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ORIGINAL ARTICLE

Clinical Methods of Spinal-level Localization in Lumbar and Lumbosacral Spine Surgeries through Posterior Approach

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ABSTRACT

Aims: Clinical methods of palpations of iliac crests and spinous processes for spinal-level localization (SLL) were evaluated for accuracy in lumbar and lumbosacral (LS) spinal surgeries through the posterior approach.

Materials and methods: Hundred and seven successive patients operated for lumbar and LS diseases operated through the posterior approach in the last 2 years were evaluated prospectively for the accuracy of clinical methods for SLL. There were 76 males and 31 females. Age ranged from 16 to 70 years (average 43.5 years). Clinical methods for SLL included palpation of iliac crests and spinal processes in correlation with midline sagittal MR images. Surgical incision and further surgery were undertaken after confirmation of spinal level by intraoperative lateral radiograph of LS spine. Accuracy of SLL by clinical methods and surgical findings at various spinal levels was observed.

Results: Spinous processes for SLL were accurate in 94.39% (n = 101) cases. The level of iliac crests were seen at or just below L3 and L4 spinous processes in 89.71% (n = 96) and 10.29% (n = 11) cases respectively. Various anatomical features like posterior surfaces of laminae, thecal sac, and positions of roots in the spinal canal were helpful in differentiating L5 to S1 level than levels above. Six errors in SLL in the study included five females with L4 to L5 prolapsed inter-vertebral disk (PIVD) and one male with L5 to S1 PIVD.

Conclusion: Spinal-level localization by clinical methods in correlation with MR images is unreliable especially in women and L4 to 5 level. Intraoperative findings of L5 to S1 interspace and S1 lamina show features that may help in SLL during surgery.

Keywords: Herniated lumbar disk, Lumbar spine, Spine, Wrong-level disk surgery, Wrong-level surgery.

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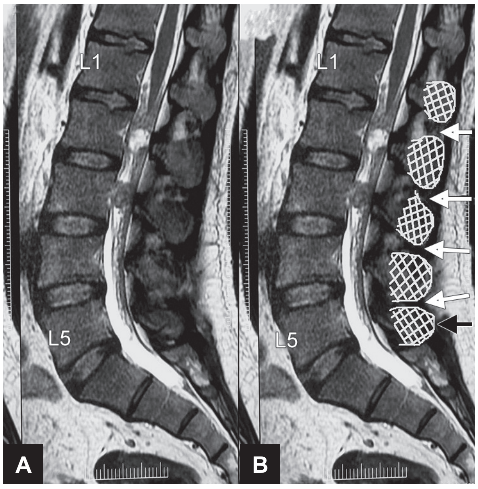
INTRODUCTION

Spinal-level localization (SLL) is the most important and the first step in lumbar (L) and lumbosacral (LS) spinal surgeries. Advanced technologies like image intensifier, mobile computed tomography (CT) scanner, and neuronavigation for spinal localizations during spinal surgeries are used for minimally invasive surgeries (MIS) like micro/endoscopic approaches. Various protocols have been introduced to prevent wrong-level surgeries of the spine.[1-5] A clinical method to identify the spinal level in the L/LS region, especially in peripheral centers having limited access to equipment for SLL,[6-9] may help spinal/neurosurgeons to safely accomplish L/LS surgeries through smaller incisions and lesser trauma to structures around the pathology than the conventional method.[4,10-13] We present our experience of a prospective study of evaluation of the accuracy of clinical methods for SLL and distinctive surgical findings at various levels in L and LS spinal surgeries through a posterior approach.

MATERIALS AND METHODS

Hundred and seven successive patients of various L and LS spinal diseases operated through the posterior approach in the last 2 years were evaluated prospectively. Spinal localizations were done by palpation of iliac crests and spinous processes in correlation with midline sagittal MR images. Due to the unavailability of an image intensifier, spinal levels were confirmed by mobile X-ray (high frequency: 150 mA, Allenger) in the operation room (OR) before surgical incision. All the patients gave their informed consent prior to their inclusion in the study. The study was designed as follows:

- After intubation and placing patients in the prone position on the OR table, patients' iliac crests and spinous processes were palpated and marked by the main surgeon (DKJ). The caudal-most spinous process (CMSP) was identified (Figs 1A and B) and its morphology was matched with the images of midline sagittal T1/2 MRI film and marked in the patient



Figs 1A and B: Midline sagittal T2 image of lumbosacral spine shows: (A) Intradural extramedullary hyperintense lesion at L2 level and mixed intensity lesion at L3 level; (B) Labeled lumbosacral spinous processes (in white grids), caudal-most well-formed palpable spinous process (black solid arrow), and grooves of inter-spinous spaces (white arrows)

(Figs 2A to C). Based on the morphologies of the spines in midline sagittal T1/2 MRI film, further counting of successive rostral/cranial spines up to the level of pathology was done and incision was marked. A transverse line was drawn connecting the highest points of iliac crests and its relation with the marked spinous processes was noted (Figs 2A to C).

