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Original Research Article

On the Geometry of Fluoroscopy Views for Cervical Interlaminar Epidural Injections

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Abstract

Objectives. To describe how the anatomy of the cervicothoracic vertebrae predicates the appropriate fluoroscopic views for confirming safe needle placement during the performance of interlaminar cervical epidural injections.

Methods and Results. Illustrations, cadaver models, and radiographic images were correlated and used to illustrate and derive a mathematical model to demonstrate the utility of a contralateral oblique fluoroscopic view during the performance of cervical interlaminar injections.

Conclusions. When confirming needle placement during a cervical interlaminar epidural injection, in addition to the anterior-posterior fluoroscopic view, the oblique image, contralateral to the needle tip position, may provide superior information to that afforded by a lateral view.

Key Words. Spinal Injection; Cervical; Epidural; Interlaminar; Oblique View; Lateral View

Introduction

Cervical epidural injection of steroids has traditionally been performed as a "blind" procedure, i.e., without radiographic guidance. Typically, the operator gauges correct depth of insertion, into the epidural space, initially by "feeling" the change of resistance as the needle penetrates different tissue layers, abuts, and comes to rest on the ligamentum flavum, and finally, by "loss of resistance" to the injection of air or saline when the aperture of needle passes through the ligamentum flavum. Although largely a safe procedure in experienced hands, cervical epidural injections are not without risks. They have been associated with spinal cord injury as a result of penetration of the spinal cord by the needle or from injection of air or other material into the spinal cord [1].

In the interests of improving safety, some operators advocate performing the procedure under fluoroscopic guidance. Later in the procedure, fluoroscopic guidance allows the injection of contrast medium to verify that injectate spreads correctly in the epidural space, and to exclude intravascular injection. Earlier, however, fluoroscopic guidance ensures that the needle is not inserted too far, before any material—air, contrast medium, local anesthetic, or corticosteroids—is injected.

However, although lateral views are advocated, there are no published, or universally accepted, guidelines for the use of fluoroscopy during the conduct of cervical epidural injections. The concepts described in this essay arose during discussions, preceding the preparation of practice guidelines, by the International Spine Intervention Society. The concepts pertain to understanding the virtues and limitations of various views of the cervical spine in the course of interlaminar cervical epidural injections. Their discussion in this essay is designed to provide practitioners with insights that they might not otherwise acquire and thereby promote practice beyond simply complying with ad hoc instructions to "take a lateral view."

Principles

Upon inspection of an axial computed tomography (CT) scan of a T1 vertebra, or of a skeletal specimen of that vertebra, or simply an accurate sketch of the vertebra, certain features should become self-evident. If a needle is inserted, slightly lateral to the midline, such that its bevel just passes the lamina (Figure 1A), the depth of its tip will appear different on different views. On a lateral view (Figure 1B), the tip of the needle will appear to lie at a certain depth (d_1) beyond the ventral margin of the lamina.

