Use of Spinous Processes to Determine Drill Trajectory During Placement of Lateral Mass Screws

A Cadaveric Analysis

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Objective: Prior cadaveric research showed that the lateral mass and facets are landmarks to determine the initial starting point for lateral mass screws and that the optimum screw trajectory was 30° lateral and 15° cephalad. The missing link was an intraoperative landmark to guide the trajectory for drilling according to these angles. The authors hypothesized that spinous processes can be used to guide the trajectory for lateral mass screw placement.

Methods: The authors analyzed 144 lateral masses of 72 cervical vertebrae in 18 cadavers (7 males and 11 females). The lateral and cephalocaudad angles were measured for each lateral mass from C3 to C6 while using the spinous processes of the adjacent three caudad vertebrae at each level to guide the starting trajectories for a total of 864 angles. The lateral and cephalad trajectory angles at each spinous process relative to the starting hole were compared with 30° and 15°. For each angle measured at a particular level, the same starting hole was used in the lateral mass, and the superolateral cortex of each spinous process was the most medial point.

Results: When drilling for the C3 and C4 lateral mass screws, the C4 and C5 spinous processes provided an accurate starting point, respectively, for the lateral angle but moderately overestimated the cephalocaudad angle. For C5 and C6 lateral mass screws, the C6 and C7 spinous processes provided an accurate starting point, respectively, for both the lateral and the cephalocaudad angles.

Conclusion: The spinous processes can be an accurate local anatomic guide for lateral mass screw trajectory and will allow greater safety while drilling before performing laminectomies. These guides may change in patients with cervical spinal deformities.

Key Words: cervical spine, spinous process, lateral mass screw, fusion, instrumentation

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There is an increasing use of instrumentation in spinal fusion. As new instrumentation is developed, the analysis of proper technique is crucial to reduce complications and poor outcomes. Posterior instrumentation is indicated in instances where there is a need to stabilize the cervical spine for trauma, neoplastic destruction, and extensive laminectomies. The current trend for posterior stabilization is to perform laminectomies, when indicated, followed by the use of lateral mass screws and posterior plates or rods with interspinous wiring playing more of a supplemental role. Screw fixation offers greater stability to the patient, allowing early mobilization and less reliance on external support.[1–6]

There are several potential complications of screw fixation that include injury of the vertebral artery, spinal cord, and nerve roots, as well as violation of the facet joints.[1] Proper surgical technique is therefore essential in the prevention of these complications.

Although there is consensus about using the medial and lateral borders of the lateral mass and the superior and inferior facets to determine the starting location for lateral mass screws (1 mm medial to the midpoint of the lateral mass), there is less agreement on drill insertion angle.[1,2,5] Reports differed on the recommended cephalocaudad and lateral angles for the insertion of these screws into the C3–C6 vertebrae so as to minimize the risk of damage to the nerve roots and vasculature. The An, Anderson, Magerl, and Roy-Camille methods have been the most widely accepted techniques in the literature. Xu found that the An technique had the lowest potential risk of nerve root violation of the three techniques.[1,2,5,7,8]

According to the An technique, a 15–18° caudad–cephalad and a 30–33° lateral angle will minimize the risk of nerve root or vascular damage.[7] Other techniques, such as the Roy-Camille technique that uses a cephalocaudad angle of 0° with a 10° lateral angle, the Anderson technique, which uses a 20° cephalocaudad and a 30° lateral angle, and the Magerl technique, which uses a 40–60° cephalocaudad angle and a 25° lateral angle, are less popular, but still exist in use among spine surgeons. Although considerable interest has focused on determining the starting point for lateral mass screws and subsequently the optimum angles for safe screw placement, this is the first report to assess the spinous processes to aide the surgeon in determining the trajectory for these angles intraoperatively.

METHODS

A cadaveric study was performed using 18 Caucasian subjects (7 males and 11 females) to measure the mediolateral and cephalocaudad trajectories from the spinous process to a standardized starting hole in the lateral mass, 1 mm medial to the midpoint of the lateral mass. A device commercially available for measuring angles of inclination in space was used to perform the measurement of each angle (Fig. 1). Although attested to be accurate by the manufacturers, testing known angles of inclination prior to the start of the cadaveric measurements validated the device in the authors' hands. None of the spines was deformed.

