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# Anatomical Study of Posterior Sacral Foramina and its Clinical Importance

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## ABSTRACT

**Introduction:** sacral nerve stimulation is a common treatment used for various pelvic floor disorders like urinary and fecal incontinence. It consists of percutaneous introduction of electrodes through the posterior sacral foramina for stimulation of the target sacral spinal nerves.

**Materials and Method:** the present study was done to determine the surface anatomical landmarks of the sacrum to facilitate identification of the posterior sacral foramina. Ten adult cadavers were taken and different measurements were taken in relation to the posterior sacral foramina, the posterior superior iliac spine (PSIS) and the median sacral crest (MSC). A median coefficient of variation (CV) was determined.

**Results:** the diameter of the second sacral foramen showed the greatest variability. The distances between each individual foramen and the MSC had an acceptable variability (CV<20%) except for S3 foramen. In contrast, the distance between foramina had a high variability. The distance between PSIS and the second posterior sacral foramen was found to have an acceptable variability (CV<20%). However, the angle formed by a horizontal line between PSIS and a line between PSIS and S2 foramina had low variability.

**Conclusions:** detailed knowledge of the anatomy of the posterior sacral foramina may facilitate correct electrode placement and is complementary to the regular use of fluoroscopy.

**Keywords:** Sacrum; Posterior sacral foramina; Sacral nerve stimulation; Neuromodulation; Fecal incontinence.

## Introduction

Sacral nerve stimulation (SNS) is done for various pelvic floor disorders, such as urinary and fecal incontinence and constipation[1–5]. In this type of treatment, sacral spinal nerves which have an influence over the pelvic organs like bladder and rectum are stimulated in incontinent patients[6]. It is the approved treatment for patients who have not responded to medical and behavioural therapies. Electrodes are introduced through the posterior sacral foramina through a percutaneous approach and a low frequency stimulation is used to stimulate the sacral spinal nerves[1-5]. The ideal nerve to stimulate is sacral spinal nerve S3, as it supplies the pelvic organs involved with minimal influence over the legs and it provides the most desired effects with minimal adverse effects[6]. Precise localisation of the S3 or S4 sacral foramina (less common) is important for optimal stimulation. In the past, various bony landmarks such as the sciatic notch, midline sacral spinous processes, iliac crest, sacral hiatus, the tip of the coccyx, and ischial spine have been used to locate these foramina[7,8]. Anatomical variations of the sacrum and sacral spinal nerves make it difficult to perform SNS[7]. The aim of the present study was to describe the morphometry of the posterior sacral foramina in Indian cadavers and to locate them using bony landmarks like the median sacral crest and posterior superior iliac spine.

## Materials and Methods

The study was conducted on ten cadavers (1male, 9 females) of age ranging from 50 to 80 years available in the Department of Anatomy, Christian Medical College, Vellore. Cadavers having gross deformities of the sacral region were excluded from the study. This study was approved by the Institutional Review Board and Ethics Committee (IRB No. 10953).

The cadavers were placed in a prone position. All the soft tissues of the sacral region were removed and the sacrum was exposed.

The measurements were taken as shown in Fig. 1

Horizontal diameter of the S2, S3 and S4 posterior sacral foramina on each side.

Distance from the medial and lateral edges of the S2 and S3 posterior sacral foramina to the median sacral crest (MSC) on each side.

(iii) Distance between the medial edges of the left and right S4 posterior sacral foramina

Distance between the lateral edges of the left and right S4 posterior sacral foramina.

Distance (vertical distance) between the S2 and S3 and S3 and S4 posterior sacral foramina on both sides

(vi) Distance from PSIS to the S2 posterior sacral foramina on both sides.

(vii) Angle formed by an imaginary line running horizontally at the PSIS and a line joining the PSIS and the S2 posterior sacral foramina bilaterally.

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The measurements were taken using a digital Vernier caliper, measuring tape, and scale.

