as per* Beaton and Anson), a new classification system is proposed, aiming to provide a standardized and reproducible morphometric framework for clinical and anatomical reference.

In this system, cases where the SN emerged from the pelvis as a single trunk below the piriformis muscle and bifurcated distally (Type A) were further subclassified using the SNDI) – a ratio representing the relative bifurcation level along the posterior thigh:

SNDI=distance between the lower border of piriformis to the bifurcation point (D)/total length from the lower border of piriformis to the apex of the popliteal fossa

The SNDI was expressed as a percentage, and the cases were grouped as follows:

- Type A-I: proximal division: SNDI < 20%, with bifurcation occurring between the inferior border of the piriformis and the upper third of the thigh;
- Type A-II: mid-thigh division: SNDI 20–80%, with bifurcation occurring between the upper and middle third of the thigh.
- Type A-III: distal division: SNDI > 80%, with bifurcation occurring in the lower third of the thigh or within the popliteal fossa.

This classification provides a quantitative and location-based refinement of Type A SN variants, which are most commonly encountered in clinical and anatomical settings. The SNDI offers a continuous and objective measure, enhancing clarity in communication and potential utility in surgical planning, radiological interpretation and anatomical education.

Statistical analysis

Statistical analysis was performed using IBM SPSS® v29. Categorical data were expressed as frequencies and percentages, while numerical data were summarized as mean ± standard deviation (SD). Group differences (by side and sex) were analyzed using Chi-square/Fisher's exact test for categorical variables and unpaired t-tests for continuous data. A p-value < 0.05 was considered statistically significant. ❑

RESULTS

Among the 58 limbs, 42 (72.41%) showed extra-pelvic (Type A) bifurcation (SN emerges as a single trunk beyond the lower border of the PM (Figure 1). Out of these type A, mid-thigh (Type AII) (Figure 2) was most common (44.8%), followed by proximal (Type AI) (Figure 3) in 29.3% and distal (Type AIII) (Figure 4) in 25.9% (Table 1). Non-Type A variants constituted 27.58%. Although variations were more commonly seen in males, the differences between sex and between left and right sides of the same

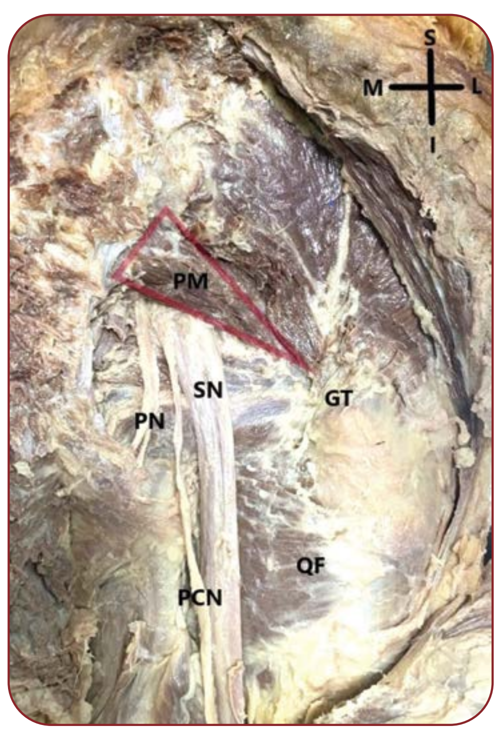

FIGURE 1. Sciatic nerve emerges as a single trunk beyond the lower border of piriformis muscle (PM). QF=quadratus femoris; GT=greater trochanter; PN=pudendal nerve; SN=sciatic nerve; TN=tibial nerve; PCN=posterior cutaneous nerve of thigh; S=superior; I=inferior; M=medial; L=lateral

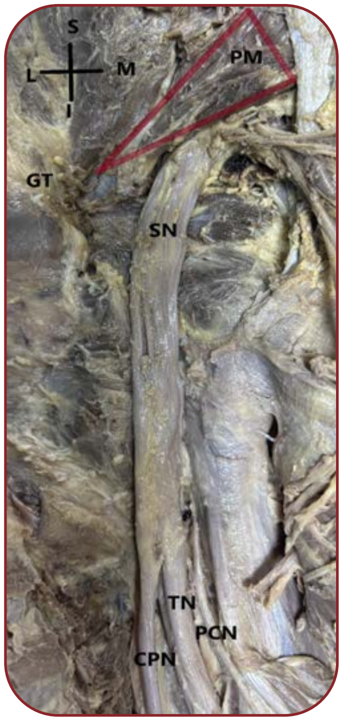

FIGURE 2. Type A-I: proximal division of SN. Bifurcation occurs between the inferior border of the piriformis and the upper third of the thigh. GT=greater trochanter; PN=pudendal nerve; SN=sciatic nerve; TN=tibial nerve; PCN=posterior cutaneous nerve of thigh; S=superior; I=inferior; M=medial; L=lateral

