INCE the realization that anteriorly located lesions are better treated using anterior procedures rather than simple laminectomies, anterior spinal surgery has become more common.1,10,16,28,29 Anterior approaches to the thoracic spine are technically difficult. Patients may be neurologically compromised preoperatively, and the risks of postoperative deficits can be substantial.10,24 The frequent use of spinal instrumentation during surgery also increases risk. Somatosensory evoked potential neurophysiological monitoring is often used to warn the surgeon of impending neurological compromise and to allow for changes in operative procedures that may reverse any neurological injury.

Somatosensory evoked potentials have been used in a variety of clinical procedures and theoretically are of great benefit in spinal surgery.2,3,7-8 They have been extensively used in the treatment of cases involving the placement of complex instrumentation in the spine. Somatosensory evoked potential monitoring alerts the surgeon to operative maneuvers that may result in neurological compromise7,4,30,31 and thus allows for appropriate corrective action. Changes in SSEP latency and amplitude indicate possible neurological compromise and return of SSEP amplitudes may indicate the adequacy of corrective maneuvers.

Somatosensory evoked potential monitoring is considered by some to be the standard of care, especially when spinal instrumentation is involved. Some authors have claimed that SSEP monitoring has replaced the wake-up test in surgery to treat scoliosis.13,21 Although the use of SSEP monitoring has become widespread, little is known concerning the sensitivity and accuracy of SSEP monitoring in all clinical situations in which it is applied. False-positive results are relatively common, and false-negative results also occur. In several case reports the authors have described occurrences in which SSEPs remained normal; however, patients were noted to have neurological deficits postoperatively.4,5,15,19

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Somatosensory evoked potential monitoring in anterior thoracic vertebrectomy

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Object. Spine surgeons have used intraoperative cortical and subcortical somatosensory evoked potential (SSEP) monitoring to detect changes in spinal cord function when intraoperative procedures can be performed to prevent neurological deterioration. However, the reliability of SSEP monitoring as applied to anterior thoracic vertebral body resections has not been rigorously assessed.

Methods. The authors retrospectively reviewed hospital charts and operating room records obtained between August 1993 and December 1998 and found that SSEP monitoring was used in 44 surgical procedures involving an anterior approach for thoracic vertebral body resections.

There were no patients in whom SSEP changes did not return to baseline during the surgical procedure. Patients in four cases, despite their stable SSEP recordings throughout the procedure, were noted immediately postoperatively to have experienced significant neurological deterioration. The false-negative rate in SSEP monitoring was 9%. Sensitivity was determined to be 0%.

Conclusions. It is important to recognize high false-negative rates and low sensitivity of SSEP monitoring when it is used to record spinal cord function during anterior approaches for thoracic vertebrectomies. The insensitivity of SSEPs for motor deterioration during anterior thoracic vertebrectomies is likely due to the limitation of SSEPs, which monitor only posterior column function whereas motor paths are conveyed in the anterior and anterolateral spinal cord. The authors believe that SSEPs can not be relied on to detect irreversible spinal damage during anterior thoracic vertebrectomies.

Key Words • somatosensory evoked potential monitoring • thoracic disc • vertebrectomy

Abbreviations used in this paper: CT = computerized tomography; MR = magnetic resonance; SSEP = somatosensory evoked potential.
The treatment of fractures, tumors, infections, and other maladies of the thoracic spine sometimes requires an anterior approach in vertebrectomy and placement of instrumentation. In our institution we have routinely used SSEP monitoring in anterior thoracic vertebrectomies. In one recent case (Case 1), significant neurological deterioration occurred immediately after recovery from anesthesia, despite stable SSEP findings throughout the procedure. This led us to review all cases of anterior thoracic vertebrectomies performed at our institution over the past 5 years in which SSEP recording was attempted. The goal of this study was determining the usefulness and reliability of SSEP monitoring during anterior thoracic vertebrectomies. This knowledge will allow surgeons to interpret SSEP data more effectively.

### Clinical Material and Methods

#### Patient Characteristics

Between August 1993 and December 1998, SSEPs were monitored in 44 patients undergoing anterior thoracic vertebral resections in the Department of Neurosurgery at the Mount Sinai Hospital in New York City. Patient charts, SSEP monitoring data, and operative reports were retrospectively reviewed. The mean patient age was 56 years (range 42–85 years). The number of male and female patients was similar (23 men and 21 women). Neurophysiological monitoring was performed successfully in 43 of the 44 patients. The diagnoses, affected vertebral level(s), Frankel grades, and SSEP data are presented in Table 1. Thoracic vertebrectomy was performed using an anterior approach to

