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Feasibility and Efficacy of Preoperative Epidural Catheter Placement for Anterior Scoliosis Surgery

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ABSTRACT

Background: Postoperative pain control *via* thoracic epidural catheters (TECs) is an important aspect of postoperative care, and ample evidence highlights its positive physiologic effects and superiority to intravenous analgesia. If epidural catheters for postoperative pain relief are used in scoliosis surgery, current practice is the intraoperative placement of the TEC by the surgeon because preoperative placement is considered challenging and dangerous. On the basis of magnetic resonance imaging of scoliotic spines, the authors developed a technique for preoperative placement of TEC and investigated its safety and feasibility.

Methods: Patients undergoing anterior scoliosis surgery were included, who received preoperative placement of TEC. Postoperative pain, problems associated with the TEC placement, possible side effects, radiographic data, and insertion levels of the TEC were noted.

Results: The apex vertebra was identified as a possible site for TEC placement due to dural sac shift leaving a wider epidural space on the convex side. Scoliosis-induced rotation of the vertebrae required realignment of the needle toward the convex side. Sixty patients were included. The success rate for TEC placement was 96.6%: one failed attempt, one catheter placed intrapleurally, and one patient with Horner syndrome. Seven percent of patients required additional rescue analgesia. All other patients had pain scores within acceptable limits (Visual Analogue Scale <5).

Conclusions: The authors have demonstrated that it is possible to insert a TEC in patients with scoliotic spines with a high degree of success using a redesigned approach and thus provide adequate postoperative analgesia with a single epidural catheter. However, precautions have to be taken.

What We Already Know about This Topic

- Thoracic epidural analgesia improves pain control after scoliosis repair surgery
- Thoracic epidural catheters are often placed surgically for fear of technical difficulties or spinal cord injury *via* percutaneous insertion

What This Article Tells Us That Is New

- In 59 patients for scoliosis surgery, percutaneous insertion of an epidural catheter with technique based on the review of magnetic resonance imaging was successful without patient injury

POSTOPERATIVE pain control is an important aspect of adequate postoperative patient care, and there is ample evidence that effective postoperative pain management reduces patient morbidity and improves patient outcome.[1,2] Perioperative continuous thoracic epidural analgesia for major surgery has positive effects on the quality of analgesia and pulmonary function as well as return of bowel function and catabolism, all of which may translate into reduced morbidity and mortality.[1–8] Inadequate postoperative pain relief can delay recovery, prolong hospital stay, and boost medical costs.[9] Patients undergoing scoliosis surgery suffer from severe postoperative pain and restrictive respiratory disease. The insertion of a thoracic epidural catheter (TEC) has postoperative benefits with respect to analgesia, physiotherapy, and mobilization because intravenous analgesia is often unsatisfactory.[10] Several authors have reported significantly better pain relief from continuous thoracic epidural analgesia compared with intravenous analgesia after scoliosis

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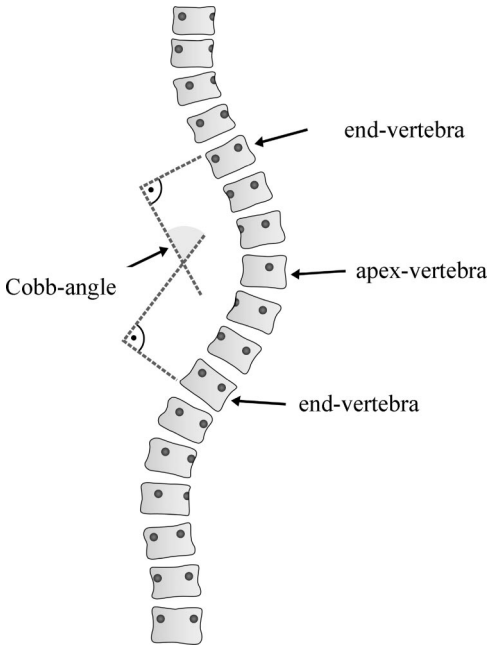

Fig. 1. Schematic display of a scoliotic spine (right convex thoracic curve) and definitions of the end (= neutral) and apex vertebra defining curve length and Cobb angle measurement.

surgery.[11,12] In most of these studies, the surgeon placed the TEC intraoperatively under direct vision during posterior scoliosis surgery. Intraoperative TEC placement by the surgeon during anterior scoliosis surgery is also possible, but it is considered more difficult and traumatic and is limited to those cases where rib head resection allows visualization of the transverse foramen and longitudinal posterior ligament.[13]