- Lumbar puncture needle (16 G) was used as a radiographic marker, and mobile X-ray was used to get a lateral exposure of LS spine to confirm the spinal level.
- Further surgery was carried out after spinal-level (SL) confirmation. Accuracy of clinical SLL and intraoperative findings were recorded in each case.

The inclusion criteria were as follows:

- Patients who needed posterior midline exposure for their lumbosacral/LS pathologies
- Those who gave consent for undergoing surgery with the facilities available in the hospital
- Those who gave consent for undergoing "conventional surgery" in case of intraoperative difficulty (localization or exposure) [conventional surgery was defined as surgery by larger incision (5–10 cm) with or without laminectomy]

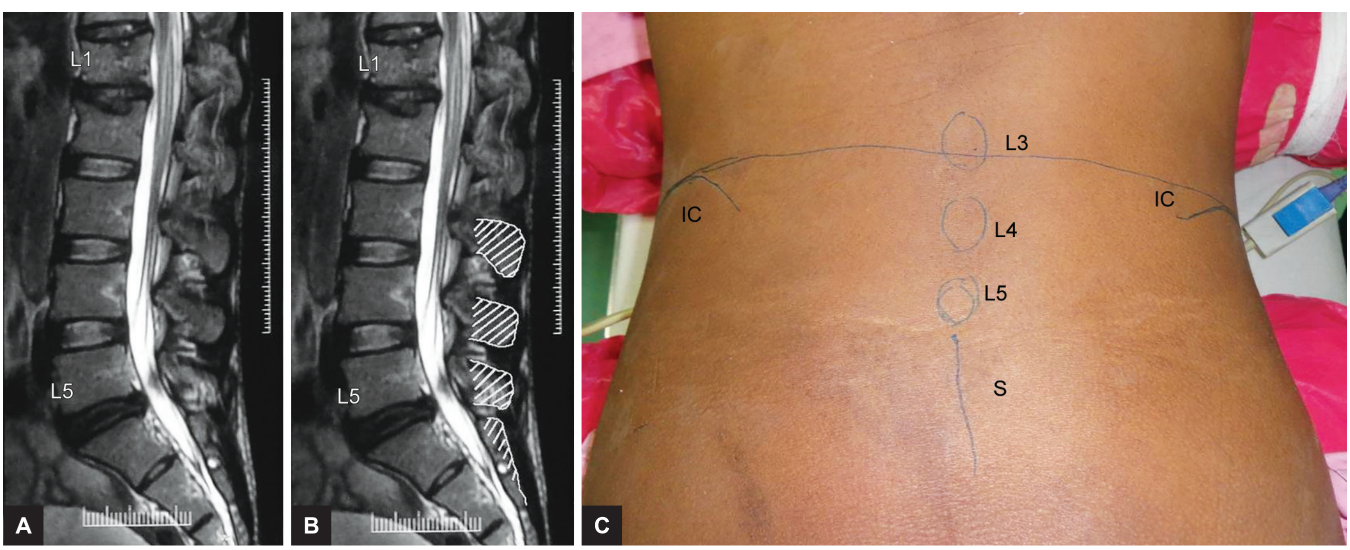
The exclusion criteria were as follows:

- Obvious anatomic deformities of the spine
- Those who needed fusion and fixation by transpedicular screws
- Patients who had previously undergone laminectomy/ies of the diseased/involved level.

Patients were operated by adequate invasion technique (AIT) using binocular loupes due to unavailability of an operating microscope. Fourteen patients were operated by endoscope-assisted discectomy using indigenously designed tubular working sheath using 4 mm 0° rigid telescope attached to a camera and monitoring system used for endoscopic awake intubation system of the Department of Neuroanesthesia. Visualizations of intradural lesions in 5 patients were intermittently assisted by an endoscope during dissection and removal.

