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ORIGINAL ARTICLE – NEURO ONCOLOGY

Optimal Approach to Circumferential Decompression and Reconstruction for Thoracic Spine Metastatic Disease

Neil R. Malhotra, MD[1], Jennifer Kosty, MD[2], Matthew Sanborn, MD[1], Jonathan M. Bekisz[3], Theodore W. Mooncai[3], Thomas M. Neustein[3], Jessica Ou[3], Anna Zhu[3], Ali Bernstein[3], and Sherman C. Stein, MD[1]

[1]Department of Neurosurgery, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA; [2]Department of Neurosurgery, University of Cincinnati, Cincinnati, OH; [3]The University of Pennsylvania, Philadelphia, PA

ABSTRACT

Background. Circumferential decompression has been demonstrated to be the first-line therapy for patients with metastatic tumors in the thoracic spine requiring surgical intervention. However, there is significant debate regarding whether these tumors are best accessed anteriorly utilizing a thoracotomy or posteriorly. We used decision analysis to determine which approach yields greater health-related quality of life (QOL).

Methods. We searched Medline, Embase, and the Cochrane Library for relevant articles published between 1990 and 2011 on anterior and posterior approaches to metastatic disease in the thoracic spine. QOL values for major treatment outcomes were determined using the existing literature. Separate models were created for ambulatory and nonambulatory patients. A Monte Carlo simulation and sensitivity analyses were used to determine which treatment strategy resulted in the highest QOL.

Results. For ambulatory patients, an anterior approach resulted in a slightly higher QOL, and for nonambulatory patients, a posterior approach was favored, but these differences were not statistically significant.

Conclusions. Using a decision-analytic model, we found no significant difference in QOL resulting from anterior versus posterior approaches to metastatic lesions in the thoracic spine. Decisions should instead be based on surgeon comfort, tumor characteristics, anatomy of the lesion, patient-related factors, and goals of the operation.

Nearly 70 % of patients with disseminated cancer have metastases to the spine, with the thoracic segment being most frequently involved.[1,2] Untreated disease may lead to cord compression, resulting in paralysis, sensory loss, sphincter dysfunction, and pain.[3,4] In the 1970s, surgical management for these patients mainly involved decompressing the spinal canal with a laminectomy, but several case series and one randomized study suggested that this procedure, by itself or with radiotherapy, was no more effective than radiotherapy alone.[5–13] The failure of decompressive laminectomy was thought to be largely due to the anterior epidural location of most metastatic tumors, which is likely inadequately decompressed by a laminectomy.[14] In the mid-1980s, procedures to circumferentially decompress the spine, largely using an anterior approach, were developed.[2,15–23] This was followed by refinement of approaches to posteriorly or posterolaterally provide circumferential decompression using the transpedicular route, costotransversectomy, or lateral extracavitary exposure.[24–35] In 2004, Klimo et al.[36] published a meta-analysis demonstrating an advantage of these procedures over radiotherapy in maintaining and restoring ambulatory function. This was followed by a landmark randomized multi-institutional trial by Patchell et al.[37] showing significant improvement in, and preservation of, ambulatory function, as well as a decreased need for corticosteroids and opioid analgesics in patients randomized to surgery plus radiotherapy versus radiotherapy alone.

Although circumferential decompression is currently considered to be the best initial treatment for patients with spinal cord compression due to metastatic disease, it is unclear whether thoracic lesions are better approached

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N. R. Malhotra, MD
e-mail: neil.malhotra@uphs.upenn.edu

anteriorly with the additional morbidity of a thoracotomy, or posteriorly.

Few authors have compared anterior and posterior approaches to metastatic lesions of the thoracic or thoracolumbar spine.[38–40] Both Xu et al. and Lu et al. examined neurologic outcome, complications, operative time, estimated blood loss, and revision rates in series of 91 and 80 patients, respectively. Whereas Xu et al. reported less blood loss with the anterior approach and higher rates of infection with the posterior approach, the study of Lu et al. and those of other authors have found these two approaches to be comparable.[39,40] Unfortunately, the small size of these studies limits generalizability of their findings.

Because metastatic disease involving the thoracic spine is relatively rare, it is an ideal candidate for decision analysis. This technique can assist clinical decision making by simulating clinical trials using statistics published in the literature.[41,42] By determining the risk of each possible outcome after surgery, and by weighting this by the estimated quality of life (QOL) associated with it, one can compare two or more treatment options. We therefore performed a decision analysis using the available literature to estimate and compare the effect of an anterior approaches requiring thoracotomy versus posterior approaches on QOL in patients with metastatic disease in the thoracic spine. Combined approaches, which are generally performed out of necessity in patients with significant deformity or instability, are not included in this study, which was intended to compare approaches in which a choice is possible.

