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Skeletal Radiology

The Sacral Foramina

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Abstract. The sacral foramina, particularly the first three, are not simple fenestrations. Each foramen is a Y-shaped complex of canals, all with indefinite margins. The complexes lie obliquely at approximately 45° to the coronal plane. An appreciation of these facts facilitates the recognition of the anatomy of plain films, tomographs, and computerized scans.

Key words: Sacrum, anatomy – Sacrum, foramina

Lesions of the sacral foramina are easily missed [5]. Their recognition depends on the identification of normal structures [3, 6, 7]. Although the anatomy has been well described by Whelan and Gold [8], further consideration of some aspects of the foramina, especially of the first three, may facilitate the recognition of sacral lesions.

Materials and Methods

Three sacra were used for this study. Specimen 1 was intact. Specimens 2 and 3 were sectioned (Fig. 1). Certain features were accentuated with barium (Figs. 3, 4, 6, and 10). Plain film radiography, tomography, and computed tomography were used to compare the anatomic features.

Discussion

Anatomy/Plain Film Radiography

The sacral foramina, which decrease in size from above down, are not simple fenestrations or cylinders. Each is a part of a Y-shaped canal, of which the anterior foramen forms the stem and the posterior and intervertebral foramina the two limbs

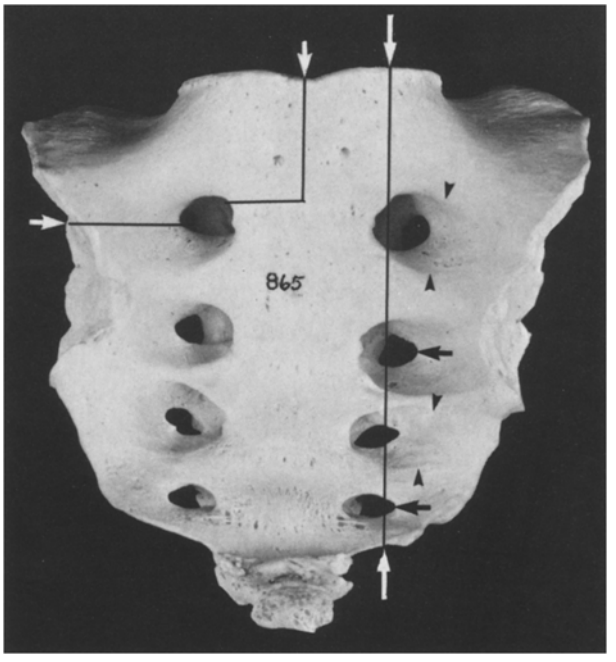

Fig. 1. Pelvic aspect of an intact sacrum (Specimen 1). Specimens 2 and 3 were sectioned as shown by the *short* and the *long white arrows*, respectively. The posterior foramina (*black arrows*) are seen through the flared or trumpet-shaped anterior foramina (*arrowheads*), as also depicted in a craniad-tilt AP radiograph (see Fig. 10)

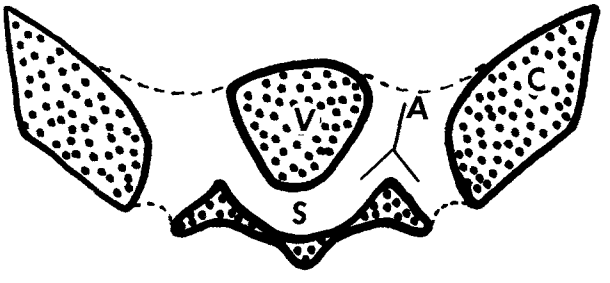

Fig. 2. Diagram of the Y-formation of the foramina. The stem of the "Y" is in the anterior foramen (A), and the lateral and medial limbs are in the posterior and intervertebral foramina, respectively. V = centrum, C = costotransverse element, S = spinal canal