Starting holes were first drilled to a depth of 2 mm at the optimum location of 1 mm medial to the midpoint of each lateral mass to provide a consistent anchoring point for the tip of the drill for each measurement. This reproduced the lateral point of drill contact. The superolateral cortex on the caudad spinous process was used as the most medial starting point of reference (Fig. 2A). The side of the drill would touch against the side of the spinous process while the tip was anchored in the starting hole. The cephalocaudad and mediolateral angles formed by the drill bit between the starting hole and the spinous process were then measured.

Using the device, the authors measured three sets of cephalocaudad and lateral angles using the three most caudad spinous processes as the most medial point of measurement for each set. The cephalocaudad angles were measured by resting the flat end of the measuring device against the drill bit in a cephalocaudad direction, whereas the mediolateral angles were measured by placing the device on the side of the drill bit at 90° to the cephalocaudad position. This process was then repeated bilaterally with holes drilled in the lateral masses of C3–C6 for a total of 12 sets of both cephalocaudad and lateral angles. This included a total of 72 cervical vertebrae, 144 lateral masses, and 864 angles measured. The final position of the drill bit was determined when two observers agreed. Each observer measured the angle with the device, and the angles were remeasured if the angles were not the same to prevent mistaken read of the angle on the device.

FIGURE 1. Angle measuring device by Johnson Level & Tool Contractor Pitch and Slope Locator 750 (Johnson Tools Mfg. Co.Ltd., Jiangsu, China).

The data were then compiled and statistically analyzed using a Microsoft Excel spreadsheet. Means, median, mode, and standard deviations for each of the three caudad angles for each lateral mass category were determined to give the reader a sense of the variability of the measurements. These data were then compared with the An, Anderson, Magrel, and Roy-Camille recommended lateral and cephalocaudad angles to determine which spinous processes could best approximate the angles corresponding to these techniques.[1,2,5,8]

RESULTS

Evaluation of the data showed reliable consistency with the data in the study by An et al[1,2,5,8] (Tables 1–4; Figs. 3 and 4). C3 and C4 had mean cephalocaudad angles of 28° and 26° and lateral angles of 31° and 30°, respectively (see Tables 1 and 2). Therefore, for C3 and C4, the C4 and C5 spinous processes provided an accurate starting point respectively for the trajectory for the lateral angle (30° in An's study) but moderately

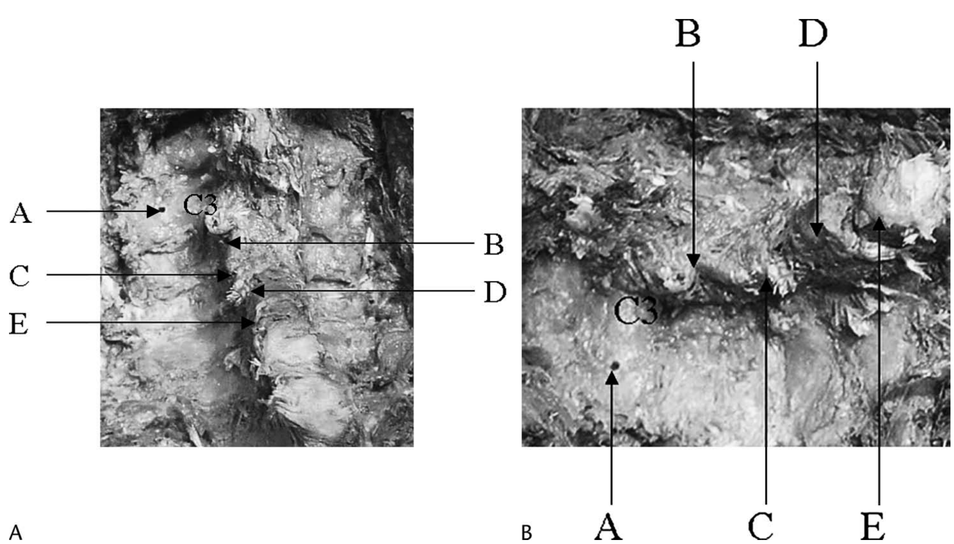

FIGURE 2. Direct posterior and posterolateral views of cadaver specimen of exposed spine, showing the starting hole (A) in the left C3 lateral mass. The locations are approximated for drilling C3 angles (B), C4 angles (C), C5 angles (D), and C6 angles (E).