RESULTS

Hundred and seven patients formed the study group. There were 76 males and 31 females. Age ranged from 16 to 70 years and the average age was 43.5 years. Table 1 shows patient characteristics and their spinal levels of diseases. Spinal degenerative disease (n = 101) was the most common diagnosis followed by intradural space-occupying



Figs 2A to C: Marking over back of the patient based on: (A) Midline T2 sagittal MR image of lumbosacral spine; (B) Shaded spinous processes of sacrum and lower lumbar spines; and (C) Spinous processes of lower lumbar spines, sacrum, and iliac crests marked over skin of the patient's low-back based on MR image

Table 1: Patients' characteristics as per their levels of disease

Diagnosis	Number of patients (n = 101)	Age			Females	Males	Wrong SLL
		Min.	Max.	Average			
L2–3 PIVD	1	NA	NA	20	0	1	0
L3–4 PIVD	3	35	60	43.3	1	2	0
L4–5 PIVD	51	16	70	41.86	14	37	5
L5–S1 PIVD	35	25	65	45.38	8	27	1
L4–5, L5–S1 PIVD	6	30	56	47.16	0	5	0
LCS	5	40	60	50.2	3	2	0
Pott's spine	1	NA	NA	56	1	0	0
SOL	5	28	65	42	4	1	0

LCS: Lumbar canal stenosis; SOL: Space-occupying lesion; Min.: Minimum, Max.: Maximum; SLL: Spinal-level localization

lesions (SOL) (n = 5) and Pott's spine involving posterior elements of L1 to 2 (n = 1).

An AIT was done in all of the single-level PIVD (n = 90) by 2 to 3 cm midline incisions. In remaining patients (n = 17), incisions of 3 to 6 cm were tailored to expose the involved spines and laminae only. Intraoperatively, exposure of caudal-most mobile joint for level localization was not required in any case. Laminectomies were done in cases of tumors and in cases with lumbar canal stenosis (LCS) due to multiple disk bulges, hypertrophy of ligamentum flavum (LF), and facet joints (n = 5). Out of 5 patients with SOL, 1 patient had L2 to 5 intradural tuberculoma, whereas remaining 4 patients had intradural neurofibromas at L1 to 2, L2 to 3, and L3 to 4, and 1 patient with two discrete neurofibromas at L2 and L3 (Figs 1A and B).

In 94.39% patients (n = 101), clinical SLL was correct, whereas it was incorrect in 5.61% patients (n = 6) identified by intraoperative mobile X-ray. Five patients with incorrect clinical SLL were being operated for L4 to 5 PIVD, whereas the remaining one was being operated for L5 to S1 PIVD. Clinical SLL was one level above in all the patients with wrong SLL, identified by intraoperative radiography. Five patients with inaccurate SLL were females suffering from L4 to 5 PIVD, whereas the remaining patient was a male with L5 to S1 PIVD. If we exclude patients with transitional vertebra (n = 5), posterior surfaces of the laminae of L5 and above were oblique anterosuperiorly with abruptly elevated postero-inferior margins as opposed to posterior surfaces S1 lamina, which were flat and roughly parallel to the skin surface. During surgery, it was easier to identify L5 to S1 inter-laminar space due to easy visibility of bilateral S1 roots without any retraction of dural sheath after removal of LF alone, whereas nerve roots of higher levels were visible only after removing LF and medial part of lamina/facet junction. Moreover, dural sheath retraction was uniformly necessary to see nerve roots of spinal levels L4 to 5 and above. S1 roots were seen uniformly located more posteriorly and almost in the same anteroposterior plane as of thecal sac, whereas nerve roots of higher levels were located more anteriorly in the antero-posterior plane as compared to thecal sac. We observed frequent presence of a thin dural/fibrous strand between midline posterior dural surface and LF up to the undersurface of S1 lamina at L5 to S1 interspace, which needed sharp division to avoid dural tear. The level of the iliac crests was most commonly at or just below the L3 spinous process in 89.71% (n = 96) cases. In the remaining 10.29% patients (n = 11), it was at or just below the L4 spinous process. In pathology involving lamina, as in patients with Pott's spine involving laminae (spine was not involved), localization was easier after initial dissection due to the presence of destructed laminae and granulation tissue. In intradural pathologies (tumors) and patients with PIVD, after removal of LF, it was possible to gently palpate the tumor or disk bulge through posterior dural surface by a blunt dissector (Penfield dissector No. 4). Five patients had transitional vertebra and SLL was accurate in all these cases.

None of our patient was too obese (morbid obesity) to make palpation of spines impossible. Palpations of spines in the midline were possible between bulges of paraspinal muscles under general anesthesia; however, it was easier to identify CMSP than counting rostral spinous processes. In thin-built patients, especially males, clinical SLL by palpation of spinous processes was easy.