A seldom used but possibly less traumatic alternative in anterior scoliosis surgery is preoperative insertion of the TEC by the anesthesiologist. The potential benefits are recognized, but preoperative placement is considered challenging and potentially risky, especially in inexperienced hands. In the scoliotic spine, the vertebral bodies are rotated in the axial plane, with their spinous processes facing into the concavity of the curve (fig. 1). Percutaneous catheter insertion requires modification of the standard paramedian approach to the epidural space. A magnetic resonance imaging study examining 307 vertebrae in patients with thoracic scoliosis with an average Cobb angle of 66° (range, 50–108°) found that the mean width of the epidural space was less than 1 mm on the concave side at the thoracic apical vertebral level and 1 mm at the lumbar level.[14] However, on the convex side, the horizontal width of the epidural space measured between 3 and 5 mm. A shift of the dural sac toward the concavity resulted in the width of the epidural space on the concave side being significantly less than that on the convex side at nearly all vertebral levels. The amount of dural sac shift diminished farther away from the apex vertebra toward the neutral vertebral levels, leaving symmetrical epidural spaces at the neutral level.[14,15]

To determine the optimal approach for preoperative TEC placement, the anesthesiologist must be able to identify the anatomic variations along the scoliotic portion of the spinal column.

The study aim, based on the findings of previous magnetic resonance imaging, was to determine the feasibility of a modified paramedian approach to the epidural space in patients with idiopathic scoliosis, placing the epidural catheter at the apex of the scoliosis or as close to the apex as possible. The efficacy and complications associated with the technique were recorded in an attempt to determine the feasibility and potential risks in these patients.

Materials and Methods

Patient Selection

An approval from the University of Muenster Ethics Committee (Muenster, Germany) was obtained, and written consent was received from the patients or their parents or legal guardian. Patients with left-sided thoracolumbar and right-sided thoracic scoliosis, who underwent anterior scoliosis surgery in one of our two spinal surgery centers (University Hospital of Muenster or St. Franziskus Hospital Muenster), were included in the study.

Patients received oral midazolam (0.3 mg/kg up to a total of 7 mg) as premedication and were placed—according to the anesthesiologist's preference—either in a sitting position or fully anesthetized in a lateral position (with the convex side of the scoliosis facing upward) for catheter placement.

Because the epidural space is wider on the convex side, we aimed for the epidural space on that side near the level of the apex vertebra, taking into account the necessary needle realignment toward the convex side because of the scoliotic-induced rotation of the vertebrae (figs. 1 and 2). Using this modified paramedian approach, loss of resistance to saline was used to identify the epidural space, and a TEC was inserted at the level of the apex vertebra and advanced 4 cm into the epidural space. All catheters were tunneled subcutaneously and secured.

Induction of anesthesia was achieved with propofol, sufentanil or fentanyl, and rocuronium or cis-atracurium. Maintenance of anesthesia was with sevoflurane or desflurane in oxygen/air and sufentanil or fentanyl. A first dose of intravenous acetaminophen (15 mg/kg) was given to all patients toward the end of the procedure.

Postoperative Care

To allow intraoperative and postoperative direct neurologic monitoring, a continuous epidural infusion was commenced only postoperatively after neurologic testing by the surgeon. A bolus of 5–10 ml plain bupivacaine (0.25%) was followed by patient-controlled epidural analgesia using a continuous infusion of 0.175% bupivacaine plus 0.75 μg/ml sufentanil at 3–5 ml/h (for patients >30 kg body weight). Weight-adjusted and time-restricted boluses on demand (1–3 ml every 20 min) were allowed. Oral acetaminophen (20 mg/kg) was administered on a regular basis, and intravenous piritramide (0.1 mg/kg) was used for rescue analgesia when necessary. Patients were closely monitored during recovery and on the wards for any signs of

