ABSTRACT

Purpose. To describe a technique involving posterior 360-degree stabilisation of the upper thoracic spine: spinal cord decompression, posterior vertebral body replacement, and then posterior instrumentation and intercostal posterolateral vertebral stabilisation.

Methods. Three men and 4 women aged 41 to 77 (mean, 58) years underwent posterior 360-degree stabilisation of the upper thoracic spine. Their indications for surgery were bone metastasis (n=5), burst fracture (n=1), and osteoporotic collapse with cord compression (n=1). Their clinical and radiological findings and treatment outcomes were retrospectively reviewed.

Results. Pain status of all patients improved after surgery: 4 had severe and 3 had mild pain preoperatively; in 3 pain became minimal and 4 had none postoperatively. All patients except one had Frankel/American Spinal Injury Association scores of E after surgery indicating complete recovery of sensory and motor function. There were no complications related to surgery or instrumentation construct. At the time of review, one patient had died of old age 8.6 years after surgery and another from local recurrence and lung metastasis 5.7 years after surgery. All other patients were living.

Conclusion. One-stage posterior 360-degree stabilisation and vertebral body replacement is a useful technique for upper thoracic spine surgery.

Key words: ossification of posterior longitudinal ligament; spinal cord compression; spinal neoplasms; spine

INTRODUCTION

Malignancy, osteoporotic burst fracture, ossification of the posterior longitudinal ligament, and traumatic fracture may involve the upper thoracic spine. In other parts of the spine, direct anterior surgery enables easy access to the vertebral body for interbody fusion. Vertebral body replacement using screws and plate constructs provides optimal spinal stability and biomechanics. However, anterior spinal instrumentation of the upper thoracic spine is difficult.
because of the major vascular anatomy and structural intricacy. A midline sternal splitting approach and an interaortocaval subinnominate window technique gives direct access to the T1 to T3 vertebrae and enables anterior spinal instrumentation, but requires refined techniques and multidisciplinary expertise. We describe a less-demanding technique of posterior 360° stabilisation and vertebral body replacement of the upper thoracic spine.

MATERIALS AND METHODS

Three men and 4 women aged 41 to 77 (mean, 58) years underwent posterior 360° stabilisation and vertebral body replacement of the upper thoracic spine. The indications for surgery were bone metastasis (n=5), burst fracture (n=1), and osteoporotic collapse with cord compression (n=1). Their clinical and radiological findings and treatment outcomes were retrospectively reviewed. Pain status of the patients was compared before and after operation. Pain was classified into severe (intractable pain needing medication and preventing normal social activities), mild (needing medication sometimes), minimal (negligible back pain, normal social activities allowed), or none. The Frankel/American Spinal Injury Association (ASIA) score was used to compare sensory and/or motor loss of patients preoperatively and 6 to 12 months postoperatively: score A indicates complete loss, no preservation of any motor and/or sensory function below the zone of injury; score B indicates incomplete loss, preserved sensation; score C indicates incomplete loss, preserved motor activity (non-functional); score D indicates incomplete loss, preserved motor activity (functional); score E indicates complete recovery.

SURGICAL TECHNIQUE

The patient was placed in a prone position and fixed with a Mayfield 3-point head-neck fixator under anaesthesia. The cervicothoracic junction was aligned to the sagittal plane. The cervicothoracic lordoskyphosis alignment was adjusted as necessary in the Mayfield fixator during posterior rod fixation. After subcutaneous epinephrine injection, a midline straight skin incision was made to expose the laminae
3 levels above and below the affected levels. With a muscle elevator, blunt dissection was performed until the facet joints on both sides were visualised. Neck and upper thoracic muscles were covered with wet towels for prevention of muscle damage. Laminae and facet joints were well-visualised by 2 sets of self-retaining muscle—Adson-type retractors. Correct vertebral levels were confirmed using intra-operative fluoroscopy.