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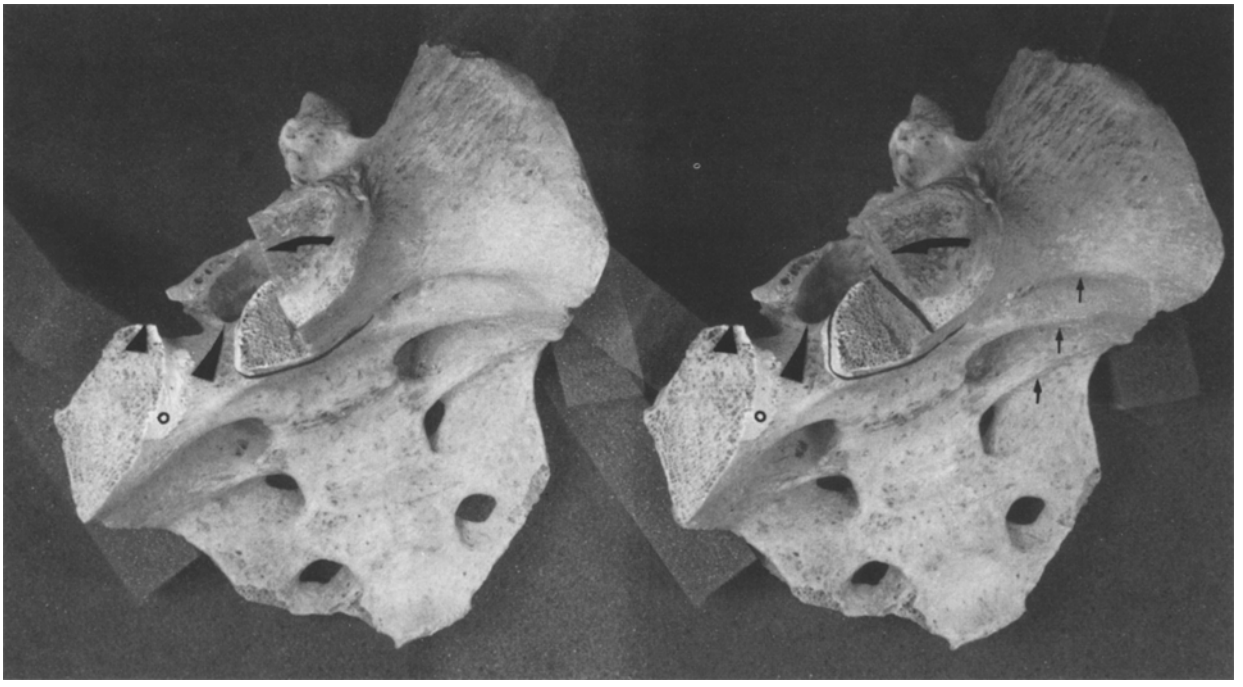

Fig. 3. Stereo-photograph of specimen 2. Indicated are: the cut sagittal edge of the centrum (*curved arrow*); the disc remnant (*thin line*); the horizontal plane (*thick line*); and the first right foraminal complex which shows the intervertebral foramen (*large arrowhead* in the floor of the anterior foramen) and the cut edge of the lateral wall of the posterior foramen (*small arrowhead*). Note the left first three costal elements (*small arrows*) whose surfaces form the arcuate lines corresponding to the roofs of the anterior foramina. The lateral wall of the barium-coated right first foramen is seen en face (o). The stereoscopic figures are much clearer viewed stereoscopically