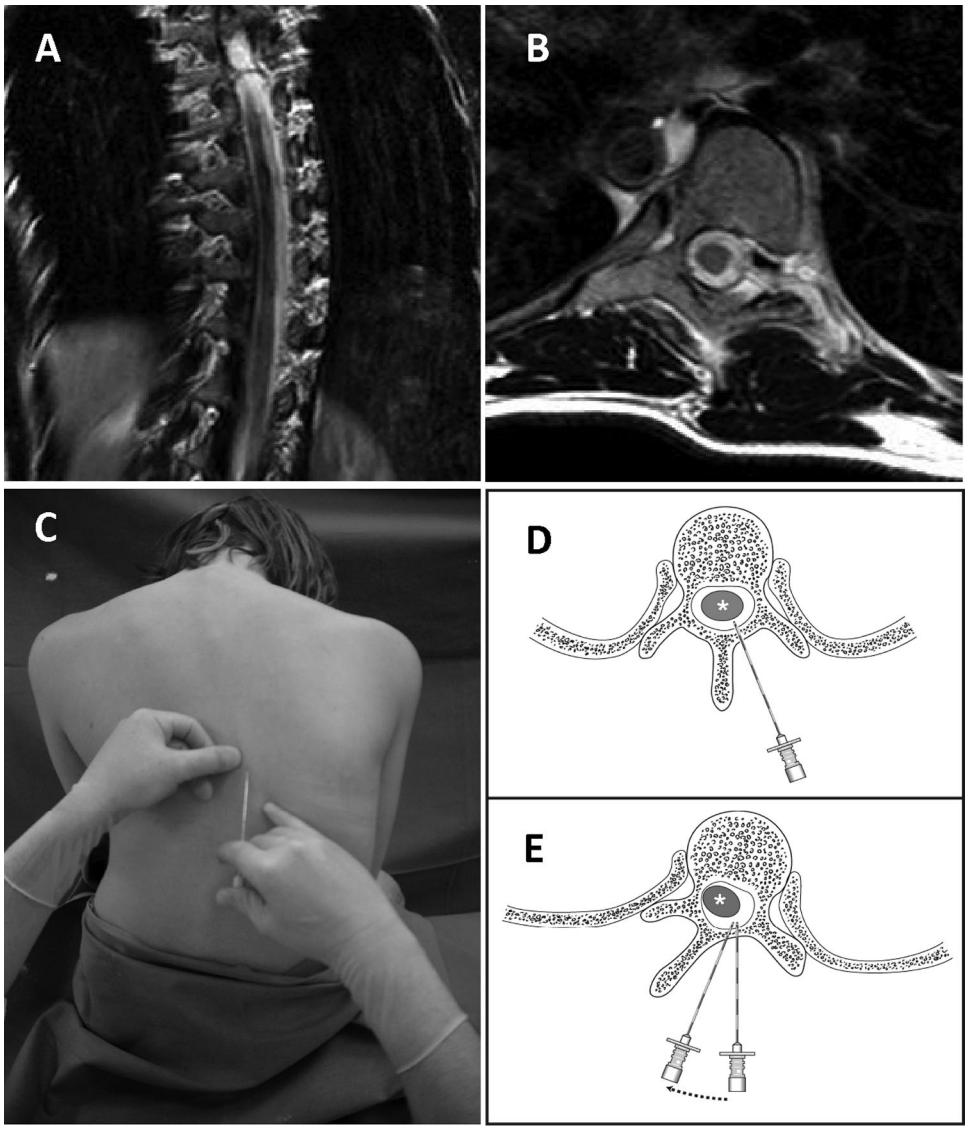

Fig. 2. Preoperative thoracic epidural catheter placement in patients with scoliotic spines. (*A*, *B*) Inverted coronal and axial T2-weighted magnetic resonance images displaying an increased epidural space capacity on the convex side because of rotational shift of the dural sac and contents toward the concave side at the level of the apex vertebra. (*C*) Patient receiving a thoracic epidural catheter preoperatively. Access to the epidural space is ideally a paramedian approach at the level of the apex vertebra. The schematic illustration displays the position of the dural sac with its contents (*) and the necessary needle realignment toward the convex side for a paramedian approach in a scoliotic spine (*E*) compared with a straight approach in a normal spine (*D*). The greater width of the epidural space on the convex side because of the rotational dural sac shift to the concave side serves as a possible safety zone.

adverse events. In addition, patients were visited twice daily by the pain service, which was composed of a trained pain nurse and an anesthesiologist. Pain therapy *via* TEC was adjusted individually according to patient demand. Pain scores for rest and dynamic pain were noted on a Visual Analogue Scale from 0 to 10 cm, with a score more than 3 mandating intervention. The complications of epidural therapy were noted and treated as required.