TABLE 1. C3

	S1	S2	S3	L1	L2	L3
An technique	15–18	15–18	15–18	30–33	30–33	30–33
Anderson technique	20	20	20	30	30	30
Magrel technique	40–60	40–60	40–60	25	25	25
Roy-Camille technique	0	0	0	10	10	10
Mean	28	38	41	31	29	27
SD	11	11	12	8	9	11
Median	28	39	43	31	27	25
Mode	23	44	60	24	26	22

S, sagittal; L, lateral angle.

overestimated the trajectory for the cephalocaudad angle (15° in An's study).

For the C5 and C6 lateral masses, the C6 and C7 spinous processes provided the most accurate medial starting point, respectively, for the trajectory for both the lateral and the cephalocaudad angles (see Tables 3 and 4). For the C5 lateral mass, the C6 spinous process starting point had a mean cephalocaudad angle of 18° and a mean lateral angle of 30°. For the C6 lateral mass, the C7 spinous process resulted in a mean cephalocaudad angle of 15° and lateral angle of 27°. Although the mean lateral angle for the C6 lateral mass fell slightly short of the range proposed by An et al,[1] both the median and the mode of C6 (30° and 31°, respectively), fell within the respective ranges for the An technique.[1]

With regards to the Magerl, Anderson, and Roy-Camille techniques, there was no caudad spinous process found to consistently align with the required angles. Further studies to determine different anatomic landmarks for these techniques are suggested.

DISCUSSION

Currently, there is no standardized intraoperative method to estimate the trajectory angle of insertion of a lateral mass screw as proposed by the techniques described by An, Anderson, Magerl, or Roy-Camille.[1,2,5,8] Therefore, spine surgeons have been left to their best visual estimate intraoperatively. This is the opposite scenario to the ease with which the drill starting position in the lateral mass can be located reliably by visualizing the lateral and medial borders of the lateral mass and the superior and inferior facet joints. Although screw-related complications with lateral mass fixation have not been publicized, there are several potential complications of lateral mass screw fixation that include injury of the vertebral artery, spinal cord, and nerve roots as well as violation of the facet joints especially at the ends of the construct.[1] This study therefore attempted to provide an intraoperative landmark to act as a reproducible visual guide for lateral mass screw trajectory. It is hoped that with widespread adoption of this technique, there will be the added benefit of encouraging greater safety because surgeons will be encouraged to drill the holes for lateral mass screws prior to performing laminectomies. There will also be advantages of having landmarks in cases where laminectomies are not needed such as during supplemental posterior fixation for an anterior corpectomy or posterior fusion for instability without decompression.

The current practice is to perform laminectomies before drilling for lateral mass screws, thus leaving surgeons without the spinous process as a landmark. When performing posterior lateral mass fixation of the cervical spine, altering the order of drilling and the laminectomy can be of benefit for two reasons. First, if drilling is performed before the laminectomy, there is no exposure of the spinal cord when drilling for lateral mass screws. Even though injury to the spinal cord is not a commonly reported phenomenon, this technique provides an extra degree of safety when drilling and can be of great benefit to less experienced surgeons. Second, the data showed that the spinous process can be a useful landmark in angle estimation so as to minimize damage to nerve roots especially when performing lateral mass fixation in cases where laminectomies are not performed.

TABLE 3. C5

	S1	S2	S3	L1	L2	L3
An technique	15–18	15–18	15–18	30–33	30–33	30–33
Anderson technique	20	20	20	30	30	30
Magrel technique	40–60	40–60	40–60	25	25	25
Roy-Camille technique	0	0	0	10	10	10
Mean	18	24	32	30*	21	18
SD	9	10	8	9	8	9
Median	16	24	31	26	20	20
Mode	17	25	28	30	18	8

S, sagittal; L, lateral angle.
*Also fits Anderson technique.

TABLE 2. C4

	S1	S2	S3	L1	L2	L3
An technique	15–18	15–18	15–18	30–33	30–33	30–33
Anderson technique	20	20	20	30	30	30
Magrel technique	40–60	40–60	40–60	25	25	25
Roy-Camille technique	0	0	0	10	10	10
Mean	26	33	36	30*	26	22
SD	9	10	9	8	8	9
Median	25	33	35	30	25	22
Mode	25	35	40	30	22	18

S, sagittal; L, lateral angle.
*Also fits Anderson technique.

