Perioperative complications with costotransversectomy and anterior approaches to thoracic and thoracolumbar tumors

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Object. Anterior decompression and stabilization for thoracic spinal tumors often involves a thoracotomy and can be associated with surgical approach–related complications. An alternative to thoracotomy is surgery via a costotransversectomy exposure.

To delineate the risks of surgery, the authors reviewed their prospective database for patients who had undergone surgery via either of these approaches for thoracic or thoracolumbar tumors. The complications were recorded and graded based on severity and risk of impact on patient outcome.

Methods. Between September 1995 and April 2001, the authors performed 29 costotransversectomies (Group 1) and 18 thoracolumbar or combined (Group 2) approaches as initial operations for thoracic neoplasms. The age, sex, preoperative motor score, and preoperative Frankel grade did not significantly differ between the groups. In the costotransversectomy group there were greater numbers of metastases, upper thoracic procedures, and affected vertebral levels; additionally, the comorbidity rate based on Charlson score, was higher. The mean Frankel grades at discharge were not significantly different whereas the discharge motor and last follow-up motor scores were better in Group 2. There were 11 Group 1 and seven Group 2 patients who suffered at least one complication. The number or patients with complications, the mean number of complications, and severity of complications did not differ between the groups.

Conclusions. Compared with anterior or combined approaches, the incidence and severity of perioperative complications in the surgical treatment of thoracic and thoracolumbar spinal tumors is similar in patients who undergo costotransversectomy. Costotransversectomy may be the preferred operation in patients with significant medical comorbidity or tumors involving more than one thoracic vertebra.

KEY WORDS • metastasis • thoracic spine • costotransversectomy • thoracolumbar spine • complication

The authors of autopsy studies have shown that skeletal metastases develop in 50 to 85% of patients with carcinoma and that the spinal column is the most common site.^{9,21,24,69} Medical treatment has improved survival length and a greater number of patients are being treated for spinal metastasis and primary tumors. Although the majority of spinal lesions can be treated with radiotherapy, those that are radioresistant and those compromising bone will continue to require surgical intervention. Approximately 80% of spinal metastases involve the VBs rather than the posterior elements.⁵⁷ There is a growing body of evidence in the literature to support anterior decompression for anterior compressive lesions.^{19,22,27,30,37,38,45,47,52,61,67,70}

The use of thoracotomy has produced good functional results, but related morbidity such as persistent pleural ef-

fusions, hemothorax, chylothorax, and dural–pleural fistulas has been reported.^{20,55,56} In addition, the 30-day mortality rate in patients undergoing thoracotomy for metastasis has been reported to range from 3 to 30 %. Neoplastic processes in the thoracic spine tend to also involve the pedicle, rib head, and costovertebral articulation. This observation, in addition to the noted morbidity related to anterior approaches, led to the modified costotransversectomy approach to thoracic spinal neoplasms. Decompression and structural reconstruction of the anterior spinal column, VBs, and discs can be performed via a posterior incision by working around the thecal sac by an extended midline costotransversectomy. When used in conjunction with posterior instrumentation, costotransversectomy has proven to be a successful method in the management of patients with metastatic lesions to the thoracic spine.^{5,11,13,14,38,40}

In many of these studies the complication rates for costotransversectomies have been reported to be very low. It is difficult to believe that major operations such as costotransversectomies for thoracic neoplasms can be performed with such low morbidity given the significant

Abbreviations used in this paper: ASIA = American Spinal Injury Association; CSF = cerebrospinal fluid; DVT = deep vein thrombosis; EBL = estimated blood loss; ICU = intensive care unit; LOS = length of stay; MMA = methylmethacrylate; VB = vertebral body.

complication rate associated with thoracic pedicle screw placement alone.⁷¹ We were interested in determining if the approach chosen for thoracic and thoracolumbar neoplasms had a significant impact on the risk of perioperative complications. We reviewed our experience and compared the perioperative complications in two groups of patients with thoracic or thoracolumbar spinal neoplasms: 1) those in whom a costotransversectomy was performed and 2) those in whom an anterior or combined approach was used.