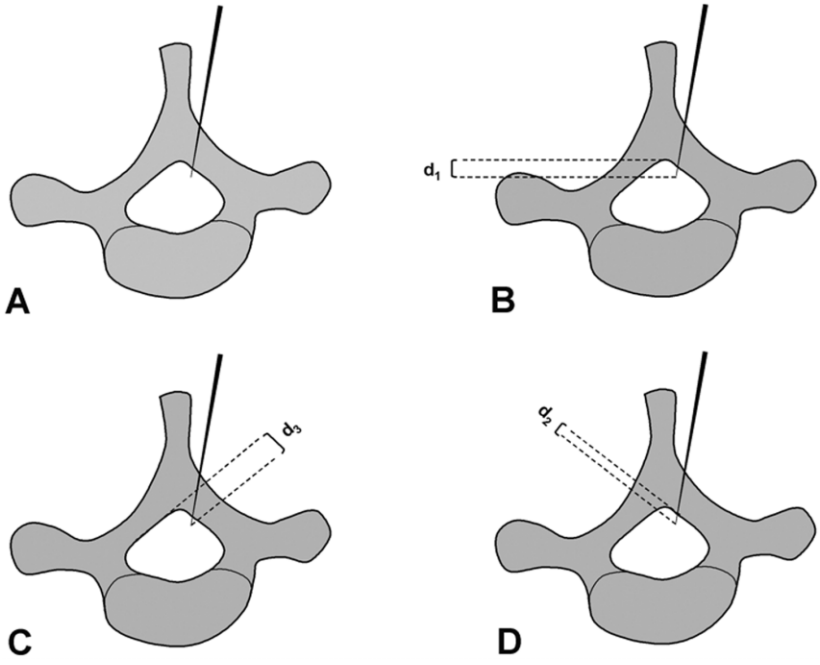

Figure 1 Tracings of an axial view of a T1 vertebra showing how different projections create different impressions of how deeply a needle has been inserted. The dotted lines depict the direction along which the vertebra is viewed with an X-ray beam. (A) A needle has been passed across the left lamina, such that its bevel projects deep to the ventral surface of the lamina. (B) In a lateral view, the needle will appear to have been inserted to a depth d_1 beyond the lamina. (C) In a left (ipsilateral) oblique view, the needle appears to have been inserted to a greater depth d_3. (D) In a right (contralateral) oblique view, the needle appears to be inserted to a depth d_2, which is substantially less than d_3 and is even less than d_1.

Different depths of insertion, however, arise if oblique views are taken.

In this context, oblique views are ones taken parallel to the transverse axis of the target lamina. In order to see the left lamina in cross-section, a posterior oblique view from the right is required. That is, the X-ray beam passes forward and to the left, from behind the patient's right hand side. Conversely, to see the right lamina, a left oblique view is required. Such views can be described as contralateral oblique views because either the source or the collector of the fluoroscope lies behind the patient on the side opposite to that on which the target lamina lies.

In a contralateral oblique view (Figure 1D), the needle will appear to be less deep (d_2) than seen in the lateral view. In an ipsilateral oblique view (Figure 1C), the needle will appear to have penetrated substantially deeper (d_3) than it does in the lateral view.

These differences arise because of the geometrical relationships between lateral and oblique views of a needle in relation to two laminae that themselves are obliquely oriented with respect to one another. When viewed in relation to the lamina that it crosses, a needle will appear to be inserted least deeply. In other views, the needle will appear to be inserted more deeply, in proportion to how far it is displaced from the midline. The further lateral that it is placed, the deeper it will appear on lateral views. It will appear even deeper in relation to the opposite lamina (Figure 1).

The geometry involved is elementary (Figure 2). The apparent depth of insertion as seen in a lateral view will be greater than that seen in an oblique view by a factor that is proportional both to the slope of the lamina and to the displacement of the needle from the midline.

Cadaver Illustration

Figure 3 is a plate that shows axial, lateral, contralateral oblique, and ipsilateral oblique views of a specimen of a T1 vertebra, across which a needle was placed, such that only its bevel projected beyond the plane of the lamina. As shown in the first row of Figure 3, the needle has been placed progressively: in the midline along a sagittal insertion, in the midline along an oblique insertion, near the midline along an oblique insertion, further from the midline along an oblique insertion, and far laterally.

The second row of Figure 3 shows the lateral views. There is not much difference in the depth of insertion relative to