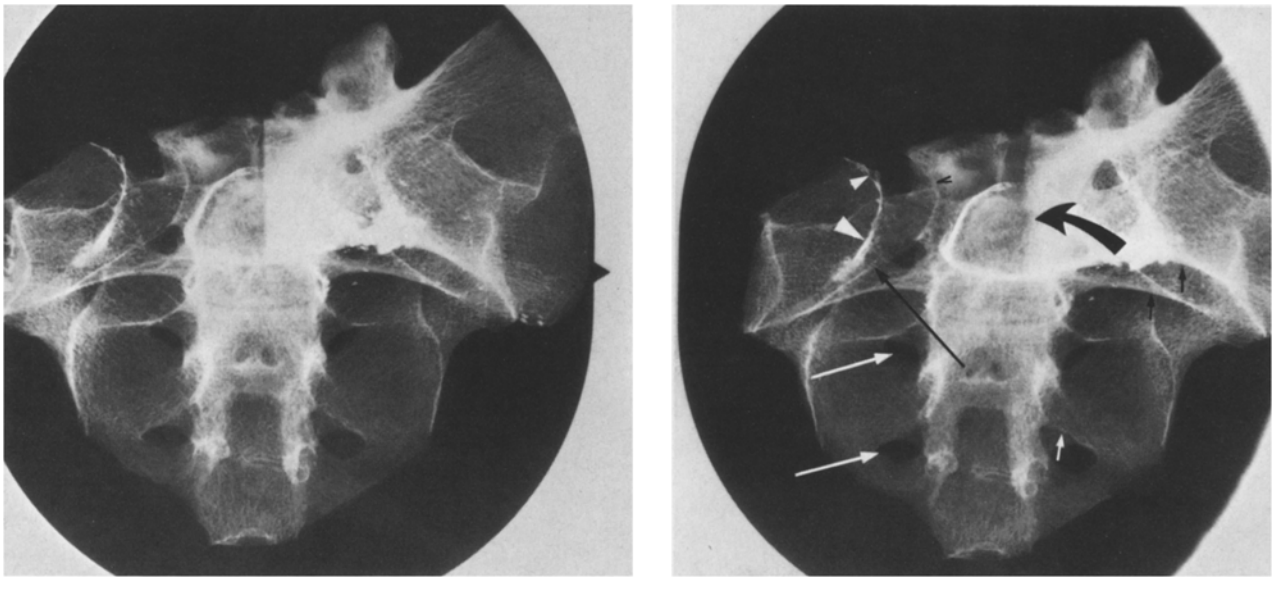

Fig. 4. AP stereo-radiograph of specimen 2. The cut edge of the centrum (*curved arrow*) and the left first two arcuate lines (*small arrows*) are indicated. The lateral wall of the right second anterior foramen appears to continue into the medial wall of the first posterior foramen (V). The lateral wall of the right first anterior foramen (*large arrowhead*) continues posteriorly into the lateral wall of the first posterior foramen (*small arrowhead*). The lateral wall of the left fourth anterior foramen (*small white arrow*) and the right third and fourth posterior foramina (*long white arrows*) are also indicated

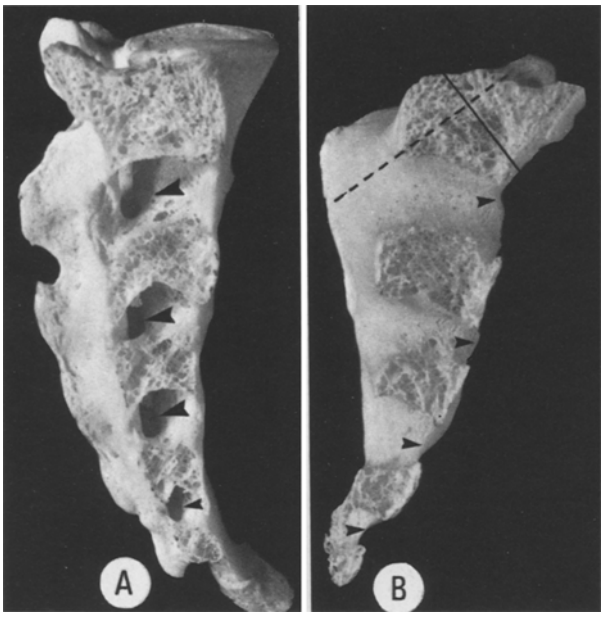

Fig. 5A, B. Cut surfaces of specimen 3 (sectioned parasagittally) for comparison with Figs. 6 and 7. The *solid line* represents the transverse plane of the CT sections; the *broken line* the coronal plane of AP tomography. In **A** *arrowheads* in the anterior foramina point to the intervertebral foramina. In **B** *arrowheads* indicate the posterior foramina

(Figs. 2 and 3). Neither the limbs nor the junction of the Y have clearly defined margins (Figs. 1–3, 5–9); nevertheless certain features are delineated radiographically by lines which represent compact bone surfaces depicted tangentially between spongiosa on one aspect and soft tissue on the other (v.i.). The intervertebral foramina are extensions of the lateral recesses of the vertebral canal (Figs. 3, 9B, C).