CLINICAL MATERIAL AND METHODS

Patient Population

We performed 60 costotransversectomies and 82 thoracotomy, thoracolumbar, or combined anterior–posterior approaches for thoracolumbar lesion between September 1995 and April 2001 at the academic hospitals of the University of Washington. Each of these cases involved one of the senior authors (S.M. or J.R.C.). This interval was chosen because the University of Washington Spine Service initiated a quality assurance program in September of 1995 to track surgery-related data and complications on inpatients prospectively. Patients were accrued by searching this prospective database. Every attempt was made to include all patients. Patients were excluded if the main disease was cervical or lumbar. In addition patients were excluded if the anterior approach was retroperitoneal and the diaphragm or root of the diaphragm did not need to be taken down during anterior exposure. There were 29 (Group 1) and 18 (Group 2) approaches performed in the treatment of thoracic or thoracolumbar neoplasms. In an effort to compare perioperative complication rates accurately, we only considered the initial operation performed at our medical center for each patient. Subsequent operations performed in the same patient were excluded in this review to reflect more accurately the actual perioperative complication rates expected when deciding to perform a costotransversectomy or thoracolumbar or combined approach for thoracolumbar neoplasms. There were 29 costotransversectomies and 18 thoracolumbar or combined initial approaches undertaken during this time period.

The patients were grouped by approach: those who underwent costotransversectomy (Group 1) and those who underwent thoracotomy, thoracolumbar, or combined anterior–posterior approach (Group 2). The patients were also grouped according to affected levels: upper thoracic (T1–6), lower thoracic (T7–12), and upper lumbar (L1–2). The records were retrospectively reviewed, and data were collected on patient age, sex, and surgical approach. Origin of tumor (metastasis, primary benign tumor, and primary malignant tumor) and tumor type (breast, renal, and so on) were recorded. We interviewed patients regarding medical history. Presence of any diagnoses identified in the Charlson index was recorded on a datasheet.^{8,36} Table 1 lists the Charlson comorbidity score for medical conditions and the relative weight of each diagnosis.^{7,8} We calculated a Charlson comorbidity score for each patient by adding the scores for individual conditions recorded as being present preoperatively.

Indications for surgery were symptomatic spinal cord compression, intractable pain from instability, impending

TABLE 1
Charlson index for comorbidities

Diagnosis	Charlson Score
myocardial infarction	1
congestive heart failure	1
peripheral vascular disease	1
cerebral vascular disease	1
dementia	1
chronic pulmonary disease	1
connective tissue disease	1
ulcer disease	1
mild liver disease	1
diabetes	1
hemiplegia	2
moderate or severe renal disease	2
diabetes w/ organ damage	2
any tumor	2
leukemia	2
lymphoma	2
moderate or severe liver disease	3
metastatic solid tumor	6
acquired immune deficiency syndrome	6

fracture, or excision of primary bone tumor. The following surgery-related data were obtained: affected vertebral level, number of levels decompressed, number of levels stabilized, EBL, and duration of surgery. Other variables collected included: number days in which a chest tube was required, number of days in the ICU, number of days intubated, and postoperative LOS. The Frankel classification system was used for preoperative and discharge assessment of neurological status. The ASIA^{16,58} motor score was used for preoperative, discharge, and last follow-up motor assessment. Patients were seen in clinic at 2 weeks, 6 weeks, 3 months, 6 months, and annually thereafter. Long-term follow-up review was difficult in this population because of the wide referral base from five states.

Each patient's records included: admission history and physical, operative notes, anesthesia record, daily progress notes, nursing notes, laboratory results, discharge summary, and follow-up clinic notes; these were thoroughly reviewed. Every event was noted as a complication if it would not be expected as a routine event in the perioperative course. All complications noted during the 30-day perioperative period were tabulated for each patient. Each patient then had a quality of care etiology assigned and severity rating placed on the complications. Table 2 provides a summary of the potential causes of complications as well as definitions of their severity. These data are featured in scales and have been used at the academic hospitals of the University of Washington to classify the severity of the complication and its potential effect on the health of the patient.