FIGURE 4. Type A-III: distal division. Bifurcation occurs in the lower third of the thigh or within the popliteal fossa. GT=greater trochanter; SN=sciatic nerve; TN=tibial nerve; CPN=common peroneal nerve; PA=popliteal artery; PV=popliteal vein; SM=semimembranosus; BF=biceps femoris; S=superior; I=inferior; M=medial; L=lateral (usual anatomical situation described in anatomical handbooks and atlases)

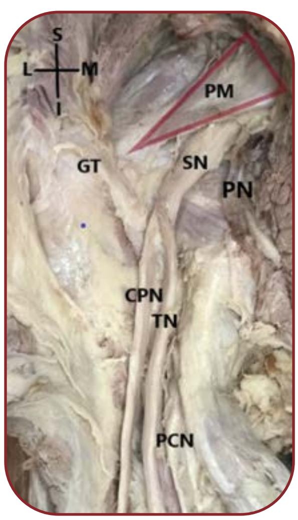

FIGURE 3. Type A-II: mid-thigh division. Bifurcation occurs between the upper and middle third of the thigh. GT=greater trochanter; SN=sciatic nerve; TN=tibial nerve; CPN=common peroneal nerve; PCN=posterior cutaneous nerve of thigh; S=superior; I=inferior; M=medial; L=lateral

TABLE 1. Prevalence of SN variation types with respect to sex and side

Type of SN		Males n (%)		Females n (%)		Total
		Rt	Lt	Rt	Lt	n (%)
Type A	Type A-I (proximal division)	-	3 (16.7)	-	-	3 (5.3)
	Type A- II (mid-thigh division)	10 (55.6)	7 (38.9)	5 (45.4)	3 (27.3)	25 (43.1)
	Type A-III (distal division)	2 (11.1)	3 (16.7)	4 (36.4)	5 (45.4)	14 (24.1)
Non-Type A		6 (33.3)	5 (27.7)	2 (18.2)	3 (27.3)	16 (27.5)
Total		18 (100)	18 (100)	11(100)	11(100)	58 (100)

cadaver were statistically insignificant. The SNDI system improved consistency and anatomical localization. ❑

DISCUSSION

The sciatic nerve, first comprehensively described by Ambroise Paré in the 16th century, has long fascinated anatomists due to its considerable variability. Early observations of its bifurcation were documented by Cruveilhier in the 19th century (9), and since then, numerous cadaveric and radiological studies have confirmed significant variation in both its course and division pattern, particularly in relation to the PM (10, 11). These anatomical differences have critical clinical implications, influencing the presentation and management of conditions like piriformis syndrome (PS), as well as the outcomes of procedures such as hip surgeries, SN blocks and posterior thigh interventions (12-14).

In our study, we observed notable variability in the level of SN bifurcation. The most frequent configuration identified was Beaton and Anson's Type A pattern, where the undivided SN passes beneath the PM. This occurred in 72.5% of our cases, lower than the global pooled prevalence of 85.2% reported by Tomaszewski *et al* (15). Interestingly, when compared to similar studies from other African cohorts including Ethiopian, Kenyan and Ugandan populations, where Type A occurs in approximately 85.9% of cases (16-18), our findings suggest a comparatively higher rate of anatomical variation within the South African sample studied.

Focusing specifically on the Type A variant, we aimed to explore the extra pelvic bifurcation patterns of the SN in greater detail. Traditionally, the SN is described as a single trunk formed by the TN and CPN, originating from the lumbosacral plexus (L4–S3) and exiting the pelvis via the greater sciatic foramen inferior to the PM (19). However, contemporary evidence has challenged this textbook depiction. Early or high bifurcation of the SN is now recognized as a common finding, with prevalence rates ranging from 16% to 60% depending on methodology and population sampled (20, 21). We did not find any statistically significant differences in bifurcation patterns between male and female and right and left side of the same cadaver. However, a greater absolute number of anatomical variants were observed in males but such findings have no link to athletic performances of both male and female performers. This trend is consistent with findings reported by Adibatti and Sangeetha (2014), who noted minor sex-based variations without significant clinical impact. Nevertheless, such insights could guide further investigation into population-specific surgical risk stratification (22).

In the present study, 72.41% of dissected limbs exhibited extrapelvic bifurcation conforming to Beaton and Anson's Type A configuration. Despite being the most common type, these findings underscore a dominant presence of anatomical variation, even in grossly normal cadaveric specimens. Our data align with studies that have described high SN division in more than half of cases, including those by Biffl *et al* (2015), which emphasize the need for clinical awareness during posterior approaches to the hip, SN blocks and surgeries involving the hamstrings (23). Various authors have studied the extra pelvic bifurcation of SN but none of them have classified them in a specified manner (Table 2).

Although the above-mentioned studies (18, 24-26) have described variations in the SN-PM relationship and levels of SN division, these descriptions are largely categorical and heterogeneous, limiting their direct clinical applicability. The proposed index-based SN division classification builds upon existing classifications by providing a standardized anatomically anchored framework that allows clearer localization of bifurcation patterns and facilitates comparison across studies. Anthropological body shape, specifically the proportions between the trunk and lower limbs, significantly influences the anatomical level of sciatic nerve division (bifurcation into tibial and common fibular nerves).