Statistical Analysis

Descriptive data are described using mean and SD or median and range, as appropriate.

Results

TEC Placement and Postoperative Care

Sixty patients were enrolled in the study, of whom 56 suffered from idiopathic scoliosis, 3 from neuromuscular disease, and 1 from Marfan syndrome. One patient was excluded because of missing data. Demographic data and information about spinal deformities are displayed in table 1.

None of the patients had undergone anterior spinal surgery previously, and all operations were performed by either of two surgeons (V.B. or U.L.).

Table 1. Demographic Data of Patients

	Patients (n = 57)
Age, yr	16.2 ± 4.9 (12–24)
Weight, kg	55.4 ± 12.4 (27–94)
Sex	
Male	15
Female	42
Cobb angle preoperative, °	63.9 ± 19 (35–124)
Cobb angle postoperative, °	25.1 ± 13.7 (0–70)
Curve length, segments	5.6 ± 1.5 (3–11)
Instrumentation length, segments	5.0 ± 1.3 (2–8)
Duration of thoracic epidural catheter therapy, d	5.4 ± 1.4 (1–8)

Values are presented as mean ± SD (range) or number.

Choice of position (lateral or sitting) and conscious level (awake or anesthetized) of the patient was handled differently in the two centers and based on the anesthetists' preferences: 31 patients in one of the two centers had been fully anesthetized for catheter placement in a lateral position. The remaining patients in the other center were being sedated using oral midazolam (0.3 mg/kg up to a total of 7 mg) as premedication or received additional intravenous midazolam (0.5–2 mg) before catheter placement in a sitting position. TEC placement proved uneventful in 58 patients. In 1 patient, multiple attempts to site a TEC failed. The correlation between the radiographically determined apex vertebra and the clinically determined apex vertebra is displayed in figure 3.

Adverse Effects and Complications

In one patient with a severe scoliosis and a preoperative Cobb angle of 124°, the TEC was placed intrapleurally, this being discovered by the surgeon when one lung ventilation was started. The catheter was removed, and the patient was excluded from our study, giving a final success rate of 96.6% for preoperative TEC placement. Five patients suffered from postoperative nausea and vomiting, and one patient (apex vertebra T8; catheter insertion T9) had a transient unilateral Horner syndrome that resolved when the epidural infusion was ceased. No patient developed a neurologic deficit, epidural hematoma, epidural abscess, or meningitis.

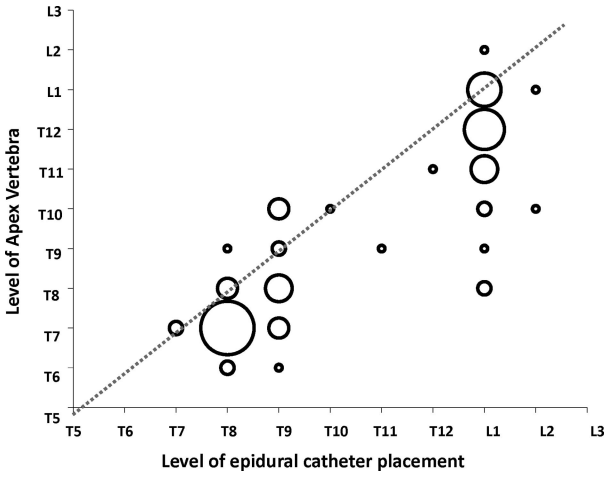

Fig. 3. Comparison of the level of the epidural catheter placement by the anesthesiologist and apex vertebra as determined by x-ray. The *dotted line* is the line of agreement between the level of the apex vertebra and the planned level of placement of the epidural catheter. The area of each *bubble plot* depends on the number of patients. The increased number of procedures around the T8 and L1–L2 levels relates to surgery for thoracic or thoracolumbar scoliosis, respectively.

Efficacy of Postoperative Pain Therapy

In 57 patients, the catheter was used for postoperative pain therapy. The average duration of patient-controlled epidural analgesia was 5.4 ± 1.4 days (range, 1–8 days). Nearly in all patients, pain scores remained within acceptable limits (Visual Analogue Scale <5) during TEC therapy (fig. 4). Four patients (7%) needed rescue analgesia at least once. The median pain scores in the recovery room were less than 3. On day 2, the median (range) scores were 2 (0–5) for pain at rest and 3 (0–8) for dynamic pain. Scores for rest pain and dynamic pain decreased to 1 (0–5) and 1 (0–6), respectively, during the next 5 postoperative days (fig. 4). Patients experiencing higher scores were those with a rib resection and a lower level of TEC placement than the apex vertebra or the level of rib resection.