**Spinal cord decompression**

The spinal processes and laminae of the affected levels as well as one level above and below were removed by a high-speed surgical airtome or surgical saw. In cases of osteoporotic or traumatic fracture, posterior elements of the vertebrae were preserved and re-fixed in situ to cover the dura mater after completion of instrumentation. With the dura mater on sight, a pair of stimulating and recording epidural electrodes was introduced into the posterior midline epidural space. The tips were usually positioned at the C3 and T10 levels. Two negative spikes (N1 and N2) were elicited in the epidural spinal cord evoked potentials. Using a high-speed surgical airtome or cavitation ultrasonic surgical aspirator (CUSA), a pair of facet joints was removed to reveal the nerve roots and dorsal root ganglia (Fig. 1a). Epidural veins, anterior intervertebral epidural veins, and radicular veins were coagulated to avoid massive bleeding. In cases of tumour, the spinal nerve one level above and below the affected level was completely exposed bilaterally. Pedicle screws were introduced one to 3 levels caudal to the affected level, under intra-operative fluoroscopy. Fixation using a pedicle screw at C7 and T1, or more cephalad, was possible, but use of a sublaminar wire or lateral mass screw was preferred.

The tumour in the epidural space and around the pedicles was resected using a CUSA. The pedicles on both sides and posterior 1/4 to 1/3 of the vertebral body were approached as laterally as possible to avoid spinal cord damage and resected with a surgical airtome. The vertebral body was resected with a diamond burr and/or a right-angled impactor. Once posterior decompression was completed, epidural spinal cord evoked potentials were checked to ensure no serious spinal cord damage.

**Posterior vertebral body replacement**

In cases of tumour, the CUSA was used to resect the affected vertebral body. In cases of traumatic or osteoporotic collapse, the combined use of angled
curets, chisels, and punches was preferred. Caution must be exercised to avoid penetrating the vertebral body causing major vascular injuries. Resection continued until the tumour was removed or the space was adequate for introduction of the strut implant for vertebral body replacement, so as to stabilise the anterior column.

Spinal nerves, proximal and caudal to the affected vertebrae, were gently distracted to let an interbody fusion strut pass through. The strut was inserted into the intervertebral space with one of its edges firmly held by an introducer. A fibular strut (allograft) or a cage strut was used. A non-expandable cage strut (Pyramesh; Medtronic Sofamor Danek, Memphis [TN], USA) stuffed with chipped bone and hydroxyapatite or $\beta$-tricalcium phosphate granules could be used for stronger mechanics. Using an impactor, the cage strut was longitudinally aligned so that it was parallel to the axis of the spinal column. With the help of intra-operative fluoroscopy, the edge of the cage strut was fixed to the vertebral endplate or subchondral bone adjacent to the affected level and located in the centre of the vertebral edge. Short latency somatosensory evoked potentials (P9, P11, N13 components) elicited by ulnar nerve stimulation were used to confirm no nerve root distraction injury in cases of T1 or T2 vertebral body replacement. When the cage strut was in the proper position (Fig. 1b), iliac graft or artificial bones such as hydroxyapatite or $\beta$-tricalcium phosphate granules were used to fill the remaining intervertebral space.

### RESULTS

The Table summarises the patients’ demographics and treatment outcomes. Pain status of all patients improved after surgery: 4 had severe and 3 had mild pain preoperatively; in 3 pain became minimal and in 4 there was no pain postoperatively. All patients except one had Frankel/ASIA scores of E after surgery.

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Sex/age (years)</th>
<th>Diagnosis</th>
<th>Vertebrae affected</th>
<th>Pain status (preop/postop)</th>
<th>Frankel/ASIA score (preop/postop)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M/55</td>
<td>Burst fracture</td>
<td>T2, T3</td>
<td>Severe/minimal</td>
<td>E/E</td>
</tr>
<tr>
<td>2</td>
<td>M/69</td>
<td>Prostate cancer metastasis</td>
<td>T3</td>
<td>Severe/minimal</td>
<td>C/E</td>
</tr>
<tr>
<td>3</td>
<td>F/77</td>
<td>Osteoporotic collapse with cord compression</td>
<td>T3, T4</td>
<td>Mild/none</td>
<td>D/E</td>
</tr>
<tr>
<td>4</td>
<td>M/57</td>
<td>Chordoma metastasis</td>
<td>T1</td>
<td>Severe/minimal</td>
<td>B/D</td>
</tr>
<tr>
<td>5</td>
<td>F/41</td>
<td>Breast cancer metastasis</td>
<td>T2, T3</td>
<td>Mild/none</td>
<td>C/E</td>
</tr>
<tr>
<td>6</td>
<td>F/44</td>
<td>Breast cancer metastasis</td>
<td>T3, T4</td>
<td>Severe/none</td>
<td>E/E</td>
</tr>
<tr>
<td>7</td>
<td>F/65</td>
<td>Uterine cancer metastasis</td>
<td>T3</td>
<td>Mild/none</td>
<td>D/E</td>
</tr>
</tbody>
</table>