Selection of Surgical Approach

The approach to the thoracic tumor was dictated by a number of variables. Each surgeon performed anterior and posterior approaches. The level of the tumor, its projection, and extent of extraosseous tumor affected the approach. If the tumor extended into posterior elements or paraspinal musculature, costotransversectomy was select-

TABLE 2

Summary of causes and severity of complications

cause of complication
error in diagnosis
error in judgment
error in management
error in technique
patient disease (expected risk)
patient noncompliance
anesthetic complication
level of severity
did not & unlikely to have had an adverse effect
did not but had the potential to have an adverse effect
had an adverse effect but not life threatening
resulted in loss of a major physical function or potentially life threatening
demonstrated a life-threatening event or resulted in death

ed. If the tumor had direct extension anterior to the spine, or through the pleura, a thoracolumbar or combined approach was selected. Patients with multiple levels of disease or noncontiguous disease underwent costotransversectomy. Patients with upper thoracic disease underwent costotransversectomy because of the difficulties in exposing the anterior upper thoracic spine via thoracotomy. If the surgeon believed that anterior stabilization was not going to restore spinal stability after resection of the tumor, the patient underwent costotransversectomy or an anterior-posterior approach. Finally, patients with significant medical comorbidities or those who could not tolerate a thoracotomy underwent costotransversectomy. There has been a tendency toward costotransversectomy as the primary approach if the neoplasm can be excised and adequate stabilization performed.

Thoracolumbar Approach. Patients with tumors above the insertion of the diaphragm underwent standard posterolateral thoracotomy after placement of a double-lumen endotracheal tube. All patients received standard perioperative antibiotic agents and DVT prophylaxis with thigh-high stockings and sequential compression devices. All patients in whom signals were present underwent electromyography and somatosensory evoked potential monitoring. We prefer a right hemithorax site of entry. In patients with lesions located above T-5, the fourth rib was removed; with those lesions involving T-5 and T-6, the fifth rib was removed; with those involving T-7 and T-8, the rib located one above the lesion was removed; with those involving T9–10, the rib two levels above the lesion was removed; and with those involving T10–L2, a left-sided T-11 thoracolumbar approach with diaphragm take-down was performed.

Resection was undertaken immediately in cases in which the tumor was grossly visible within the chest cavity. When the affected level was in doubt, however, the level was localized using intraoperative radiography. The parietal pleura was incised and reflected anteriorly. The segmental vessels were identified above and below the VB of interest and doubly ligated and transected. We performed discectomies rostral and caudal to the vertebrectomy site. The anterior vertebrectomy was performed using osteotomes and rongeurs. The posterior VB and posterior

longitudinal ligament were removed using upward-angled curettes, Kerison punch, and high-speed air drill. Both pedicles and the whole anterior thecal sac were visualized to ensure that complete decompression had been achieved.

The VB defect was reconstructed using either tibia fresh-frozen allograft or a vertical titanium mesh cage filled with MMA. We were careful to prevent contact between the MMA and the thecal sac. The construct was irrigated with cool saline during polymerization to prevent heat-related injury to the spinal cord. An anterior thoracolumbar locking plate or buttress plates were placed to provide additional anterior spinal stabilization. In four patients, additional posterior segmental instrumented fusion was performed as part of the initial procedure either during the same period of anesthesia or later during the hospitalization.

We placed one chest tube in the thoracic cavity and performed standard closure. The chest tubes were removed when the 24-hour drainage was less than 150 ml. If the pleura had not been violated, we placed a suction drain and performed standard closure.

Costotransversectomy Procedure. Patients were positioned prone on a Jackson table. Standard perioperative antibiotic agents were administered and DVT prophylaxis were ensured by using thigh-high stockings and sequential compression devices. All patients in whom signals were present underwent electromyography and somatosensory evoked potential monitoring. A midline skin incision long enough for placement of planned posterior instrumentation was made. Bilateral subperiosteal muscle takedown was performed to the tip of the transverse processes. Fluoroscopy was used to localize the pathologically affected level. Thoracic pedicle screws were placed bilaterally, usually three above and two below the pathologically affected level. A temporary rod was connected to the pedicle screws contralateral to the planned approach. The proximal ribs were exposed, and the proximal portion 3 cm lateral to the junction of the rib and the transverse process was removed. A hemilaminectomy was performed and the transverse process removed. Usually the rib at the level of the lesion and one below were removed to obtain exposure. The pleura was bluntly dissected off the VBs. The intercostal bundle was followed back to identify the neural foramen. The intercostal artery and nerve root at the pathologically affected level were identified, doubly ligated, and divided. The ipsilateral pedicle was removed to allow visualization of the thecal sac. The vertebrectomy was performed using down-ward angled curettes and a high-speed drill. Complete anterior decompression was assured by resecting across to the contralateral pedicle.