Discussion

Idiopathic scoliosis causes a distinctive intravertebral deformity of the spine. There is a shift of the dural sac and contents toward the concavity of the scoliosis, resulting in the epidural space being widest on the convex side in the periapical region. We previously used magnetic resonance imaging scans to investigate vertebral morphology in the scoliotic spine focusing on pedicle morphology.[14] As an incidental finding, the displacement of the dural sac toward the concave side that diminishes farther away from the apex vertebra producing symmetrical spaces at the level of the neutral vertebra was described.[14,15] It does not seem that this information has prompted consideration of the apex convexity as a suitable insertion site for an epidural catheter, despite it offering a potentially safe zone within the scoliotic spine. This led to the idea of percutaneous TEC placement at the level of the apex vertebra, where the epidural space was largest in volume. We believe that this is the first series to describe direct thoracic epidural catheterization at the apex vertebra level in a scoliotic segment of the spinal column.

Despite concerns about feasibility,[16,17] we have shown that preoperative epidural catheter insertion can be performed without raising significant concerns and a high success rate of 96%, corresponding to that reported in the nonscoliotic spine.[18]

Obstacles to TEC placement in the scoliotic spine are most often caused by the axial rotation of the vertebral bodies and angulation of the spinal processes. Using ultrasound in 11 scoliosis surgery patients, McLeod *et al.*[17] identified the

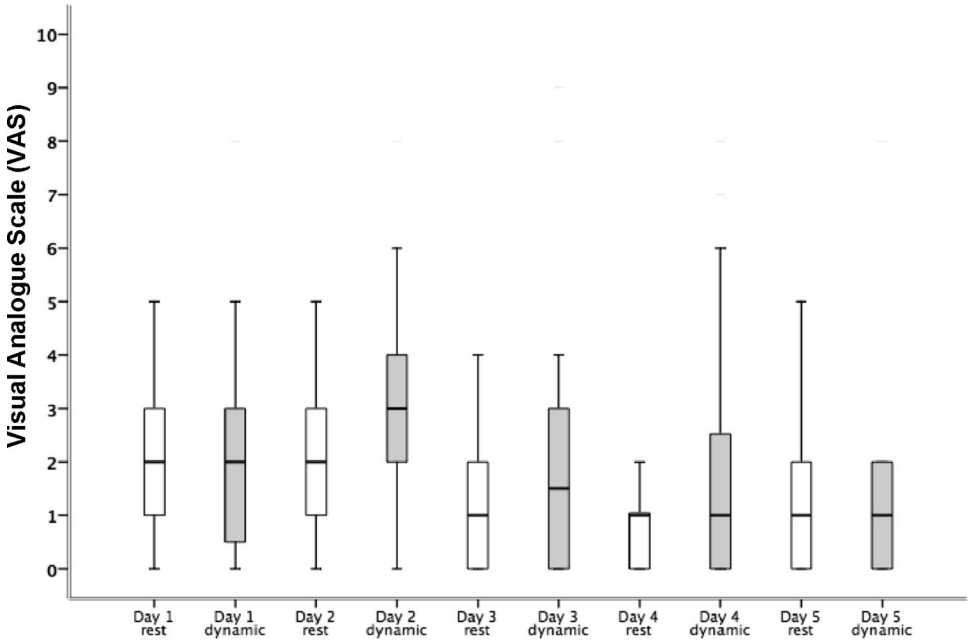

Fig. 4. Comparison between rest (*white*) and dynamic (*gray*) pain scores across the first 5 postoperative days in patients receiving a thoracic epidural catheter before anterior scoliosis surgery. The *box plots* show the median, interquartile range, and the extremes of individual recordings.

least rotated vertebra (the neutral vertebra) to facilitate epidural catheter insertion. This technique may produce higher rates of successful insertion, but it can result in ineffective analgesia in the upper segments of the instrumented spine. The neutral vertebra appears to be located too caudal for adequate distribution of epidural solution across the entire segmental area required, particularly if only one TEC is used. If the tip of the epidural catheter is not located in the center of the scoliotic curve, two epidural catheters are necessary for adequate pain relief.[3] Blumenthal *et al.* state that the two catheters need to be inserted by the surgeon—one catheter from a cephalad entry point and the second from a caudal entry point. However, we believe that our technique provides the best possible access to the center of the scoliotic curve, and furthermore—with regard to the extra space produced by the shift of the dural sac—even preoperative insertion of a second epidural catheter by the anesthesiologist would be possible if considered necessary.