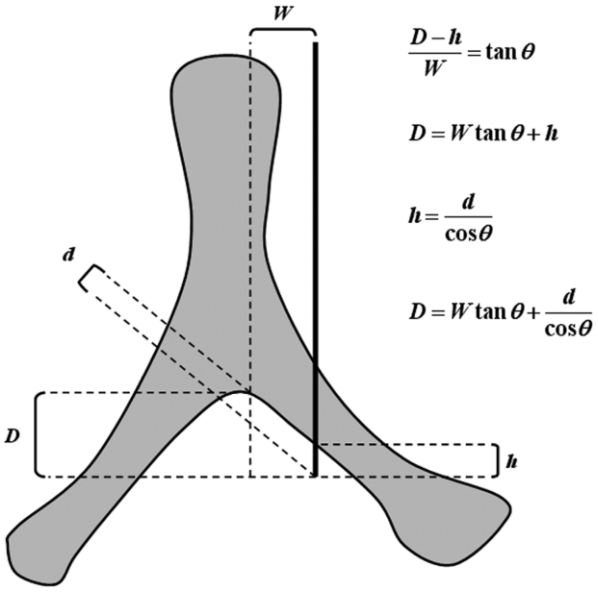

Figure 2 The trigonometry of oblique views. W is the displacement of the needle from the midline. h is the depth of insertion of the needle into the vertebral canal (along the sagittal plane). d is the projection of h, as seen in the oblique view. D is the depth of insertion as seen in a lateral view. θ is the obliquity of the lamina, ~45°. The calculations in the inset derive the relationship between D and d.

the posterior, midline margin of the vertebral canal. However, close inspection reveals that with progressively more lateral placements, the tip of the needle lies progressively more deeply.

The third row of Figure 3 shows the contralateral oblique views. Across all placements, the depth of insertion is uniform. For the more lateral placements, the depth of insertion is evidently less than in the corresponding lateral view.

The fourth row of Figure 3 shows the ipsilateral oblique views. These vividly show that with progressively more lateral placements, the tip of the needle appears to lie alarmingly deeper in the vertebral canal. This is an illusion of projection and interpretation. The axial views and the contralateral oblique views reassuringly show that the needle has entered the vertebral canal only minimally.

Most pertinent in Figure 3 are rows two and three. The true depth of insertion is demonstrated by the contralateral oblique view and is the same irrespective of how laterally placed the needle is. The lateral views, although reassuring, are not properly indicative of the depth of insertion. For insertions at or near the midline, the lateral view is equivalent to the contralateral oblique view and shows minimal depth of insertion. However, for more lateral insertions, the lateral view exaggerates the depth of insertion; the needle appears slightly deeper than it does in the corresponding contralateral oblique view.

In this regard, the lateral view can be construed as having reasonable sensitivity but good specificity. If a needle appears to be not "too far in" on a lateral view, it will not be too far in when checked on a contralateral oblique view. However, on a lateral view, the needle that is placed lateral to the midline might disturbingly appear further in than desired, but a contralateral view will reassuringly show minimal entry into the epidural space.

Clinical Illustrations

Three cases, drawn from clinical practice, illustrate the foregoing principles. None of the cases necessarily illustrate what might be construed as correct or ideal placement of the needle. However, they had been presented because they illustrate placements that may occur, and have occurred, in actual clinical practice, and because each illustrates a different virtue of the contralateral oblique view.

In the first case, the needle was introduced on the right-hand side, and its tip entered the epidural space to the right of the midline (Figure 4A). On a lateral view, the tip of the needle has clearly entered the epidural space, but some operators might be concerned that it has penetrated a bit too far (Figure 4B). The contralateral oblique view, however, shows that entry into the epidural space is minimal (Figure 4C). This was subsequently confirmed upon injection of contrast medium, which spread through the epidural space (Figure 4D). This case illustrates that when needles are introduced lateral to the midline, a conventional lateral view may overstate its depth of insertion, but a contralateral oblique view provides the reassuring, correct information.

In the second case, lateral view is imperfect, and the contralateral oblique view would ideally show the interspinous space (Figure 5), but they serve to illustrate a particular phenomenon. The needle was introduced from the right, but its tip crossed the midline to lie under the left lamina (Figure 5A). Under these conditions, the reference lamina (for oblique views) is not the lamina on the same side as the side of insertion, but the lamina to which the tip of the needle is related. In the case illustrated, the oblique view required is the one that shows the left lamina in profile. Accurately stated, the required view is a posterior oblique view from the right. This view is contralateral to the target lamina, but happens to be ipsilateral to the side on which the needle was inserted. The lateral view appears to show that the needle has entered the epidural space by the length of its bevel and has therefore been inserted too deeply (Figure 5B). However, this interpretation would be valid only if the needle was inserted perpendicular to the plane of view. In fact, the needle passes obliquely to the left, essentially tangential to the dural sac. The right oblique view (Figure 5C) shows that needle occupies the epidural space only by the thickness of its bevel, not by its full