### TABLE 1

Summary of characteristics in 44 patients who underwent SSEP monitoring

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Diagnosis</th>
<th>Treated Levels</th>
<th>Frankel Grade</th>
<th>Sensory Change</th>
<th>SSEP Change</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>lung carcinoma</td>
<td>T4–6</td>
<td>D</td>
<td>E</td>
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</tr>
<tr>
<td>2</td>
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<td>T-3</td>
<td>D</td>
<td>D</td>
<td>improved</td>
</tr>
<tr>
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<tr>
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<tr>
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</tr>
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<td>C</td>
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<td>A</td>
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<tr>
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</table>
SSEPs in anterior thoracic vertebrectomy

the thoracic spine in all patients. Surgical approaches included posterolateral thoracotomy,8,9 anterior thoracotomy,10,11 and lateral extracavitary.12,13 Anterior instrumentation with bone graft or methylmethacrylate was placed in all patients. The vertebral level involved most often in these procedures was T-5. Sixteen patients had two vertebral levels involved, and seven patients had three vertebral levels involved.

Exclusion Criteria

Patients were excluded from this study if SSEP monitoring was not attempted. Patients who underwent an anterior approach to the thoracic spine for the purpose of a discectomy or vertebral biopsy were excluded. Patients in whom thoracic vertebral resection was performed via a transpedicular approach1 were not considered to have undergone an anterior thoracic vertebrectomy and thus were excluded from this study.

Monitoring Technique

Noninvasive SSEP monitoring was conducted in 43 patients undergoing anterior thoracic decompression and placement of spinal instrumentation. Somatosensory evoked potentials were elicited by alternatively stimulating the left and right posterior tibial nerve at the medial malleolus, and at times, the common peroneal nerve at the knee. Stimulation parameters were 80- to 100-V intensity, 0.3-msec duration, and a 3.24 stimulations/second rate. Each SSEP was the average of the responses to 50 to 200 stimuli, depending on the signal-to-noise ratio. Recordings were made from C'z (2 cm posterior to the vertex) and Cs7 (C-7). The active leads were referenced to Fpz (frontal midline position). The cortically recorded P30 and N40 were used when the stimulation involved the common peroneal nerve. Recorded potentials P38 and N48 were used when stimulations involved the posterior tibial nerve. The recording and stimulating electrodes were disposable subdermal stainless steal needles (Nicolet Biomedical, Madison, WI). The resulting waveforms were recorded using a UNIX-based workstation (Fig. 1). The criterion for significant change in the SSEPs was either a 50% decline in SSEP amplitude or a 3-msec increase in latency.

Illustrative Cases

Case 1

Examination. A 35-year-old man presented with a 1-week history of progressive spastic paraparesis, sensory loss, and urinary incontinence. On admission the patient was shown to have Frankel Grade D strength (Table 2) in both lower extremities and a mild decrease in all modalities of sensation below T-4.14 Neuroimaging, including an MR image and a CT scan, demonstrated a fracture at the T-2 and T-3 level with more than 60% canal compromise (Fig. 2.left). During further workup a right lung lesion consistent with bronchogenic carcinoma was revealed. Results of an endobronchial biopsy were consistent with a squamous cell carcinoma. Computerized tomography–guided biopsy sampling of the vertebral lesion confirmed the diagnosis of squamous cell carcinoma.

Operation. Radiation therapy was initiated, and the patient was placed in an external orthosis. Despite radiation treatment, the patient’s motor function deteriorated (from Frankel Grade C to D), necessitating an emergency operation. The patient underwent a posterolateral thoracotomy in which a T2–3 vertebrectomy was performed. Instrumentation with Steinmann pins and methylmethacrylate was inserted. Somatosensory evoked potentials were unchanged intraoperatively.

On postoperative evaluation, the patient was noted to be paraplegic with no changes from his preoperative sensory examination (Frankel Grade B). High-dose steroid therapy was initiated. Postoperative CT scanning revealed that the Steinmann pin instrumentation had entered the spinal canal (Fig. 2.right). The patient was taken back to the operating room for instrumentation revision.

Postoperative Course. The patient’s postoperative course was otherwise uncomplicated, and he was transferred to the rehabilitation service. Over several weeks his status improved to that of Frankel Grade D.

One year after surgery the patient again experienced progressive weakness due to local tumor growth. No operative intervention was undertaken because of the extent of the patient’s systemic disease.

Case 2

Examination. A 75-year-old woman with adult-onset diabetes, hypertension, and osteoporosis presented with a several-month history of severe low-back pain. She was admitted to the medical service. The patient had a history of staphylococcus aureus sepsis, with positive blood cultures evident 3 months previously. Physical examination demonstrated normal strength (Frankel Grade E), although she was bed-ridden because of severe unremitting pain that was refractory to medical treatment. Her sensory status and bowel and bladder functions were within normal limits. Neuroimaging evaluation included MR imaging and CT scanning. Collapse of T-4 with signifi-
significant canal compromise was revealed on MR imaging (Fig. 3 left). An electrolyte sedimentation rate of 115 was noted.