The intraoperative use of the epidural catheter is mostly limited by the surgeons' demand to perform intraoperative wake-up tests and direct postoperative neurologic testing. Whether the possible positive effects of continuous thoracic epidural analgesia such as earlier return of bowel function, cardiac protection, and catabolism pertain when the epidural catheter is not used intraoperatively is not fully clear.[1–8] However, there is little doubt that epidural catheters provide superior analgesia and improved respiratory function postoperatively when compared with intravenous analgesia, which is highly desirable especially in this group of otherwise healthy patients where postoperative pain and respiratory function are the predominant problems.[4,13,19–23]

The success rate in this series was higher than we had anticipated, but there were some perioperative complications. In one patient, intrapleural misplacement of the epidural catheter occurred, and another patient suffered from a transient unilateral Horner syndrome. Intrapleural location is a known complication of thoracic epidural anesthesia that has been described before in patients with normal anatomy.[24,25] Although potentially life threatening, no postoperative sequelae were observed in the existing case reports and in our patient. Whether preoperative placement of the TEC in patients with scoliotic spines *per se* bears a higher risk of pleural puncture compared with patients with normal anatomy cannot be answered. To date, there are no sufficient data available on pleural epidural catheter misplacements in patients with normal anatomy. At least, anterior scoliosis surgery with one-lung ventilation always allows visual inspection of the thoracic cavity for catheter misplacement.

Horner syndrome and neurologic complications such as hypoglossal or trigeminal nerve palsy are also recognized complications of both thoracic and lumbar epidural analgesia.[26–28] Anatomic variations within the epidural space may lead to unpredictable spread of local anesthetic.[28] Similar alterations of the epidural space might be present after scoliosis surgery, although in this series, only one patient developed a neurologic deficit, so this does not seem to be a common problem in these patients, and it has furthermore not been reported before in patients undergoing scoliosis surgery who have received an epidural catheter.

Whether the wider "target zone" on the convex side of the spinal cord could also lead to catheter migration anteriorly resulting in an increased risk for anterior neurologic or isch-

emic injury seems—from our experience—unlikely; however, it cannot be fully answered until larger studies have been performed.

The majority of our patients suffered from idiopathic scoliosis. It might be worthwhile to investigate whether this approach could be generalized to patients with neuromuscular disorders. However, it has to be taken into account that many of the patients with neuromuscular diseases are severely mentally handicapped, and compliance in that group is generally low and communication hindered. Therefore, postoperative pain therapy with an epidural catheter in those patients is a demanding task and will require a well-organized and experienced pain service.

We have demonstrated that it is possible for an experienced anesthesiologist to insert a TEC preoperatively in patients routinely with severely scoliotic spines with a high degree of success and thus provide adequate postoperative analgesia with a single epidural catheter at the level of the apex vertebra.

It seems to be a feasible and useful technique; however, several precautions must be emphasized: It is essential to use a percutaneous paramedian insertion approach on the convex side of the scoliotic spine at the level of the apex vertebra taking into consideration the necessary needle realignment. In addition, information from anteroposterior and lateral radiography and magnetic resonance imaging should be obtained and thoroughly reviewed preoperatively. Even though the shift of the dural sac provides a wider target zone for catheter entry on the convex side, we suggest that only a highly experienced anesthesiologist should perform the technique described because of the increased level of difficulty and the associated possible risk of catheter misplacement. Furthermore, additional techniques that may enhance the safety of the new approach include the use of imaging technology such as radiographic guidance or ultrasound to assist placement of the catheter and to verify correct location of the catheter tip.