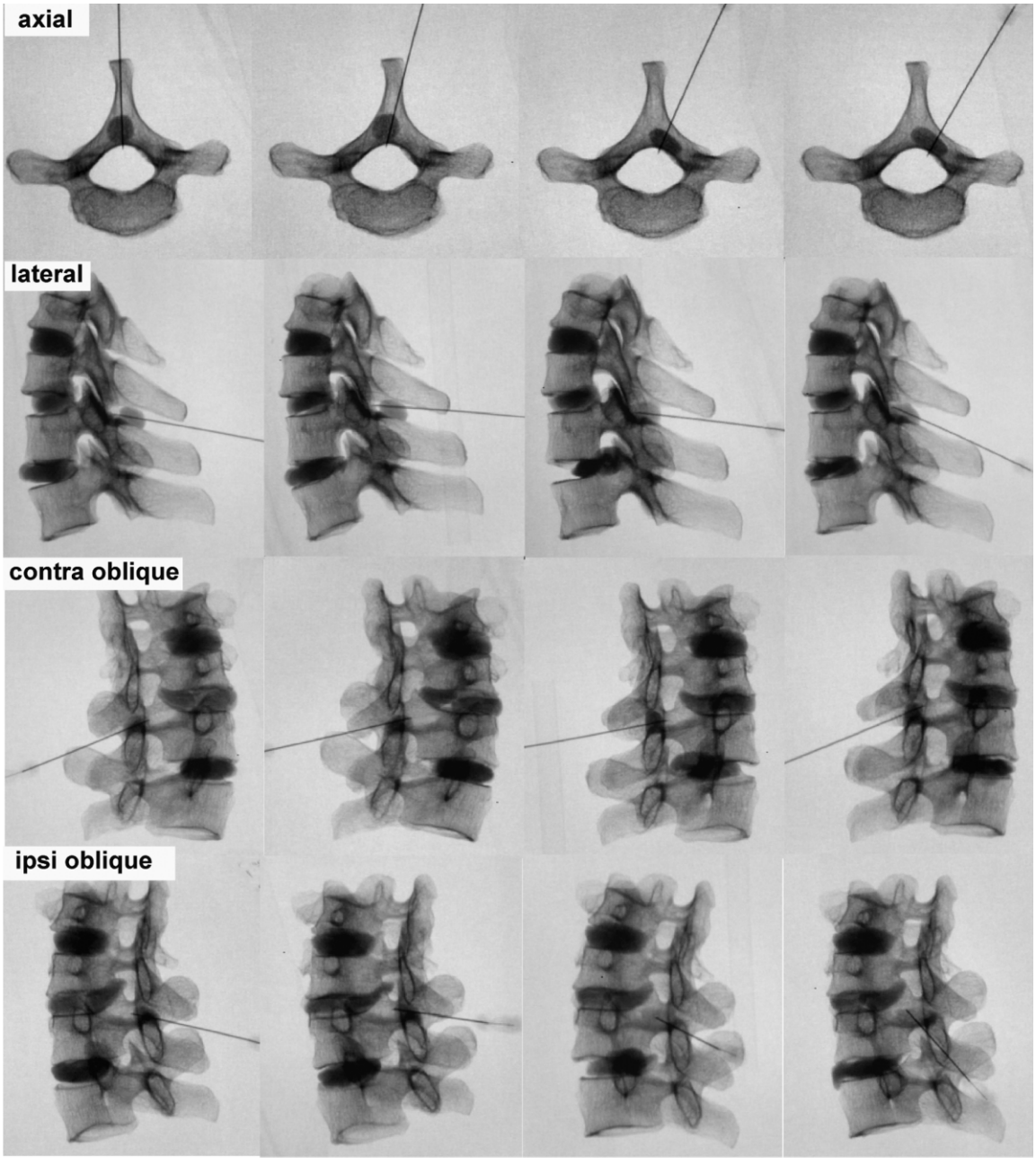

Figure 3 Radiographs, in different views, of a skeleton specimen in which a needle has been inserted across the left lamina of the T1 vertebra, to a depth such that only its bevel projects beyond the lamina. From left to right, the columns show the corresponding views of the needle inserted in the midline along a sagittal insertion, in the midline along a slightly oblique insertion, along an oblique insertion but close to the midline, along an oblique insertion but further from the midline, and along a parasagittal insertion substantially to the left of the midline. From above downward, the rows show axial views, lateral views, contralateral (right) posterior oblique views, and ipsilateral posterior oblique views. The lateral views show reasonable depths of insertion, but which are progressively greater across the columns, with the far lateral insertion showing the greatest depth of insertion on the lateral view. In contrast, the contralateral views uniformly show minimal depth of insertion, across all columns. The ipsilateral views show progressively deeper and bizarre depths of insertion.

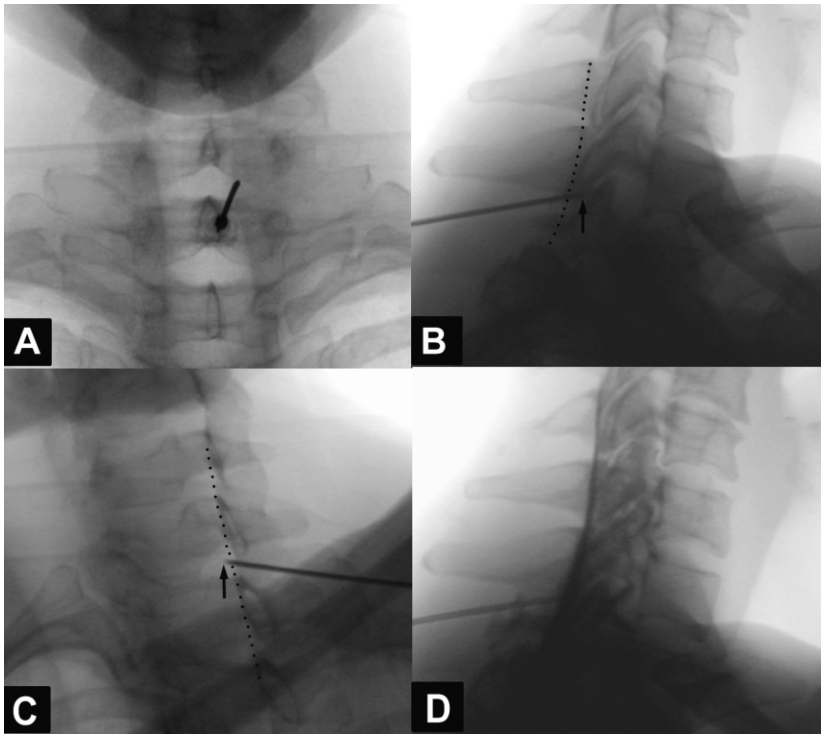

Figure 4 Fluoroscopy views of a needle placed for a cervical interlaminar epidural injection. (A) Postero-anterior view showing a needle passing through the C7-T1 interlaminar space, across approximately the center of the right lamina of T1. (B) Lateral view, which implies that the needle has passed substantially into the epidural space. Broken black line represents the spino-laminar line. Black arrow indicates needle tip. (C) Left (contralateral) posterior oblique view, which reassuringly shows minimal penetration of the needle beyond the laminae. Broken black line indicates the ventral laminar line. (D) Lateral view after injection of contrast medium, which flows into the epidural space.

length. This was corroborated upon injection of contrast medium, which flowed into the epidural space (Figure 5D). This case illustrates that the obliquity of the needle needs to be taken into account, and that the target lamina is the one that the needle tip crosses and defines the contralateral oblique, which is not necessarily the one on the side on which the needle was inserted.

Figure 6 illustrates why the switch in oblique views arises. A needle that has been introduced obliquely, and which crosses the midline, will lie closer against the opposite lamina, and with reference to that lamina, it will appear less deeply inserted than in other views. Conversely, in lateral views and ipsilateral views, the tip of the needle will appear more deeply inserted than it actually is.

Trying to remember whether it is a contralateral or ipsilateral view that is required can be confusing. The appropriate rule of thumb is to use the view that passes parallel to the lamina to which the tip of the needle is more closely related. This avoids confusion arising from the assonance between the words—contralateral and ipsilateral, and whether they apply to the side of insertion.