**Operation.** The patient underwent a posterolateral thoracotomy in which a T-4 vertebrectomy was performed. Somatosensory evoked potential tracings were unchanged intraoperatively. Postoperatively, however, Frankel Grade C strength was demonstrated. The postoperative sensory status was unchanged. Postoperative CT myelography demonstrated no spinal compression (Fig. 3 right).

**Postoperative Course.** The patient underwent an 8-week course of intravenous antibiotics and was transferred to the rehabilitation service. Over several months her motor function improved to a Frankel Grade D, and her preoperative complaints of pain resolved.

**Results**

Forty-four surgeries were performed for an anterior thoracic vertebrectomy at the Mount Sinai Hospital in New York City. The mean operative time was 5.2 hours (range 2.5–10 hours). Surgeries were performed by various neurosurgeons in conjunction with a thoracic surgeon and, at times, with an orthopedic spinal surgeon.

Preoperative neurological disability was present in 28 (64%) of the 44 patients. Motor strength in six patients (14%) improved in the immediate postoperative period. An additional four patients experienced improvement of their sensory symptoms. Immediate postoperative decline in motor function was demonstrated in four patients (9%), three of whom had already shown preoperative deficits. However, none of the four experienced intraoperative SSEP changes. Three of the four patients with postoperative neurological decline underwent surgery of more than one vertebral level. Two of these patients required immediate reoperation to reposition instrumentation. Two patients were managed conservatively. All patients experiencing postoperative deficits recovered their strength to preoperative levels. There were four false-negative results (9%).

Somatosensory evoked potential declines were noted intraoperatively in three patients. These changes resolved (the tracings reverted to baseline) with a brief pause during the operation. None of those patients experienced any postoperative motor weakness.

Baseline SSEPs were not obtainable in one patient. The patient had a preoperative motor deficit that was unchanged after surgery.

**Discussion**

Complex spinal instrumentation carries a significant risk of neurological compromise. The incidence of postoperative deterioration approaches rates of 6% for surgical procedures involving anterior decompression for neoplastic disease of the thoracic spine. Noninvasive neurophysiological monitoring is used to prevent intraoperative neurological injury or to reverse it once it occurs. Experiments in animal models have demonstrated that compression or ischemia of the spinal cord produces a progressive decrement in the amplitude and an increased latency of SSEPs. Furthermore, these studies reveal that decreased SSEPs are associated with neurological deficits. Somatosensory evoked potentials have been used intraoperatively because of the assumption that intraoperative changes in SSEP amplitude and latency would allow for interventions to reverse any spinal cord compromise. However, there have been no blinded, randomized studies in which the efficacy of SEP monitoring has been proven, and it is unlikely that such a study will take place because of ethical considerations.
SSEPs in anterior thoracic vertebrectomy

\[ \text{Fig. 3. Case 2.} \quad \text{Left: Preoperative MR imaging revealing T-4 and T-5 involvement. Ost} \]
\[ \text{teomyelitis involved the T-4 and T-5 levels.} \quad \text{Right: Postoperative CT myelogram demonstrating no spinal cord compression.} \]

\text{Literature Review}

Dinner, et al.,\(^9\) have reviewed the cases of 121 patients who underwent surgery to treat scoliosis and 99 patients who underwent surgery for the treatment of neoplasm. The authors included cases in which anterior or posterior approaches were performed at various levels of the spine. Seven patients experienced postoperative neurological decline. In only three of these cases were intraoperative SSEP changes demonstrated, and in the other four no SSEP changes were found. An additional four patients had a greater than 50% SSEP amplitude loss but no neurological deficits. In two cases, intraoperative SSEP decline led to changes in the surgical technique and to subsequent resumption of normal SSEPs; in these two cases the patients were neurologically unchanged postoperatively. In the other two cases, no changes in surgical technique were possible, but a normal neurological status was demonstrated despite loss of SSEPs.

Meyer, et al.,\(^{24}\) have reported on 295 patients with acute spinal cord injury in whom surgery was performed and instrumentation placed. The study included patients who underwent anterior or posterior approaches at various levels of the spine. Of the 295 patients, 150 underwent intraoperative SSEP monitoring. In the patients who underwent neurophysiological monitoring, intraoperative SSEP changes were shown in six, only one of whom demonstrated a postoperative neurological deficit. In the 145 cases in which SSEP monitoring was not performed, postoperative deficits were found in eight patients. The authors concluded that SSEPs provided important intraoperative information in spinal surgery during which instrumentation is placed, and the result was fewer patients with neurological compromise.