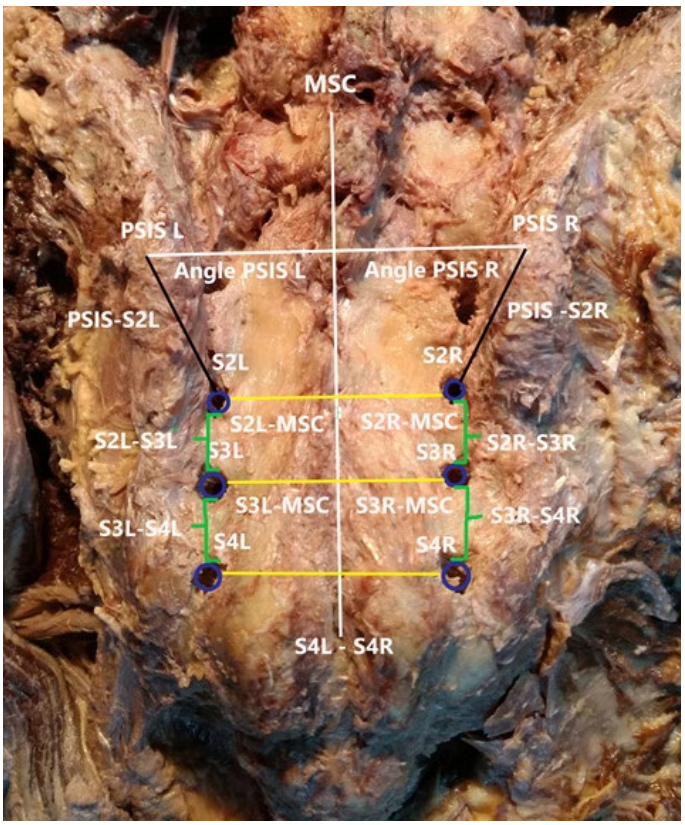


**Figure 1.** Yellow line - distance between sacral foramina and median sacral crest (MSC). Green bracket - distance between sacral foramina on each side. Black line - distance from each posterior superior iliac spine (PSIS) and second sacral foramina.

## Results

The median size of the sacral foramina was as follows: 6.5, 7.0, and 7.0 mm for the S2, S3 and S4 posterior sacral foramina, respectively (Table 1). No significant differences were found between sides.

The median distance between the medial edge of the S2 foramen and the MSC was 20 mm, and between the medial edge of the S3 foramen and the MSC was 15 mm. The median distance between the lateral edge of the S2 foramen and the MSC was 25 mm, and between the lateral edge of the S3 foramen and the MSC was 21 mm (Table 2).

The median distance between the medial edge of the left S4 foramen and the medial edge of the right S4 foramen was 37.5 mm. The median distance between the lateral edge of the left S4 foramen and the lateral edge of the right S4 foramen was 47.5 mm (Table 3).

The median distance between the S2 and the S3 foramina was 15 mm on the right side and 16.5mm on the left side. The median distance between the S3 and the S4 foramina was 15 mm on the right and left sides (Table 4).

The median distance from the PSIS to the S2 foramen was 30 mm on the right and left sides. The median of the angle formed by a line passing horizontally from the PSIS and a line between the PSIS and the S2 foramen was $51^0$ on the right side and $50^0$ on the left side (Table 5).

Statistical analysis to compare the differences between sides was done and it did not show any significant differences.

**Table 1.** Diameter of S2, S3, S4 foramina.

| | Right side | | | Left side | | | Combined measurements | | |
|---|---|---|---|---|---|---|---|---|---|
| | S2 | S3 | S4 | S2 | S3 | S4 | S2 | S3 | S4 |
| Median | 6.5 | 7 | 6.5 | 6.5 | 7 | 7 | 6.5 | 7 | 7 |
| Minimum | 4 | 5 | 5 | 3 | 5 | 5 | 3 | 5 | 5 |
| Maximum | 8 | 8 | 9 | 8 | 8 | 9 | 18 | 8 | 9 |
| Interquartile range | 1.8 | 1 | 1.8 | 2.5 | 0.7 | 2 | 2.2 | 1 | 2 |
| CV(%) | 20.8 | 16.3 | 19.9 | 26 | 15.8 | 21.3 | 22.9 | 15.6 | 20.1 |

All measurements in mm. Low variability CV< 10%, acceptable variability CV< 20%.

**Table 2.** Measurements from the sides of S2 and S3 posterior sacral foramina horizontally to median sacral crest (MSC).

| | Right side | | | | Left side | | | |
|---|---|---|---|---|---|---|---|---|
| | S2 Medial-MSC | S2 Lateral-MSC | S3 Medial - MSC | S3 Lateral-MSC | S2 Medial-MSC | S2 Lateral-MSC | S3 Medial – MSC | S3 Lateral-MSC |
| Median | 20 | 25 | 15 | 21 | 20 | 25 | 15 | 21 |
| Minimum | 19 | 24 | 14 | 18 | 20 | 23 | 15 | 19 |
| Maximum | 25 | 31 | 23 | 27 | 25 | 31 | 24 | 28 |
| Interquartile range | 2.5 | 3 | 4 | 1.5 | 1.8 | 3 | 4 | 1.5 |
| CV(%) | 10.4 | 9.6 | 21.7 | 14 | 8.8 | 10.5 | 22.2 | 13.6 |

All measurements in mm. Low variability CV< 10%, acceptable variability CV< 20%.

**Table 3.** Measurements between S4 posterior sacral foramina

| | Distance between medial sides of S4 | Distance between lateral sides of S4 |
|---|---|---|
| Median | 37.5 | 47.5 |
| Minimum | 30 | 40 |
| Maximum | 42 | 60 |
| Interquartile range | 5 | 5 |
| CV (%) | 10.1 | 12.1 |

All measurements in mm. Low variability CV< 10%, acceptable variability CV< 20%.

**Table 4.** Measured vertical distances between posterior sacral foramina.

| | S2-S3 Right | S2-S3 Left | S3-S4 Right | S3-S4 Left |
|---|---|---|---|---|
| Median | 15 | 16.5 | 15 | 15 |
| Minimum | 10 | 10 | 10 | 10 |
| Maximum | 20 | 20 | 20 | 20 |
| Interquartile range | 8 | 7 | 4 | 3 |
| CV (%) | 28 | 26.2 | 24.2 | 23 |

All measurements in mm. Low variability CV< 10%, acceptable variability CV< 20%.