In the third case, the needle was inserted to the right of the midline (Figure 7A). The lateral view, however, is very unclear; the depth of the needle cannot be ascertained with any confidence owing to the prominent shadow of the shoulder and the use of a small gauge needle (Figure 7B). The contralateral (left posterior) oblique view, however, is very reassuring that the needle has not entered too far into the epidural space (Figure 7C). This was corroborated upon injection of contrast medium, which flows into the epidural space (Figure 7D). This case illustrates how the correct oblique view can be used to substitute for ambiguous lateral views.

Discussion

Consumers of medical literature are not accustomed to evidence in the form of theorems and mathematical proofs. These are more the province of physics. Readers of medical literature are more accustomed to rules that are empirically derived from observations. In the present instance, readers might expect the virtues of oblique views to have been derived from correlations between measure-

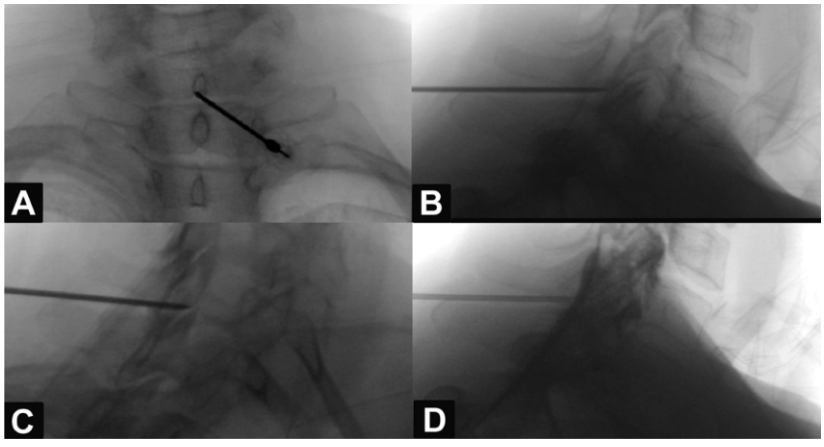

Figure 5 Fluoroscopy views of a needle placed for a cervical interlaminar epidural injection. (A) Postero-anterior view showing a needle passing through the C7-T1 interlaminar space, inserted from the right, but with its tip lying to the left of the midline. (B) Lateral view, which implies that the needle has passed substantially into the epidural space. (C) A right (contralateral) posterior oblique view reassuringly shows minimal penetration of the needle beyond the laminae, to a depth substantially less than that implied by the lateral view. (D) Lateral view, after injection of contrast medium, which flows into the epidural space.

ments of fluoroscopy views and CT scans of needles placed in various locations in many patients or in anatomic specimens. Such an approach is superfluous when the principles are self-evident from a consideration of Euclidean geometry.

Inspection of any facsimile of a thoracic vertebra (Figure 1) plainly reveals that if needles are introduced in the midline, a single, lateral view is sufficient and appropriate to gauge the depth of insertion, for no errors due to parallax arise. While so long as the needle is in the midline, oblique views convey no relevant information that is not already available in a simple lateral view. The only exception arises when the lateral view is not clear, for reasons such as overlying shadows of the shoulders. In such cases, the appropriate oblique view can substitute for the lateral view.