In this study, SNDI – a morphometric tool – was developed to subclassify Type A bifurcation patterns based on their vertical location along the posterior thigh. Rather than replacing earlier systems, this classification intends to integrate and refine prior observations into a unified model that enhances surgical planning, anaesthetic accuracy and anatomical reporting. This classification re-

Authors and population under study	Type A (outside pelvis)			Non-Type A (within pelvis)
	Proximal	Mid-thigh	Popliteal	
	Inferior border of the piriformis – upper 1/3 of the thigh	Junction of upper and middle 1/3 of the thigh	Lower 1/3 of the thigh – upper half of the popliteal fossa	
Ogeng'o *et al* (Kenyan) (18)	2.4	10.4	67.1	12.2
Prakash *et al* (Indian) (24)	5.3	2.3	75	17.4
Kiros & Woldeyes (Ethiopian) (25)	16	4	72	8
Grewal *et al* (Indian) (26)	20	6.7	63.3	10
Present study (Indian)	5.3	43.1	24.1	27.5

TABLE 2. Frequency (%) of division of SN at different levels in various studies

solves longstanding ambiguity in defining "high" versus "low" divisions, a dilemma that has plagued anatomical studies due to subjective zone demarcations (27). In our series, Type AII (mid-thigh bifurcation) emerged as the most common subtype, which was seen in 44.8% of cases. By using clear anatomical landmarks and vertical reference points, the SNDI enhances objectivity, offering a framework suitable for anatomical education, clinical imaging interpretation and operative planning.

Developmental insights

Variations in the extra pelvic bifurcation of the SN are believed to arise during the complex development of the lumbosacral plexus and the lower limb buds in early embryogenesis. The SN is formed by the union of the tibial (ventral divisions) and common peroneal (dorsal divisions) components from the sacral plexus (L4–S3). The final pathway of the nerve depends on the coordinated migration, growth and fusion of these components along with the surrounding musculoskeletal structures.

Disruptions or deviations during this developmental process, particularly in the relative growth of the PM, the greater sciatic foramen, and the course of nerve fibers may lead to anomalous courses or early bifurcation patterns of the SN. For instance, a delay or failure in the fusion of the tibial and peroneal divisions could result in high division of the nerve even before it exits the pelvis (18). Similarly, abnormal muscle development or differentiation, especially of the piriformis, may alter the spatial orientation of nerve branches, leading to variations such as nerve piercing through or above the muscle (2).

These anatomical variants are not pathological per se, but they have significant clinical relevance due to their association with piriformis syndrome, increased risk of nerve injury during procedures and challenges in regional anaesthesia.

Understanding the precise anatomical configuration of the SN and its bifurcation is crucial in multiple clinical disciplines. In the piriformis syndrome, CPN passing through or above the muscle lead to nerve compression within the muscle, causing sciatica-like buttock pain, particularly when the muscle is inflamed. In high bifurcation, the nerve divides in the pelvis rather than the thigh, causing the CPN to pass directly through the muscle, increasing vulnerability to injury. A high pre-existing division can lead to an incomplete SN block. In orthopaedic and neurosurgical procedures, including hip arthroplasty, posterior approaches to the pelvis and nerve decompression unrecognized variations can increase the risk of iatrogenic injury (28). In the realm of regional anaesthesia, especially during SN blocks, early SN division can lead to partial or failed blocks when the anesthetic is administered proximal to the bifurcation point, without separately targeting the TN and CPN (29).

Additionally, standardized morphometric indices like the SNDI may aid radiologists in localizing SN entrapments or variant courses more accurately during MRI assessment. This is especially valuable in distinguishing the piriformis syndrome from lumbar radiculopathies, which often present with similar clinical features. A precise anatomical framework supports more targeted diagnostic and therapeutic interventions, reducing both diagnostic delay and procedural complications.

Limitations and future scope

The use of formalin-fixed cadavers, that induces a 10-14% tissue retraction which may alter morphometric measurements, tissue softness, which otherwise ensures structural integrity and measurement accuracy, the lack of correlative imaging or intraoperative validation may limit the direct applicability of the present study. Future studies could focus on MRI-based validation of the SNDI in live patients, particularly in symptomatic cases of nerve entrapment or failed blocks.

Furthermore, integrating SNDI into 3D anatomical atlases and surgical simulation models may bridge the gap between gross anatomy and clinical practice. There is also scope for evaluating whether SNDI values correlate with anthropometric parameters or population-based genetic traits. ❑

CONCLUSION

Our study reaffirms the considerable anatomical variability of the SN, particularly its extra pelvic bifurcation patterns. The introduction of the SNDI offers a novel, objective and reproducible approach to sub classify these variations, with direct applications in teaching/learning (hhighlights anatomical variations, moving beyond textbook normal), surgical planning (identifies high-risk patients for nerve injury during posterior hip dislocations, total hip replacements), anesthesia (prevents failed popliteal nerve blocks, sciatic nerve block) and diagnostic imaging. As anatomical variations continue to emerge across populations, integrating morphometric precision with clinical awareness remains essential to uphold patient safety and procedural success. ❑

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