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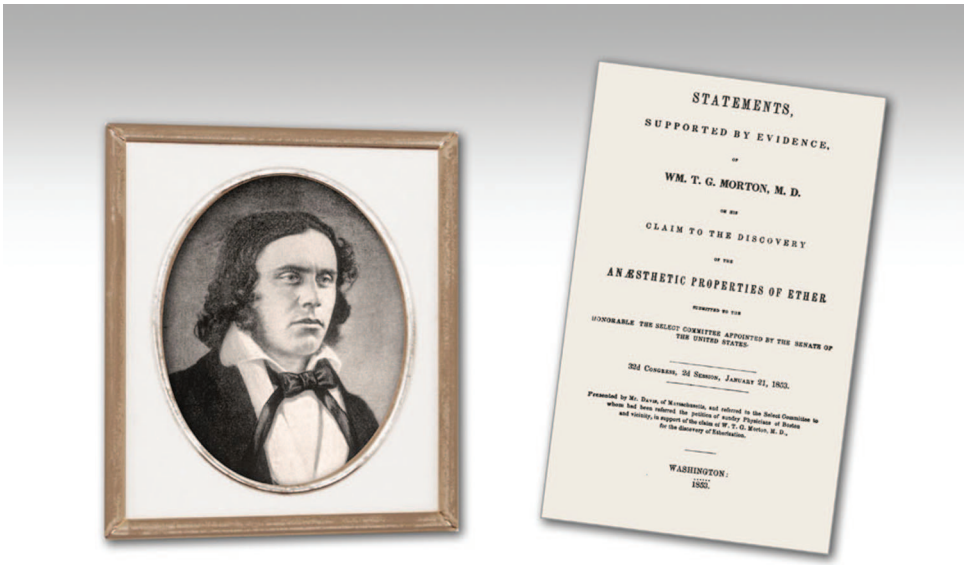
ANESTHESIOLOGY REFLECTIONS

W. T. G. Morton's Dana, Maritime Attorney



With his vision compromised by measles acquired during his junior year at Harvard, Richard Henry Dana, Jr. (1815–1882, *see above left*) sought relief by sailing from Boston in 1834 around Cape Horn to California and back. He recorded his 2-yr odyssey "before the mast" (*i.e.*, in the seahands' quarters in the ship's bow). In 1840 he not only published his diaries as a best-selling book, *Two Years before the Mast*, but also passed the Massachusetts bar. Specializing in maritime law, Dana forsook water for ether by 1853 to serve as an attorney to W. T. G. Morton when the latter sought congressional recognition (*see above right*) for his . . . *Discovery of the Anaesthetic Properties of Ether*. (Copyright © the American Society of Anesthesiologists, Inc. This image appears in color in the *Anesthesiology Reflections* online collection available at www.anesthesiology.org.)

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In Response

Both Chhabra and Ganesan[1] and Lalwani[2] question the use of bupivacaine with epinephrine in our study on ethical grounds, because of the potential for bupivacaine toxicity. Our study was not the first to use an intravascular injection of bupivacaine with epinephrine to simulate a positive test dose.[3,4] When designing the study, we considered whether to use lidocaine or bupivacaine as the local anesthetic in our intravascular test dose. We decided to use bupivacaine for several reasons. First, bupivacaine with epinephrine is frequently used for test dosing in many institutions; indeed, it is the most frequently used combination at our hospital when single shot blocks are used. Second, the dose that was used was far less than that shown to produce toxic levels in humans.[5] All patients in our study were carefully screened for increased risk factors for local anesthetic toxicity, which, if present, excluded the patient from enrollment. As noted in the Methods section of our article, the study protocol was vetted and approved by our local IRB, who felt that the risk to participation in the study was acceptably low. The risks of toxicity were disclosed to the parents of our study subjects, as was required by the IRB.

Drs. Chhabra and Ganesan pose 2 additional questions. The article by Mauch et al.[6] that they cite was not yet published when we submitted our manuscript, so we had no access to those findings when planning or writing our study. However, an older report suggests that the local anesthetic alone can be responsible for the electrocardiographic changes seen with positive test doses.[7] Based on the conflicting data in the literature, we believe that the question of whether an effective test dose must contain both local anesthetic and epinephrine was unresolved at the time our study was performed.

They also suggest that differences in the depth of anesthesia among subjects may have contributed to our results. First, we are unaware of a reliable method of accurately measuring depth of anesthesia in children under the conditions of our study. Second, all of our patients underwent a stabilization period before the injection of the test dose and had no surgical or other stimulation during the study period, so we believe that any differences in anesthetic depth were highly unlikely to have either occurred or to have influenced the results.