The anterior foramina are flared or trumpet-shaped. Narrower posteriorly, where they join the posterior and intervertebral foramina, they widen anteriorly to blend with the neural grooves of the alae (Figs. 1–3). The long axes are directed antero-inferiorly and laterally; thus the "roofs" and the "floors", formed by the costal elements, are antero-superior and postero-inferior surfaces respectively. Because of the sacral angle of inclination the "roofs" are profiled in the anteroposterior (AP) projection to produce the important [2, 3, 5–7] arcuate lines of the first three segments.

In the AP radiograph an oblique line represents the lateral wall of the anterior foramen; it begins near the lateral end of the arcuate line and extends supramedially. Anatomically (Fig. 3) and in some radiographs (Figs. 4, 6C, 11 and 12) this line continues into the lateral wall of the posterior foramen; in other radiographs it continues into the roof of the intervertebral foramen (Fig. 11), the difference probably depending on the angle of the incident beam. The lateral wall is less often seen than the arcuate line. It may be involved in fractures (Figs. 11 and 12) and in other pathology. The medial wall of the anterior foramen is formed by the vertebral bodies and intervening disc (Figs. 3, 4 and 10).

The posterior foramina are much shorter than the anterior. They may be partially visible on the

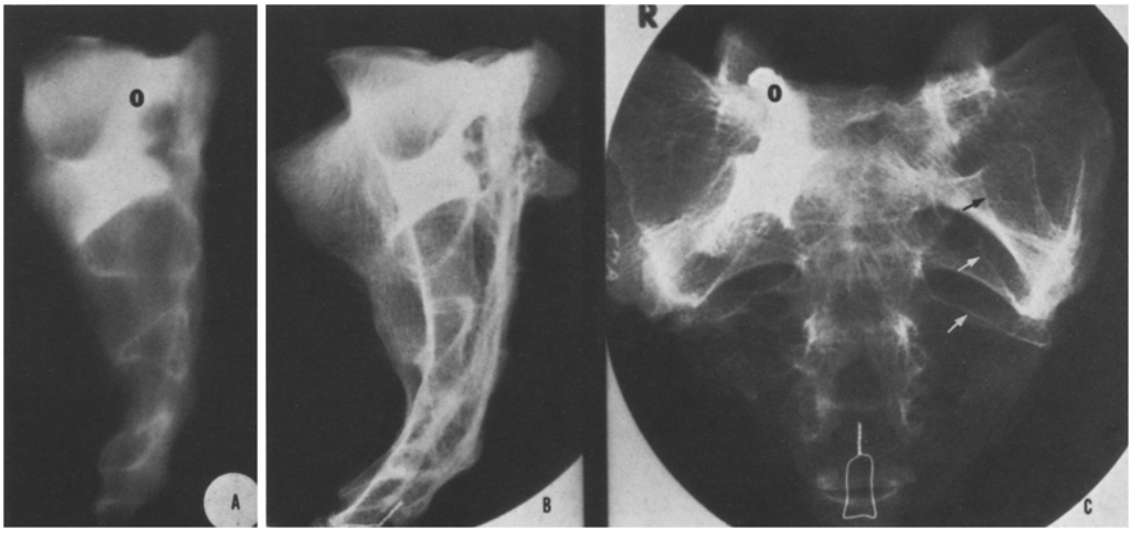

Fig. 6A–C. The right first anterior foramen is coated with barium. **A** Lateral tomogram at the level of the right foramina. **B** Lateral and **C** AP radiographs. In **C** the lateral walls of the left first three anterior foramina (*arrows*) are indicated. Barium has spilled into the L5/S1 intervertebral foramen (o) (compare with Figs. 7 and 10)