DISCUSSION

Most of the developing countries have some outstanding centers of excellence, but these state-of-the-art facilities are few and far between, whereas suburban and rural parts still have very limited direct access to even primary general neurosurgical services.[14] Recent reports show that significant numbers of community health centers in rural areas of developing countries like India don't have even X-ray facilities.[14,15] Human resource, i.e., number of spinal surgeons and paramedical staffs, is progressively increasing, but the adequate number of free health centers (government institutes/hospitals) for poor patients is still a distant goal. Though health professionals of government hospitals are working beyond their capacity, significant numbers of patients who need surgeries, including spinal surgeries, keep waiting due to gross disparity in infrastructure and the number of poor patients. The situation is more or less similar in most of the developing countries including India.[8,13,14] Incidence of spinal ailments is not uncommon among the underprivileged and laborers, and many of them lose their livelihood due to degenerative or other lumbosacral/LS diseases.[12] Spine/neurosurgeons are operating these patients by conventional methods, mainly due to unavailability of intraoperative radiographic localization equipment. Conventional lumbar disk surgery as described in textbooks employs a midline incision 5 to 10 cm in length from the spinous process of involved lumbar-level spine to S1 mainly to identify mobile L5 to S1 as the reference and results into long skin incision and extended skeletonization of paravertebral muscles leading to its long-term effects.[13] Clinical SLL methods till date are not reliable enough to lessen the invasion in centers with limited resources; however, quest for an alternative to the radiological method will go on.

Operating at the wrong-level disk is a rarely discussed issue, but nonetheless occurs with relative frequency and is often the basis of a malpractice suit.[16-18] JCAHO Protocol,[2] SMaX Program,[4] and IRACE[3] are various protocols for preventing wrong-level surgeries, and intraoperative radiography for SLL is a uniform constituent of all these. Wrong-level spinal surgery may occur despite adhering to the universal protocol.[19,20] Maroon et al[21] had advised to perform microlumbar discectomy at the L5 to S1 level without intraoperative X-ray control, only by recognizing anatomical features of sacrum. Palpatory accuracy has been studied by Snider et al[22] using the 12th rib, L1 to 5 spines, sacrum, and iliac crests, which showed 69% accuracy. They also observed that obesity significantly decreased accuracy. In modern times, with expected zero error in SLL, 5.60% wrong SLL, observed in our study, is not acceptable. Surprisingly, there is no study in developing countries recently that report its true incidence, though it does occur at centers with and without radiographic localization equipment. Our experience may help reduce the incidence of wrong SLL, during conventional surgeries, at many remotely placed centers where facility of radiographic localization is not available. Palpation of CMSP in correlation with midline sagittal MRI images disregards frequent minor variations of other landmarks like iliac crests, 12th rib, or position of umbilicus, and furthermore, CMSP is patient specific as opposed to any generalization. Distinctive surgical findings at the L5 to S1 level and above and greater precaution in female patients with L4 to 5 surgeries will further help them reduce the chances of error in SLL. Additionally, in view of likelihood of error in clinical SLL one level above than the actual level, one should explore adjacent lower level, in a situation where expected pathology seen in MR images is not found.

Advancements in the imaging studies have led to laxity in the basic clinical methods in the clinicians of younger generation. "Palpation of spine" appears to be given less importance nowadays, and "MR imaging localization" is gradually replacing "clinical localization" in patients with spinal pathologies. Morphology of spines by palpation necessarily corresponds to MR images and is specific to a particular patient. Presence of transitional vertebra[23] does not affect localization in this technique, as it takes care of the disease level in relation to the CMSP instead of label or numbering of vertebra. We found L5 spine as CMSP uniformly in all of our cases. We understand that palpation of CMSP in morbidly obese patients will not be possible, but we had no such patient in our study. More errors in female patients in our study are likely due to more subcutaneous fat in females in the pelvic region, making palpation of CMSP and inter-spinous grooves at rostral levels imprecise. Though it has not been mentioned earlier, one should strictly refer to the MR images of a particular patient without any generalization.

The frequency of wrong-level exposure in lumbar procedures has been reported up to 15% in various series, but it is not possible to provide definitive estimates of the occurrence of wrong-site spinal surgery.[24] Obtaining intraoperative radiographs does not always guarantee the correct level of surgery.[24,25] Limitations of intraoperative radiograph[17,26] include inadequate radiological visualization, which we did not experience perhaps because none of our patients was morbidly obese. In the absence of radiographic localization, the conventional method should be used for these surgeries. Comparative localization of spinal landmarks for lumbar puncture by ultrasonography and palpation has shown no difference in results.[27] Variable degree of difficulty in palpation of lumbar spinous processes has been reported by Pisupati et al.[28] The conventional method of localizing the correct level is palpation of the spinous processes of the lumbar spine and iliac crests.[10,11] The level of the iliac crest revealed by the plain film of the lumbar spine was used to determine the spinous process of L4.[11] The most common level of iliac crests at or just below the L3 spinous process in our study may be due to prone position over bolsters under chest and pelvis under general anesthesia. However, we feel that mobility of the iliac crest in relation to L5 vertebra and above led to a variation in the level of the iliac crest from L3 to L4 spinous processes in our study. We, as a practice, palpated iliac crests, and it gave us an overall idea of the L3 or L4 spinal level, but it was not relied upon for surgical incision marking.