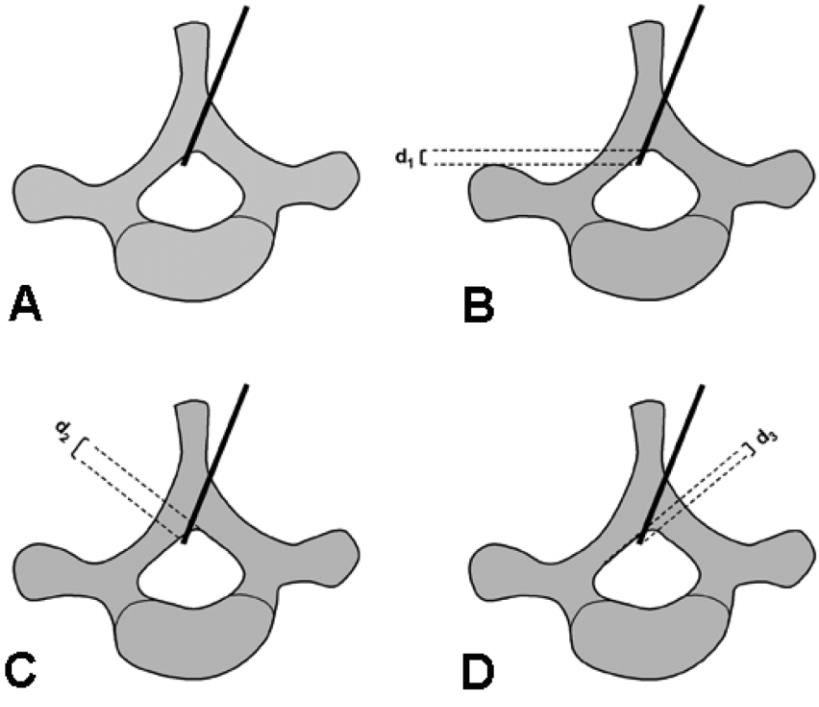

Figure 6 Tracings of axial views of a T1 vertebra, illustrating the geometry of different views of a needle that crosses the midline. (A) A needle has been introduced from the left, but its tip lies to the right of the midline. (B) A lateral view indicates that the tip of the needle lies at a depth d_1 beyond the lamina. (C) A right (ipsilateral) posterior oblique view shows a substantial depth of insertion d_2. (D) A left (contralateral) posterior oblique view reveals the depth of insertion d_3 is less than that seen in either the ipsilateral oblique view or the lateral view.

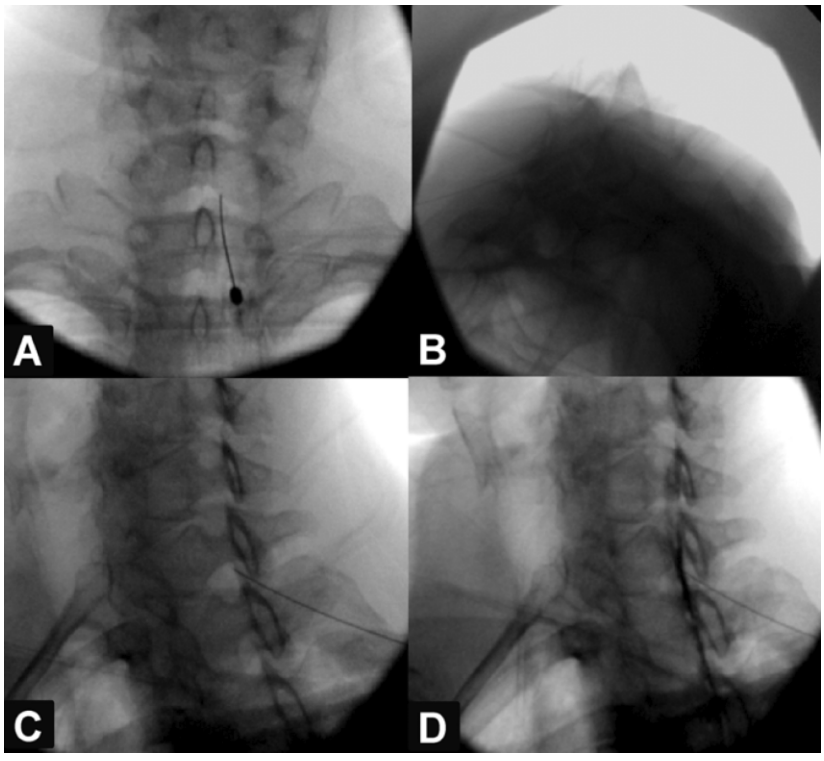

Figure 7 Fluoroscopy views of a needle placed for a cervical interlaminar epidural injection. (A) Postero-anterior view showing a needle passing through the C7-T1 interlaminar space, to the right of the midline. (B) Lateral view, in which the tip of the needle is difficult to see, and from which the depth of insertion cannot be confidently gauged. (C) A left (contralateral) posterior oblique view clearly and reassuringly shows minimal penetration of the needle beyond the laminae. (D) Contralateral view, after injection of contrast medium, which flows into the epidural space. Courtesy of Dr. Ray Baker.