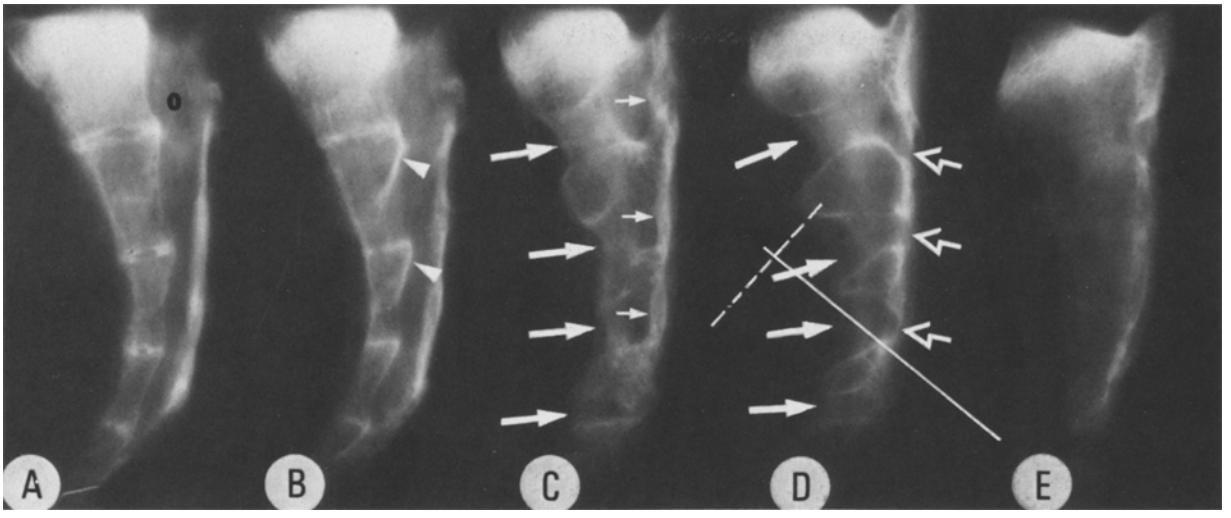

Fig. 7A–E. Lateral tomograms. The sections extend laterally from the sagittal plane (**A**) to beyond the foraminal complexes (**E**). The *solid line* represents the horizontal plane of CT and the *broken line* the coronal plane of AP tomography. Indicated are: the vertebral canal (o), the lateral recesses (*arrowheads*), the "roofs" of the intervertebral (*small arrows*), the anterior (*large arrows*) and the posterior foramina (*open arrows*)