Reconstruction of the VB defect was performed using tibia fresh-frozen allograft or a vertical titanium mesh cage filled with MMA. The posterior instrumentation was then connected with precontoured rods and cross links. The wound was closed in layers over a suction drain. If the pleura was inadvertently entered, a chest tube was placed.

Statistical Analysis

Continuous variables (age; disease levels; anterior decompression levels; anterior stabilization levels; posterior stabilization levels; blood loss; operative time; the number of days required for ICU stay, chest tube insertion, intuba-

tion, and postoperative hospitalization; pre- and postoperative Frankel grade; preoperative, postoperative, and last follow-up motor score; number of patients with complications; number of complications per patient; severity of complications; and follow-up time) were compared using a two-sample t-test. The Frankel grade was converted into numerical form for statistical evaluation (Grades A, B, C, D, and E were equal to 1, 2, 3, 4, and 5, respectively). Probability values of less than 0.05 were considered to be significant. Grouped variables (sex, diagnostic group, and level of approach) were evaluated using a Pearson chi-square test; values of less than 0.05 were considered significant.

RESULTS

Patient Data

Group 1. Twenty-nine patients underwent costotransversectomy for spinal thoracic tumors between September 1995 and April 2001. Table 3 provides a summary of baseline characteristics for this patient group. The mean age was 58.1 years (range 17–80 years). There were 13 women and 16 men. Twenty-two patients harbored metastatic tumors (lung [six cases], kidney [five cases], breast [four cases], prostate [three cases], endometrial malignant nerve sheath tumor, malignant melanoma, and multiple myeloma [one case each]). Three patients harbored primary benign tumors (hemangioma) and four patients harbored primary malignant tumors (chondrosarcoma, fibrosarcoma, osteosarcoma, and schwannoma).

Group 2. Eighteen patients underwent a thoracolumbar or combined approach. In four of these patients anterior–posterior operations were planned. There were eight women and 10 men in this group. The mean age was 48.0 years (range 17–76 years). Nine patients harbored metastasis (lung [three cases], kidney [two cases], and prostate, breast, melanoma, and multiple myeloma [one case each]). Seven patients harbored primary benign tumors (giant cell [three cases], neurofibroma [two cases], and hemangioma and osteoblastoma [one case each]). Two pa-

tients harbored primary malignant tumors (mesothelioma and sarcoma, respectively). There was no intergroup statistical difference in age or sex. A greater number of patients undergoing costotransversectomy harbored metastatic ($p = 0.05$) and upper thoracic tumors ($p = 0.002$). The graph in Fig. 1 demonstrates the distribution of disease level stratified according to group.

The mean Charlson comorbidity score demonstrated in the Group 1 patients was 7.3 (range 0–11), and that in Group 2 patients was 4.8 (range 0–10). This difference was statistically significant ($p = 0.02$). The mean preoperative Frankel grade was not statistically different (4.2 in Group 1 and 4.6 in Group 2). The preoperative ASIA motor score was also not statistically different, although there was a trend toward a lower motor score in those who had undergone costotransversectomy (89.4 in Group 1 and 96.5 in Group 2, [$p = 0.10$]).