If the tip of the needle lies lateral to the midline, inspection of the geometry (Figure 1) shows that an oblique view will more directly demonstrate the depth of insertion than a lateral view. A lateral view overstates the depth of insertion in proportion to the slope of the lamina and the displacement of the needle from the midline (Figure 2). Insertions that appear alarmingly deep on lateral views can be reassuringly adequate on oblique views.

The crucial issue for clinical practice is understanding which oblique view is the appropriate one. For that purpose, a simple set of instructions applies. Identify the

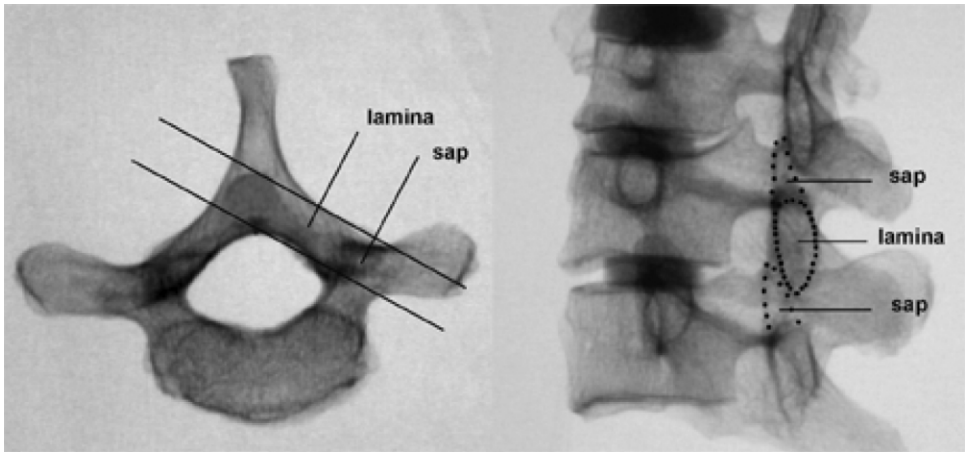

Figure 8 Defining the contralateral oblique view. (A) An axial radiograph of a cadaveric T1 vertebra. The contralateral oblique view will be parallel to the posterior and anterior surfaces of the target lamina. The superior articular process (sap) will project from the center of the lamina. The intervertebral foramen is in front of the lamina. (B) Contralateral oblique view. The superior articular processes are co-aligned with the lamina, and the intervertebral foramen is clearly evident in front of the lamina.

lamina to which the tip of the needle is related. Imagine the slope of that lamina. Rotate the X-ray beam so that it runs parallel to that slope. Such a set of instructions avoids the confusions that might arise if operators try to learn, or to teach, using terms such as contralateral oblique, posterior oblique, anterior oblique, or ipsilateral oblique. It serves also to avoid practitioners moving the fluoroscope randomly while "hunting" for the correct view. In the correct view, the superior articular processes above and below the lamina will be longitudinally co-aligned with the lamina, and the intervertebral foramen will be open, i.e., not encroached by articular processes (Figure 8). Typically, this occurs at about 40° rotation from a lateral view. In such a view, a line simultaneously tangential to the posterior margins of the intervertebral foramina and to the superior articular processes and laminae has been called the Puttlitz line [2], which is recommended as the maximum depth of insertion of a needle in a contralateral view [2].

Several authors previously have extolled the virtues of contralateral oblique views, for various purposes [2–5], but without exploring the geometrical basis for their use. Not known is the extent to which practitioners use oblique views, or simply rely on a routine lateral view to check the depth of their needles. Nor is it known if practitioners are confused by oblique views, or do not know how to obtain them expeditiously and accurately. Such deficiencies typically come to public light when patients suffer catastrophic injuries. If practitioners are empowered by the insights provided in this essay, and can thereby avoid catastrophic complications of cervical interlaminar injections, then the objectives of the essay will have been served.

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