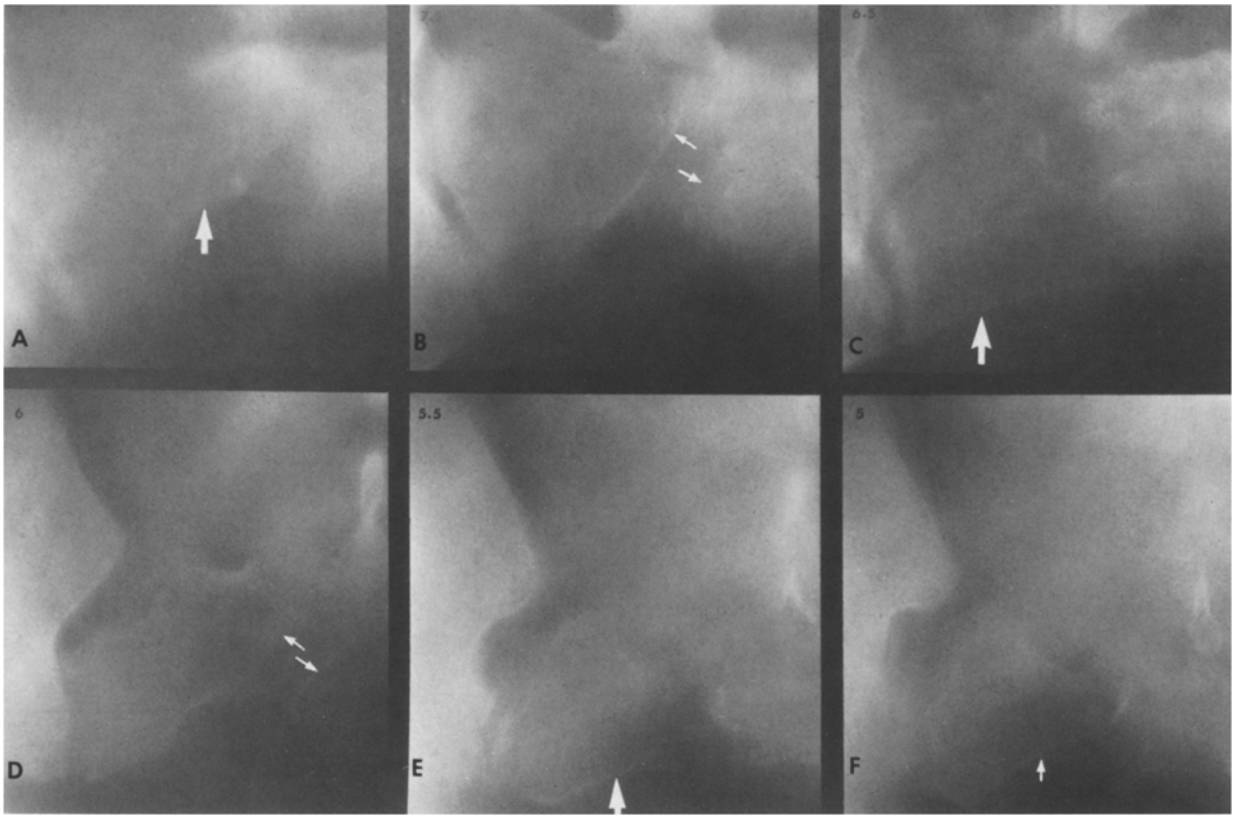

Fig. 8A–F. AP tomograms in vivo. Coronal sections from anterior (**A**) to posterior (**F**) showing the first, second, and third arcuate lines (*large arrows* in **A**, **C**, **E**), and the first and second anterior foramina (*small arrows* in **B**, **D**). The lateral wall of the third anterior foramen (*small arrow* in **F**) is indicated

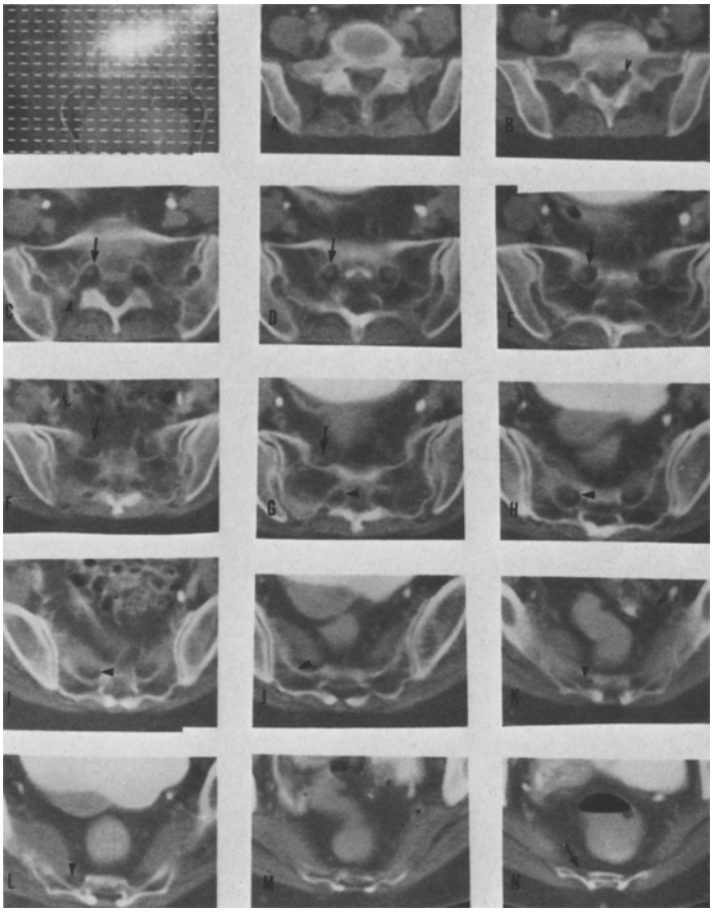

Fig. 9A–N. Composite CT of two cases. The cuts (**A**) through (**N**) are progressively more caudal. The "V" points to the left first lateral recess (**B**). The right first (**C–G**), second (**G–J**), third (**K**, **L**), and fourth (**N**) anterior foramina are shown (*arrowheads*). The right first posterior foramen (*arrowhead*, **C**) is also indicated