Perioperative Data

Table 4 provides a summary of the perioperative data obtained in both groups. In patients undergoing costotransversectomy, a mean of 1.6 anterior levels were decompressed (range zero–three levels). A mean of 1.4 anterior levels were decompressed (range one–three levels) in those who underwent thoracolumbar or combined approaches. A mean of 2.97 anterior levels were stabilized in Group 1 (range zero–four levels) and 3.0 in Group 2 (range zero–five levels). Neither the numbers of anterior levels decompressed nor the anterior levels stabilized were statistically different between groups. A mean of 7.7 posterior levels (range five–16 levels) were instrumented in Group 1. In Group 2 four patients underwent simultaneous or planned, staged placement of posterior instrumentation. The mean EBL was 2276 ml (range 300–10,000 ml) in Group 1 and 2492 ml (range 250–6000 ml) in Group 2. The mean operative time was 420 minutes (range 260–730 minutes) in Group 1 and 384 minutes (range 230–780 minutes) in Group 2. Neither the EBL nor the operative time between groups was statistically differ-

TABLE 3
Baseline characteristics in both patient groups

Characteristic	Group 1 (29 patients)	Group 2 (18 patients)	p Value
age (yrs)	58.1	48.0	0.45
female	13 (44%)	8 (44%)	0.98
tumor type			0.07
metastatic	22	9	
primary benign	3	7	
primary malignant	4	2	
affected levels	2.28	1.56	0.05
affected region			0.02
upper thoracic	17	3	
lower thoracic	10	7	
upper lumbar	2	8	
Charlson score	7.3	4.8	0.02
preop Frankel grade*	4.2	4.6	0.31
preop ASIA motor score	89.4	96.5	0.10

* Frankel score was converted to numeric form (A = 1, B = 2, and so on).

Fig. 1. Number of costotransversectomy and thoracolumbar procedures performed and grouped by level of spinal involvement.

TABLE 4
Perioperative characteristics

Characteristic	Group 1	Group 2	p Value
no. anterior levels decompressed	1.6	1.4	0.42
no. anterior levels stabilized	2.97	3.00	0.92
no. posterior levels stabilized	7.7	0.9	0.00
EBL (ml)	2276	2492	0.73
op time (mins)	420	384	0.38
no. of ICU days	1.8	1.4	0.56
no. of chest tube days	0.1	2.4	0.00
no. of intubated days	0.5	0.3	0.54
postop LOS (days)	8.3	8.6	0.83
discharge Frankel grade	4.1*	4.7	0.74
discharge ASIA motor score	90.4*	98.3	0.04
last follow-up ASIA motor score	90.8*	100	0.01
follow up (mos)	5.9*	12.6	0.59

* One patient died.

ent. The patients who underwent costotransversectomy spent a mean of 1.8 days (range 0–13 days) in the ICU and those who underwent a thoracolumbar or combined approach spent a mean of 1.4 days (range 0–6 days) in the ICU. The mean number of intubation days in Group 1 patients was 0.5 (range 0–4 days) and that in Group 2 patients was 0.3 (range 0–2 days). There was no intergroup statistical difference for the number of ICU days or intubation days. One patient in the costotransversectomy group underwent placement of a chest tube after removal of an osteosarcoma; it was removed 3 days later. In Group 2, the chest tubes were removed after a mean period of 2.2 days (range 0–7) days. The mean postoperative LOS in Group 1 was 9.2 days (range 3–27 days) and that in Group 2 was 8.6 days (range 4–27 days). This was not statistically significant.

Postoperative Neurological Function

Preoperatively 15 of the 29 patients were Frankel Grade E. One patient with preoperative Frankel Grade E status developed a watershed stroke on postoperative Day 2 and was discharged with Frankel Grade D status. None of the other Frankel grade E patients suffered deterioration. One patient with Frankel Grade C developed aspiration pneumonia postoperatively and died after the family agreed to withdraw supportive care. Another patient with a Frankel Grade D declined postoperatively secondary to a vascular spinal cord injury. His status at discharged Frankel Grade C. Frankel grade in two patients had improved at discharge—from D to E and from C to D, respectively. The Frankel grade remained the same in all other patients.

All 16 patients in whom admission status was Frankel D or E were discharged with the same grade. One patient with a preoperative Frankel grade of C improved one grade, and one patient with a preoperative Frankel grade of A improved to two grades. There were no deaths in the Group 2. We converted the Frankel Grade into a numeric scale (1–5). There was no difference in mean discharge Frankel grade (4.1 in Group 1 and 4.7 in Group 2).