Few studies of morphology of lumbar spines have shown that L3 has the longest spinous process, whereas L5 has the smallest spinous process; however, there are only few studies that regard the quantitative anatomy of the lumbar spinous processes.[29,30] Tokgoz et al[31] assumed that the tip of the spine of L3 could be used as a preoperative anatomic landmark in order to avoid wrong-level surgery. Degenerative spines and patients with back pain and radiculopathies, variable degrees of muscle spasm, changes in lordosis, and presence of scoliosis are common, which may lead to change and difficulty in identification of the longest L3 spine. We believe that morphology of the spine, as opposed to numbering of the spines done by radiologists, is helpful for a surgeon in the OR, as palpation and simultaneous resemblance with MR images can be done as and when required.

Wider L5 to S1 interspace and lesser or no need of any bony removal after removal of LF, to approach roots or disk, has been reported earlier also and can be a useful finding to be looked for during L5 to S1-level surgery.[32] The difference in relative positions of nerve roots between L5 to S1 and above, variable need for bony removal for exposure of nerve roots, and flat posterior surface of S1 lamina, though not reported earlier, should be taken into consideration during surgery. Frequent presence of a thin dural/fibrous strand between the midline posterior dural surface and LF up to the undersurface of the S1 lamina at L5 to S1 interspace also has not been reported, and it needs sharp division to avoid dural tear. Pathologies like disk bulge, anteriorly located extradural tumor, and intradural tumor can always be identified by gentle palpation by a blunt dissector as soon as a small portion of LF is removed. If the lesion cannot be palpated at this stage as per MRI findings, one should reconfirm the level. Oblique posterior surfaces of laminae of L5 and above and their abruptly elevated posteroinferior margins can easily be differentiated from the flat posterior surface of S1 lamina. Posteriorly located extradural lesions are easy to find during initial exposure. Lumbar canal stenosis due to LF hypertrophy or facet joint hypertrophy is also identifiable at initial stages of LF removal. The most common incidence of wrong-level surgery has been reported in patients with L4 to 5 PIVDs.[22,33,34] Five out of six cases of inaccurate SLL in our study were female and were being operated for L4 to 5 PIVD. It is therefore advisable to be more careful while operating female patients with L4 to 5 PIVD. We share the earlier experience of more chances of error one level higher.[22,34]

Various risk factors like emergency surgery, unusual patient characteristics (morbid obesity, physical deformity, or congenital variations), unusual pressures of time to start or complete the procedure, involvement of multiple surgeons or multiple procedures in a single surgical visit, and surgery performed by less-experienced surgeons have been identified for wrong-level surgery.[2,24] It is advisable for any spinal/neurosurgeon to remember all the risk factors for wrong-level exposure or surgery. It is further highlighted that one should not hesitate to go for conventional surgery if findings of palpation of spinous processes are doubtful. Poor state of health care facilities in developing countries is a reality, and as long as it improves to a desired level, clinical methods for SLL and for minimizing invasion will have a role.

CONCLUSION

- Clinical methods of SLL are not reliable for lumbar and lumbosacral spinal surgeries through posterior approach.
- There are higher chances of wrong-level exposure or surgery in female patients and L4 to 5-level surgeries.
- Thecal sac and nerve roots at L5 to S1 interspace lie roughly in the same anteroposterior plane, and removal of LF alone exposes them. At spinal levels L4 to 5 and above, nerve roots lie anterior to the thecal sac in the anteroposterior plane. Moreover, retraction of the thecal sac is required after removal of medial lamina/facet junction in addition to LF to see exiting nerve roots at these levels.
- Oblique posterior surfaces of laminae of L5 and above and their abruptly elevated posteroinferior margins can easily be differentiated from the flat posterior surface of S1 lamina.
- At L5 to S1 interspace, there is frequent presence of a thin dural/fibrous strand between the midline posterior dural surface and LF up to the undersurface of S1 lamina and needs sharp division to avoid dural tear.

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