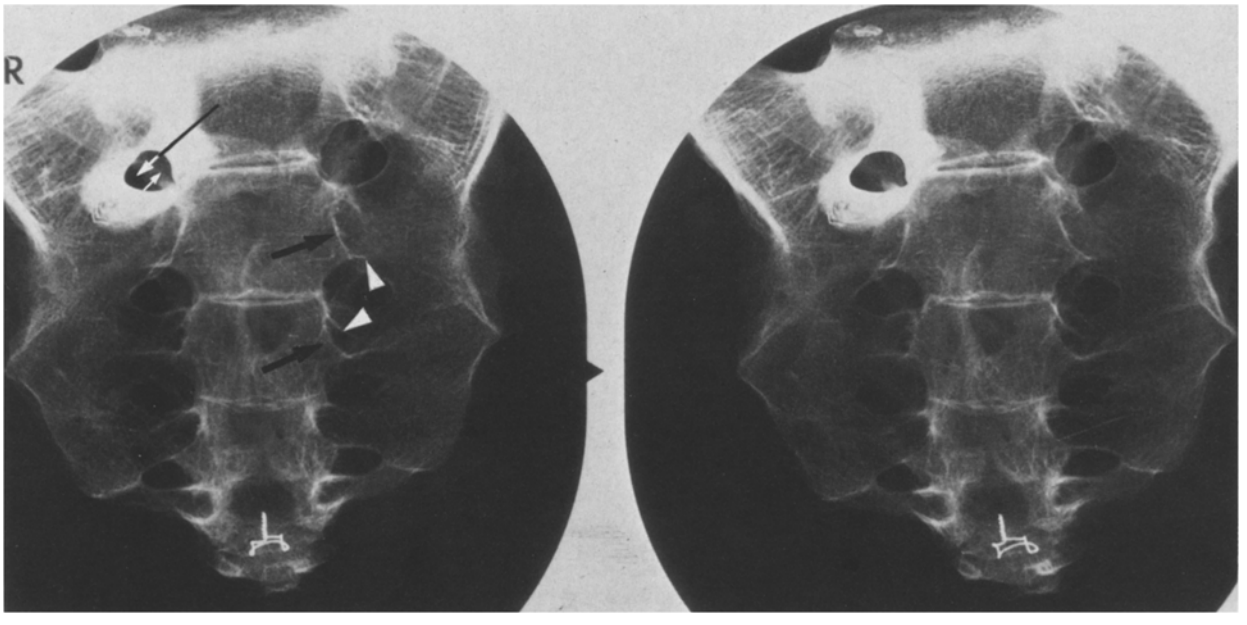

Fig. 10. AP craniad-tilt stereo-radiograph of specimen 1 with barium-coated right first foramen. The posterior (*long arrow*) and the intervertebral (*short arrow*) foramina are indicated. The *black arrows* indicate the lateral walls of the left second and third anterior foramina, and the *arrowheads* the supero- and inferomedial margins of the left second anterior foramen

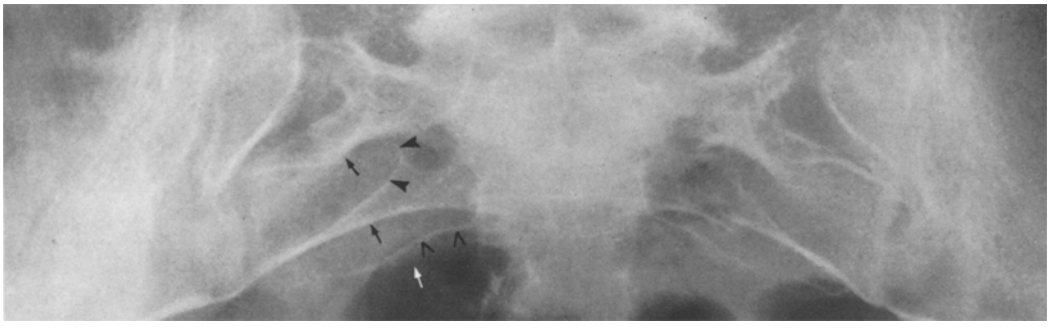

Fig. 11. Fracture of the left ala involving the first through third foramina. Normal anatomy is indicated on the right: the arcuate lines (*arrows*), the continuation of the lateral wall of the second anterior foramen into the lateral wall of the first posterior foramen (*arrowheads*); the second posterior foramen is below and medial to the upper arrowhead. The lateral wall of the third anterior foramen runs into the roof of the intervertebral foramen (Vs). The fracture involves these landmarks on the left