At discharge the mean ASIA motor score was 90.4 (range 50–100) in Group 1 and the mean ASIA score in Group 2 was 98.3 (range 75–100). This was statistically significant ($p = 0.04$). The mean last follow-up ASIA mo-

tor score was also statistically significant (90.8 in Group 1 and 100 in Group 2; $p = 0.01$); follow-up period was short in both groups: 5.9 and 12.6 months in Groups 1 and 2, respectively.

Perioperative Complications

Table 5 provides a summary of the complications observed in each group. There were several complications in the costotransversectomy-treated group. As noted earlier, one patient developed aspiration pneumonia and died, one patient developed a watershed stroke on postoperative Day 2, and another sustained a vascular cord injury that improved to Frankel Grade C while in the hospital. Four patients developed wound-related complications requiring reoperation: one had an infection and three were due to CSF leaks after sustaining intraoperative dural tears. One patient required a return to the operating room to remove a drain that could not be removed at the bedside. In one patient ST segment changes occurred intraoperatively but myocardial infarction did not develop. The same patient also developed diabetes insipidus and a pleural effusion treated without a chest tube. Both resolved with time. Two patients developed DVT treated with an inferior vena cava filters. One patient developed a urinary tract infection.

In Group 2, two patients awoke with unilateral blindness. This was believed to be caused by posterior ischemic optic neuropathy. One of these patients developed a fever of unknown origin during a prolonged hospital stay. In one patient an intraoperative dural tear occurred, followed by a small postoperative superficial wound dehiscence without evidence of CSF leakage, which that was treated with local dressings and resolved. Two patients developed a small pneumothorax after their chest tube was removed. Both resolved spontaneously without replacement of the chest tube. One of these patients also developed a significant postoperative ileus, which resolved after conservative treatment, and a urinary tract infection. One patient devel-

TABLE 5
*Summary of complications**

Complication	Group 1	Group 2
death	1	
neurological decline	2	
blindness		2
wound complication requiring op	4	
retained drain	1	
wound complication, nonop		1
ileus		1
atrial fibrillation		1
intraop ECG changes	1	
fever of unknown origin		1
pneumothorax		2
pleural effusion	1	
pneumonia	1	
DVT	2	1
dural tear	3	1
urinary tract infection	1	1
diabetes incipitus	1	
deformity		1

* Values represent the number of occurrences of a complication. A single patient may have experienced more than one complication. Abbreviation: ECG = electrocardiography.

TABLE 6
Overall complications and severity of complications

	Group 1	Group 2	p Value
no. of patients w/ complications	11 (38%)	7 (39%)	0.95
mean no. of complications per patient	0.59	0.67	0.79
mean quality of care score (severity scale)	1.8	1.9	0.76

oped atrial fibrillation requiring elective cardioversion. Another patient developed a DVT treated with an inferior vena cava filter. One patient who underwent an anterior decompression and T7–T10 anterior stabilization developed progressive kyphosis 3 weeks later and underwent T5–T12 posterior fusion in which instrumentation was placed. She did well thereafter.

Table 6 provides a summary of the complications and their severity. There were 11 (38%) Group 1 and seven (39%) Group 2 patients who suffered at least one complication. The mean number of complications per patient was also not statistically different (0.59 in Group 1 and 0.67 in Group 2). The mean quality of care severity score (see Table 2 for summary of items) did not show a difference between the two groups (1.8 in Group 1 and 1.9 in Group 2). Each patient with a complication was classified to the cause (error in technique or patient disease). In Group 1, there were six patients in whom technical errors occurred and five in whom the cause was related to the disease. In Group 2 there were three patients in whom technical errors occurred and three in whom the cause was related to the disease. Neither of these was statistically significant.

DISCUSSION

The region of the spinal column most frequently involved with metastases is the VB. Epidural spinal cord compression therefore usually results as tumors extend posteriorly from the VB into the spinal canal.⁶⁰ Laminectomy was the traditional approach to spinal metastases. When laminectomy without stabilization followed by radiotherapy^{2,3,10,39,42,65} was compared with radiotherapy alone,^{2,10,17,22,25,46,53} there was no significant difference in neurological recovery. When a posterior stabilization procedure is performed in conjunction with laminectomy, neurological improvement increases from approximately 44 to 72%.^{4,6,14,29,49,53–55,57,63} Laminectomy is not, however, the proper surgical procedure because much of the spinal cord compression is caused by anterior disease. Thoracic approaches were then performed more for spinal metastasis in an effort to achieve a more complete and direct decompression of the spinal cord.