May, et al.,\(^{23}\) have recently reviewed 191 cases of cervical spine surgery monitored with SSEPs. They reported a complete loss of SSEPs in 16 patients and a partial loss in 17 patients. In nine of these 33 patients with SSEP changes, postoperative neurological deficits were noted. One patient suffered a postoperative deficit without SSEP changes. The specificity in their series was 27% and the sensitivity was 90%.

Stechison and coauthors\(^{26}\) monitored SSEPs in 161 various spinal operations and noted SSEP changes in 12% of the patients. Postoperatively, 18% of patients with SSEP changes experienced neurological deficits. They found 100% sensitivity of SSEPs in their study and an 18% positive predictive value. Anterior thoracic surgery was not performed in any of their cases.

Manninen\(^{22}\) has reviewed 309 cases in which monitoring was performed at one institution. Surgery was performed in the cervical, thoracic, and lumbar spine. Fifty cases involved the thoracic spine. The authors determined that SSEP monitoring had a false-positive rate of 4.4% and a false-negative rate of 1.1%. A total of three patients had sustained neurological deficits without demonstrable changes in SSEPs. Sensitivity was 57% and specificity was 95%.

Somatosensory evoked potentials have also been used in operations other than spinal surgeries. Bejjani, et al.,\(^2\) reviewed 244 cranial base surgeries in which intraoperative SSEP monitoring was performed. They found that the positive predictive value of SSEP monitoring was 100%, and the negative predictive value was 90%. Their conclu-
signal-averaged data that are time delayed up to several minutes, and therefore SSEPs will only change several minutes after the injury occurs.

We conclude that SSEPs are not a sufficient monitoring modality during anterior thoracic vertebrectomy.

Conclusions

The results of this study demonstrate that in anterior thoracic surgery, SSEP monitoring is not reliable in predicting postoperative neurological deterioration. In the review of 44 patients, there were no demonstrable SSEP changes in the four patients who experienced postoperative neurological decline. There are several factors that contribute to the difficulty in SSEP monitoring. Somatosensory evoked potentials monitor function in the posterior cord and anterior surgery places the anterior cord structures at risk. Patients may sustain damage to anterior and lateral spinal cord structures, resulting in motor decline, but still have intact posterior column function and normal SSEPs. Additionally, intraoperative variations in anesthetic technique may confound the results of SSEPs. Furthermore, SSEPs represent signal-averaged data that are time delayed up to several minutes, and therefore SSEPs will only change several minutes after the injury occurs.

We conclude that SSEPs are not a sufficient monitoring modality during anterior thoracic vertebrectomy.

References


Thoracic Vertebractomy and SSEPs

In contrast to the studies reviewed previously, this study is intended to evaluate the usefulness of SSEP monitoring in a specific clinical situation. We only evaluated patients undergoing anterior thoracic vertebrectomy. In our series, four patients sustained immediate postoperative neurological decline without demonstrable intraoperative changes in SSEP recordings: a false-negative rate of 9%. In addition, there was no case in which a change in intraoperative SSEPs predicted a postoperative neurological decline: a sensitivity rate of 0%. The false-negative, false-positive, and sensitivity rates are compared with those found in the literature (Table 3).

We also noted three cases of SSEP decline that reversed intraoperatively. These occurrences potentially represent cases in which SSEP changes led to changes in the surgeon’s technique, which prevented permanent neurological deficits. The significance of these SSEP changes is unclear. None of the patients with transient SSEP changes suffered any new neurological deficit postoperatively. One would expect that patients with transient SSEP changes would demonstrate at least some evidence of posterior column dysfunction or some motor weakness. In our study, the three patients experienced no postoperative deficits.

Conclusions

The results of this study demonstrate that in anterior thoracic surgery, SSEP monitoring is not reliable in predicting postoperative neurological deterioration. In the review of 44 patients, there were no demonstrable SSEP changes in the four patients who experienced postoperative neurological decline. There are several factors that contribute to the difficulty in SSEP monitoring. Somatosensory evoked potentials monitor function in the posterior cord and anterior surgery places the anterior cord structures at risk. Patients may sustain damage to anterior and lateral spinal cord structures, resulting in motor decline, but still have intact posterior column function and normal SSEPs. Additionally, intraoperative variations in anesthetic technique may confound the results of SSEPs. Furthermore, SSEPs represent signal-averaged data that are time delayed up to several minutes, and therefore SSEPs will only change several minutes after the injury occurs.

We conclude that SSEPs are not a sufficient monitoring modality during anterior thoracic vertebrectomy.

References


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SSEPs in anterior thoracic vertebrectomy


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