**Table 5.** Measurements between posterior superior iliac spine and second posterior sacral foramina.

| | PSIS – S2 Right | PSIS – S2 Left | Angle PSIS – S2 Right | Angle PSIS – S2 Left |
|---|---|---|---|---|
| Median | 30 | 30 | 51 | 50 |
| Minimum | 20 | 20 | 46 | 46 |
| Maximum | 40 | 35 | 62 | 61 |
| Interquartile range | 5 | 6.5 | 4.4 | 3.5 |
| CV (%) | 18.5 | 17 | 9 | 8.3 |

PSIS - posterior superior iliac spine. Measurements in mm and degrees. Low variability CV< 10%, acceptable variability CV< 20%.

### Coefficient of variation

Regarding the diameter of the posterior sacral foramina, all the results had high variability except diameter of S3 foramina which had acceptable variability (CV=15.6) (Table 1). The distances between the medial and lateral sides of S2 foramen and the median sacral crest showed low variability. The distance between the lateral side of S3 foramen and the median sacral crest had acceptable variability whereas the distance between the medial side of S3 foramen and the median sacral crest showed high variability. The distances between the medial sides of S4 (CV = 10.1%) and the lateral sides of S4 (CV = 12.1%) showed acceptable variability. The vertical distances between the S2 – S3 foramina and S3 – S4 foramina showed high variability on both sides. The distance between the posterior superior iliac spine and S2 showed acceptable variability on both sides (CV = 18% and 17%). However, a low variability was found when looking at the angle formed by a line passing horizontally from the PSIS and a line between the PSIS and the S2 posterior foramina (CV = 9% on the right and CV = 8.3% on the left) (Table 5).

## Discussion

Sacral nerve stimulation (SNS) has been advocated for chronic voiding dysfunction, especially in patients with urinary symptoms refractory to conventional treatment[9,10]. Sensory and motor improvements have been seen in patients with fecal incontinence using SNS[2]. The correct identification of the posterior sacral foramina is important for successful sacral nerve stimulation[7,8]. In previous studies, identification of a particular posterior sacral foramen was done using various bony landmarks such as the sciatic notch, the midline sacral spinous processes, the iliac crest, the sacral hiatus and the tip of the coccyx[7,8]. In the present study, only the median sacral crest (MSC) and posterior superior iliac spine (PSIS) were used to identify the foramina, as they are easily palpable.

The maximum width of emerging sacral nerve roots at the foramina decrease in descending order. It has been found that, instrumentation of the SI foramen would result in a higher incidence of nerve root penetration and injury to the lateral sacral artery, as it lies close to this foramen[7]. The S2 nerve root also occupies a large part of its foramen. Hence, the S3 and S4 foramina appear the safest sites for insertion of needles and electrodes for electrical stimulation. Adipose tissue was found along with the S3 and S4 nerve roots in their foramina. This provided added protection by allowing the nerve roots to be pushed during procedures[7].

There are only two studies that look at bony landmarks in the sacral region related to the PSIS and the S2 posterior sacral foramina [11,12]. In the studies by Povo (2016) and McGrath *et al.* (2011), the angle formed by a line that runs horizontally at PSIS and a line joining the PSIS and the S2 posterior sacral foramen (angle PSIS–right S2 foramen) = 39.0 and angle PSIS–left S2 foramen = 51.0 in the study by Povo and 56.8 in the study by McGrath. In the present study the angle PSIS–right S2 foramen was 50.0 and PSIS–left S2 foramen was 51.0. The left angle was in accordance with that of Povo and McGrath[12,13].

In the study by Povo *et al.* (2016), there was great variability in the diameter of S2 foramen of the right side and acceptable variability on the left side, whereas there was great variability in the diameter of S2 on both sides in the present study. Povo *et al.* (2016) found great variability in the vertical distances between the foramina, except the right S2-S3 which had acceptable variability[14]. In the present study, there was great variability in the vertical distances between

the foramina on both sides. The distance between PSIS and S2 was 18.5 mm on the right and 17 mm on the left side in the present study which was similar to the findings by Povo *et al*. (26 mm on both sides)[13].

The present study provides data for correct localization of the posterior sacral foramina for sacral nerve stimulation. The most common complications associated with sacral nerve stimulation are: infections in 1–9% of cases and pain in 4–24% of cases. Complications related to electrode placement are poor positioning of the electrode (2–7%) and migration of the electrode (1–20%)[14-16].

## Conclusions

The results in the present study provide information for the surface localization of the different posterior sacral foramina using only two easily palpable anatomical reference points, the median sacral crest (MSC) and posterior superior iliac spine (PSIS). This model can be easily applied in most patients, complementing the regular use of fluoroscopy for the electrode placement.

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## Mini Curriculum and Author's Contribution

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