The reported thoracotomy-related risks with a 30-day mortality in patients metastases range from 3 to 30%. This has led to the development of alternative posterolateral techniques.^{23,28,31,51,53,60,63,66–68} Many authors have described techniques for resection of spinal metastasis that do not require a transcostal approach.^{5,12–14,18,34,35,41,43,44,57,59,64} Costotransversectomy was first described by Menard⁴⁸ in 1894 for drainage of tuberculous abscesses in patients with Pott paraplegia. Various modifications of this procedure have been developed for removal of anterior thoracic

disc herniation,^{32,33,40,56,62} traumatic lesions,⁴⁰ and metastatic tumors of the spine.^{15,55} In the present study we have attempted to elucidate the perioperative complications in patients with thoracic and thoracolumbar neoplasms undergoing either thoracotomy or thoracolumbar approaches compared with costotransversectomy.

Although this study is retrospective, with its attendant confounding factors, the two groups were fairly evenly distributed. The age and sex distribution was not significantly different. The most striking intergroup difference was the higher percentage of metastases and the greater number of upper thoracic procedures in the costotransversectomy-treated group. This difference is based on selection bias, as described in the *Clinical Material and Methods* section. Patients with upper thoracic lesions were preferentially treated using costotransversectomy to avoid the somewhat technically challenging anterior approach to the upper thoracic spine. As it turned out, because many of the upper thoracic lesions were metastases, there was a higher percentage of metastases in this group. Despite this difference in location and tumor type, there was no difference in either preoperative Frankel grade or ASIA motor score, although the latter did show a trend toward being higher in Group 2 patients. In assessing the influence of individual interventions, the confounding influence of comorbid disease must be controlled. Restricting the treatments to patients without coexisting disease limits the generalizability of the results.⁷ Comorbidity has been classified by consensual criteria, but these criteria are difficult to quantify. Charlson, et al.,⁸ developed a weighted index for measuring comorbid diseases in longitudinal studies. This index was validated for predicting mortality rates in patients with breast cancer. The summary score calculated by the sum of score for each individual diagnosis—that is, the Charlson comorbidity score—has also been useful in predicting complications, hospitalization, LOS, and functional status in patients with spinal and other musculoskeletal disorders.^{26,50} A significantly higher level of comorbidity was seen in costotransversectomy-treated patients, as reflected by the higher Charlson scores. The main influence on higher Charlson scores is the higher percentage of patients in the costotransversectomy group with metastasis.

In comparing the two groups, we found no significant difference in the number of anterior levels decompressed and stabilized. Anterior approaches have the theoretical advantage of providing direct exposure to the diseased VB, allowing for maximum exposure and decompression of the anterior spinal cord and theoretically limiting blood loss. In the current series, EBL was slightly higher in Group 2 (2492 ml) than in Group 1 (2276 ml), although the difference was not significant. Operative time was slightly longer in the costotransversectomy-treated group (420 minutes) than in the other group (384 minutes), although this was not significant. This difference in time is a reflection of the larger exposures and multilevel instrumentation placed in the costotransversectomy-treated patients. Essentially all intraoperative intergroup variables were similar except the number of posterior levels stabilized, which was higher in the costotransversectomy-treated patients by design of the operation. The number of days in the ICU (1.8 in Group 1 and 1.4 in Group 2), days intu-

bated (0.5 in Group 1 and 0.2 in Group 2), and postoperative length of stay (8.3 in Group 1 and 8.6 in Group 2) was not statistically different. Not surprisingly, the number of days in which a chest tube was required was longer in patients in whom thoracolumbar procedures were performed (2.4 in Group 2 and 0.1 in Group 1). Overall, the patients in the two groups underwent surgery for treatment of a similar magnitude of disease and had similar postoperative courses. The main difference between the two groups was the higher percentage of metastases and upper thoracic lesions in the Group 1 patients, which influenced the Charlson score and led to a significantly higher preoperative comorbidity rate in this patient group.