TABLE 4. C6

	S1	S2	S3	L1	L2	L3
An technique	15–18	15–18	15–18	30–33	30–33	30–33
Anderson technique	20	20	20	30	30	30
Magrel technique	40–60	40–60	40–60	25	25	25
Roy-Camille technique	0	0	0	10	10	10
Mean	15	23	31	27*	19	18
SD	8	8	8	7	8	8
Median	14	24	31	30	18	16
Mode	12	21	25	31	18	16

S, sagittal; L, lateral angle.
*Mean and modes were better estimates of the averages.

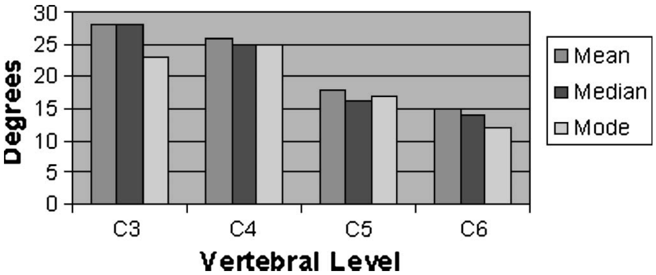

FIGURE 3. Cephalocaudad angle data for the first caudad spinous process.

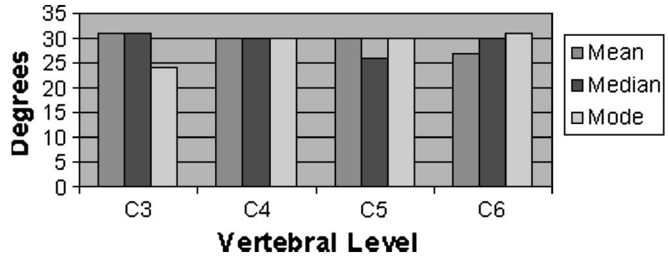

FIGURE 4. Lateral angle data for the first caudad spinous process.

Our results showed that for the C3 and C4 lateral masses, the C4 and C5 spinous processes overestimated the cephalocaudad angles, respectively, but accurately predicted the lateral angles as proposed by the An technique.[1] For the C3 and C4 lateral masses, the trajectories from the C4 and C5 spinous processes had mean cephalocaudad angles of 28° and 26°, respectively, which slightly overestimated the An angles (30° mediolateral and 15° cephalocaudad) and did not fit into any of the angles put forth by the Anderson, Magerl, or Roy-Camille methods. However, the trajectories from the C4 and C5 spinous processes had mean mediolateral angles of 31° and 30°, respectively, which both fell into the range of angles proposed by An et al.[1] To compensate for this, a surgeon may need to adjust the cephalocaudad trajectory angle for the C3 lateral mass screws to start approximately midpoint between the C3 and C4 spinous process. Similarly, to adjust the cephalocaudad trajectory angle for the C4 lateral mass screw, start approximately midpoint between the C4 and C5 spinous processes.

In instances where lateral mass screws are being placed at C5 and C6, our results showed that the superior lateral cortex of the C6 and C7 spinous processes provided a reproducible starting trajectory point respectively for both the mediolateral and the cephalocaudad angles. The trajectories from the first caudad spinous processes of the C5 and C6 lateral masses (the C6 and C7 spinous processes, respectively) have mean cephalocaudad angles of 18° and 15°, respectively, with mean lateral angles of 30° and 27°, respectively. Whereas the mean lateral trajectory angle for the C6 lateral mass from the C7 spinous process fell slightly below the averages proposed by An et al,[1] both its median of 30° and its mode of 31° indicated that with a larger sample complement, this data point would likely have more closely approximated the lateral angles proposed by An et al.[1] These reference points for C3–C6 could potentially vary as patient size and spinal curvatures deviate from the norm (see Fig. 2, B–E).

A potential weakness of this study was the approximately 10° SD that was also noted in An's study. This may reflect the anatomic variability in the size of cadavers, but this variability will also exist among surgical patients.

Surgeons have become accustomed to identifying the starting hole near the center of the lateral mass by visualizing the lateral and medial borders of the lateral mass and the superior and inferior facet joints. The optimum angles for safe placement are now widely accepted as 30° lateral and 15° cephalad. Despite the potential weaknesses, this current study demonstrated that the spinous processes can be an intraoperative landmark to aid the surgeon in determining the correct lateral mass screw trajectory that will add greater safety and efficacy to current techniques of lateral mass screw placement. The authors do not propose this technique in lieu of others, and we recommend confirmation of screw trajectory after placement according to current practice.

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