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Paramedian Approach for Neuroaxial Anesthesia in Parturients with Scoliosis

To the Editor

In response to the review by Ko and Leffert[1] of neuraxial techniques in parturients with scoliosis, I suggest that the modified paramedian approach of Boon et al.[2] may offer several advantages. With this approach, the skin is entered just lateral to the dorsal spine perpendicular to the skin (Fig. 1). The needle is advanced toward and onto the lamina and the needle then is "walked" cephalad over the lamina until the interlaminar space is entered. When used in parturients with scoliosis, this technique may have the following advantages. First, parturients with scoliosis have distortion of the spinous processes. The wider angle between the spinous and transverse processes on the convex side of the curve allows a wider field for needle insertion and advancement. Second, the needle is inserted perpendicular to the skin. This needle insertion technique is simpler than the standard paramedian approach in which the needle is angled in both sagittal and transverse planes.[3] In addition, the needle can more likely enter the epidural space in the midline in parturients with scoliosis, because of rotation of spinous processes and laminae.

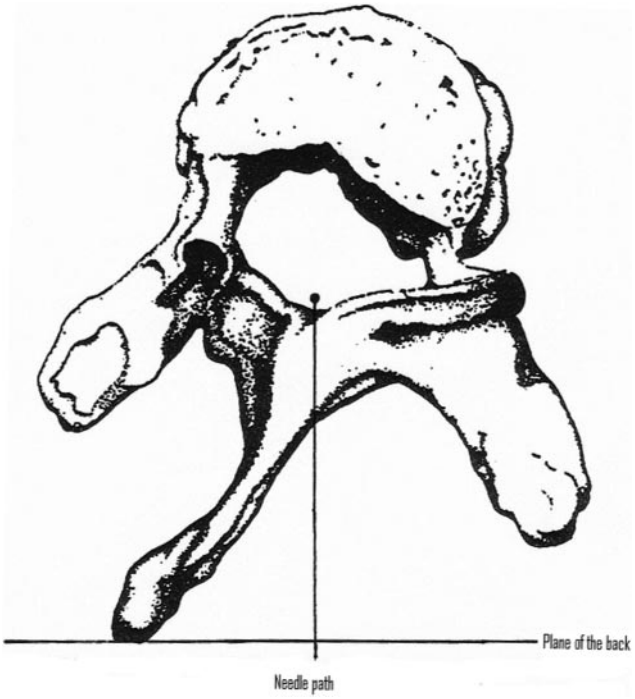

Figure 1. Modified paramedian approach for parturients with scoliosis.

Third, the lamina is used as the landmark, facilitating placement of the needle. Finally, the larger interlaminar space on the convex side of the scoliosis[1] also facilitates needle entrance into the epidural space. However, these are all theoretical advantages that are based on anatomic consideration in patients with scoliosis. Randomized trials in parturients with corrected and uncorrected scoliosis are required to further define efficacy and optimal techniques.[1]

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In Response

We appreciate Dr. Huang's suggestion[1] of using the modified paramedian approach of Boon et al.[2] for neuraxial anesthetic placement in parturients with scoliosis, and are intrigued by the theoretical anatomic advantages that this technique may offer. With the development of new techniques, as well as the application of existing alternative approaches, we hope that there will be further expansion of the armamentarium at the disposal of clinicians caring for these patients.

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Malignant Hyperthermia in the Absence of Triggering Agents

To the Editor

Upon review of Table 1 in the recent review by Larach et al.[1] summarizing the presentation, treatment, and complications related to malignant hyperthermia, I was concerned to see a reference to a patient with a family history of malignant hyperthermia who developed an episode despite the absence of what we would ordinarily consider to be the usual triggering agents (succinylcholine or a volatile agent).

I would welcome further elaboration by the authors as to their speculated mechanism for the development of malignant hyperthermia in this patient.

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In Response

Dr. Setzer-Saade[1] questions a malignant hyperthermia (MH) episode in a child without exposure to volatile anesthetics or succinylcholine. We now have the patient data reported to the North American Malignant Hyperthermia Registry of MHAUS via the AMRA (adverse metabolic/musculoskeletal to anesthesia) from 2004 and new information from the patient's anesthesiologist, whose contact information was still accurate.

This 2-year-old, 12.7-kg girl with a lean build presented for elective dental restorations due to dental caries (without known abscesses). She had a positive family history of MH but no personal history of muscle weakness, cramps,