If one considers patients who developed at least one complication, the rates of complications are similar between the two groups. Of the 29 costotransversectomy procedures, at least one complication developed in 11 cases (38%). Of the 18 thoracolumbar or combined approaches, complications occurred in seven patients (39%). To assess the severity of complication, we graded each patient on a 1 to 5 scale that takes into consideration the actual harm done to the patient and the potential for significant complication-related consequences. Even if one considers the severity of the complications, a significant difference did not exist between the two groups.

There have been several series in which surgery was performed via anterior approaches for spinal metastases. In 1985, Siegal and Siegal⁶⁰ reported 61 patients who underwent surgery via an anterior approach for spinal metastases of which 44 were thoracic lesions. The authors used Harrington rods and MMA for reconstruction. Three percent suffered wound-related complications. Three percent developed hardware-related failure, and there was a 6% mortality rate. Additionally in 1985, Sundaresan, and associates⁶⁷ reported 101 patients who harbored mixed spinal tumors of which 68 were thoracic. They reported wound-related complications in 4% and death in 8%, with hardware failure in 5% of their patients. In a more recent article, Sundaresan and colleagues⁶⁶ reported 110 patients in whom MMA or bone and instrumentation reconstruction was performed. They reported wound-related complications in 16%, hardware-related failure in 11%, and death in 5%. In our thoracolumbar/combined approach group, there were no cases of death. Most of the complications were minor: DVT, atrial fibrillation, fever of unknown origin, nonoperative-related wound infection, pneumothorax, and dural tear. Many of these complications we have noted are not considered in the complications reported in other series. Overall, the complications reported in Group 2 patients are comparable with those in previously reported series.

There are several series in which surgery was performed via posterior approaches for spinal tumors. Akeyson and McCutcheon¹ reported 25 patients who underwent posterior bilateral transpedicular decompression for complete spondylectomy in which Steinmann pin, MMA, and Luque rectangle stabilization were performed after resection of spinal metastases. They reported no surgery-related deaths. Thirteen complications occurred in 12 patients. There were eight major complications requiring reoperation or in which a change in neurological status occurred: two infections, four hardware migration, one

CSF leak, and one delayed postoperative paresis. There were also five minor complications: three CSF leaks, one wound dehiscence, and one thoracic radiculopathy. In other series examining posterior approaches to spinal tumors the authors have reported mortality rates ranging from 11 to 16%.^{6,18,35,59} Morbidity rates as high as 50% have been reported.^{1,5,18,35,59} Wound-healing problems have been reported in 12 to 24% of these patients.^{1,5,35} In the present series, in the costotransversectomy-treated group, death occurred in one patient (3%) and neurological deterioration in two (7%). This is comparable with other reported series.

Although neither prospective nor randomized, this study does provide a candid and comprehensive accounting of all perioperative complications in this difficult patient population. We tried to account for all complications that occurred in each patient, no matter how seemingly inconsequential. Because some of these complications may not have been reported in previous series, the appearance of a high complication rate, may be given in this series. This is a candid accounting provided by a busy spine service in a major academic institution. The costotransversectomy-treated group had more upper thoracic metastasis and a higher mean Charlson comorbidity score. The intra- and postoperative courses of the two groups were very similar. Despite the fact that costotransversectomy-treated patients had a significantly higher incidence of comorbidities, its perioperative complications were very similar to those in whom thoracolumbar approaches were performed.

CONCLUSIONS

Surgical procedures for the treatment of thoracic metastases vary widely. We have reviewed our experience with costotransversectomy and anterior approaches in patients with spinal thoracolumbar neoplasms. We have retrospectively thoroughly identified the complications associated with these two approaches. Although both approaches were associated with several complications, the results are comparable with those reported in previous studies of this challenging patient population. In the costotransversectomy group, despite having a larger percentage of upper thoracic metastases and higher rate of comorbidity, rate and severity of complications appear to be similar to those demonstrated in patients who underwent surgery via anterior and combined approaches.

Costotransversectomy appears to be preferred in sicker patients, those with a greater number of pathologically affected levels of disease, and those with upper thoracic lesions.

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