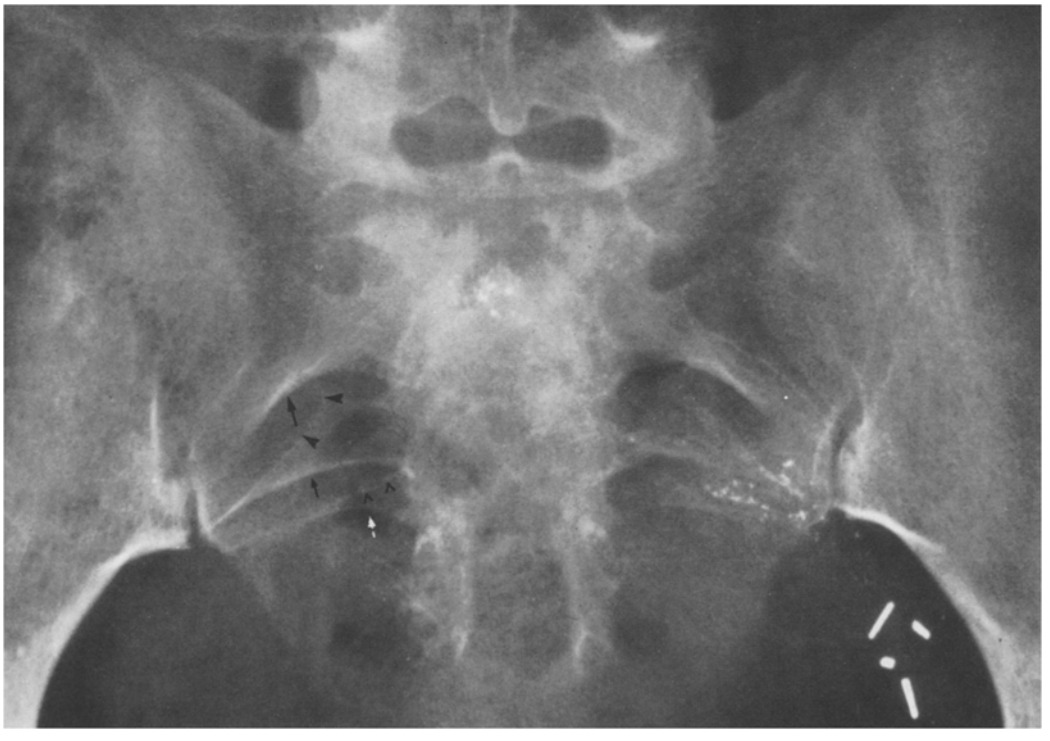

Fig. 12. Gunshot injury, AP radiograph. Indicators are as in Fig. 11. Small metal fragments mark the course of the bullet which appears to have entered the spinal canal and traversed the left second anterior foramen. There is loss of definition of its acurate and oblique lines

AP radiograph (Figs. 4, 11 and 12), and are usually seen on the AP-15°-craniad tilt radiograph as elliptical radiolucencies (Fig. 10). The fourth foraminal complex has no arcuate line. It may appear as an oval lucency (Figs. 4, 10 and 12), at times with the oblique line of its lateral wall (Fig. 4). A fifth foramen is occasionally present between the sacrum and the coccyx when both costal elements are well developed.

Anatomy/Tomography and Computed Tomography

In AP tomography the sections are parallel to the coronal plane so that the upper foramina appear in the more anterior and the lower in the more posterior sections (Fig. 8). In the horizontal plane of computerized tomography the posterior parts of the upper foramina appear on the craniad sections and their more anterior parts on the caudad

sections (Fig. 9). The lateral recesses of S1 are seen in the uppermost section, then in order, its posterior and intervertebral foramina, and the posterior and anterior parts of the anterior foramina. As the sections progress caudally, and depending on their level and thickness, the decreasing size of the foramina results in more nearly complete demonstration of individual Y-complexes (Fig. 9).

Conclusions

Knowledge of anatomic detail is important to avoid missing lesions that are "not invisible but unnoticed" [1]. Kundel and Nodine [4] have stated that "... it may be necessary to have seen radiological abnormalities in the past to be able to form an appropriate visual concept for a current abnormality." We prefer to believe that the first essential in recognizing the abnormal is deliberately to seek the normal.

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