* ASIA denotes American Spinal Injury Association; score A indicates complete loss, no preservation of any motor and/or sensory function below the zone of injury; score B indicates incomplete loss, preserved sensation; score C indicates incomplete loss, preserved motor (non-functional); score D indicates incomplete loss, preserved motor (functional); score E indicates complete recovery

Posterior instrumentation and intercostal posterolateral vertebral stabilisation

A pair of instrumentation rods was contoured lordotically proximally, and kyphotically distally. In cases of tumour at T2, pedicle screws were inserted first at T3, then at T4 and T5 levels; sublaminar wiring or lateral mass screwing was performed cephaladly at C7, then at C6 and C5 levels. To avoid long-range fixation in the mid-cervical spine, the C5 vertebral body may be spared. A titanium laminar wire of 1.0 to 1.2 mm diameter was preferred. To avoid the rolling effect of the wires through the instrumentation rods, transverse fixation devices were placed between the rods and wrapped with sublaminar wires. After the instrumentation rods and sublaminar wires were tentatively fixed in a proper position, the cage strut was delivered longitudinally under fluoroscopy. Once the instrumentation assembly was appropriately set, the pedicle screws were fixed firmly (Fig. 1c). The iliac strut was placed on the ribs of the affected vertebrae and the ones above and below.
indicating complete recovery of sensory and motor function. The Frankel/ASIA score of one patient improved from B to D, in 2 patients from C to E, in 2 others from D to E, and remained at E in 2 others. The latter 2 patients with a preoperative score of E underwent surgery because of the intolerable pain.

Figure 2 shows preoperative magnetic resonance images and postoperative radiographs of patients 5, 6, and 7. Pedicle screws or sublaminar wires were used 2 or 3 levels caudal to those that were affected, whereas sublaminar wires or lateral mass screws were used at 2 or 3 levels rostral to the affected levels. For vertebral body replacement, a bioactive glass-ceramic strut containing apatite and wollastonite was used in one patient, a Pyramesh in 5, and an autograft in one to stabilise the anterior column. The operating time ranged from 4.1 to 11.1 hours and blood loss ranged from 230 to 5400 g. There were no complications related to surgery or instrumentation construct. At the time of review, patient 2 had died of old age 8.6 years after surgery and patient 4 from local recurrence and lung metastasis 5.7 years after surgery. The other 4 patients with metastatic malignancy were living, after a mean follow-up of 3.4 (standard deviation, 1.5) years.

**DISCUSSION**

Cervicothoracic junction (T1–T3) is the site where anterior spinal reconstruction is technically demand-
advised to avoid T1 spinal nerve damage (innervating the ulnar nerve peripherally). Thus, we used a microsurgical technique with ulnar nerve–stimulated short-latency somatosensory evoked potential monitoring for T1 costotransversectomy.\textsuperscript{10–12}

It is technically difficult to properly place the cage strut into the intervertebral space. There is no convenient device for twisting, rotating, and properly placing a cage strut inside the intervertebral space. When needed, sacrificing T2 or T3 spinal nerves and widening the internervous space for insertion of a wider cage is allowable in selected cases.

Instrumentation in the cervical spine is also difficult. Pedicle screw fixation in C7, C6, and C5 levels is feasible with the aid of intra-operative computed tomography. It may provide rigid stabilisation by means of a refined sublaminar wiring or lateral mass screwing. In conclusion, one-stage posterior 360\textdegree stabilisation and vertebral body replacement is a useful technique for upper thoracic spine surgery.

ACKNOWLEDGEMENTS

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REFERENCES