MATERIALS AND METHODS

We performed a search of Medline, Embase, and the Cochrane Library for relevant articles published in English between 1990 and February 2011. Our search strategy used combinations of the terms "spine," "spinal," "metastases," "metastasis," "metastatic," and "thoracic" in the title. We supplemented this search by using the Related Articles feature of PubMed and by manually searching the bibliographies of selected articles. We limited the search to adults with open decompression of thoracic spinal metastases and spinal cord compression, with or without stabilization. We excluded reports with fewer than ten operative cases, reports limited to a single group, such as children or the elderly, a single histology, and primary or intradural tumors. Articles were divided into those in which the approach for spinal cord decompression was anterior (transthoracic) and those approached posteriorly, including transpedicular exposure, costotransversectomy, and lateral extracavitary exposures. If a report included cases in which tumors also involved the cervical or lumbar regions or cases in which both anterior and posterior approaches were used, we included it only if the outcomes of the surgeries could be separated or if at least 60 % of the cases involved one approach to the thoracic spine. The surgical approach referred to the manner of decompression; if another approach was used for stabilization, the latter was not considered. We also excluded case series reporting only stabilization, kyphoplasty, or endoscopic techniques. Articles were reviewed by at least two authors to obtain pooled data for the evidence tables, from which we calculated the probabilities of the various treatment outcomes. Medline was also searched for articles on the health-related QOL associated with complications of surgery and other possible outcomes.

The decision analytic model to compare the anterior and posterior approaches followed standard procedures.[41] Our primary analysis calculated the likely outcomes following anterior and posterior approaches for decompression of the spinal cord. Possible pathways and outcomes after surgery are illustrated in Fig. 1. Separate subtrees (not illustrated) were created to calculate the expected probabilities and QOLs of patients with nonfatal complications. Surgery can be uneventful or can be followed by perioperative (within 30 days) death or nonfatal complications. Within the months after surgery, survivors may require repeat exploration for recurrence of spinal cord compression, spinal instability, infection, or other complications. The second operation may also be associated with perioperative complications and involves additional impact on QOL. Separate models were created for ambulatory and nonambulatory patients. We set the rate of reoperation for nonambulatory patients at 50 % that of ambulatory ones because we expected that they will need fewer repeat explorations. Our model does not consider the effects of metastatic disease at other sites or mortality beyond the perioperative period. Observational data were pooled meta-analytically using an inverse variance-weighted random-effects model.[42] Analyses of the model were performed by TreeAge Pro 2011 (Tree Age Software, Williamstown, MA, USA). Sensitivity analysis was done using a two-dimensional Monte Carlo simulation (expected value for 100 simulated trials, each made up of 1,000 microsimulations) Outcome comparisons between the two approaches used the Student's t test, and meta-analytic pooling used the metan function of Stata (v. 12, StataCorp, College Station, TX, USA). Given the time span we studied for this analysis and the possibility that improvements in technique, particularly after the publication of the landmark study by Patchell et al., may confound our results, we performed a metaregression to assess changes in complication rate; rate of cases losing and regaining ambulation; and rate of reoperation for each approach over time.[37,43]

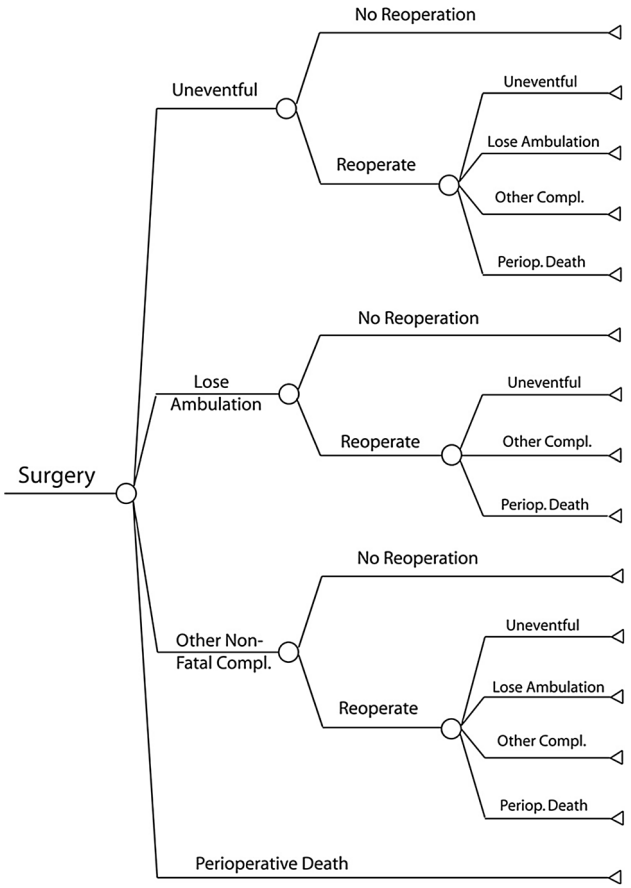


FIG. 1 Decision tree (detail), showing all possible outcomes after choice of surgical approach in an ambulatory patient. The tree is slightly modified in a patient who is nonambulatory before surgical decompression

Differences for which the probability was <0.05 were considered significant.

RESULTS

Our online search yielded 2,668 abstracts, of which 2,032 were discarded as unsuitable because of language, spinal location, or topic, such as diagnosis or radiotherapy. This left 636 articles, which we reviewed. Figure 2 illustrates the results. We used 33 articles to obtain data. Table 1 summarizes the 13 reports of anterior decompression (671 cases) and 21 reports of posterior decompression (1,281 cases). One case series reported cases with both approaches.[39] Another also reported both but failed to give adequate follow-up data on the posterior group; only their patients with anterior decompression are included in our analysis.[1] Because all series, including those comparing both anterior and posterior approaches, involve retrospective case reviews, they can be considered level III evidence.[44]

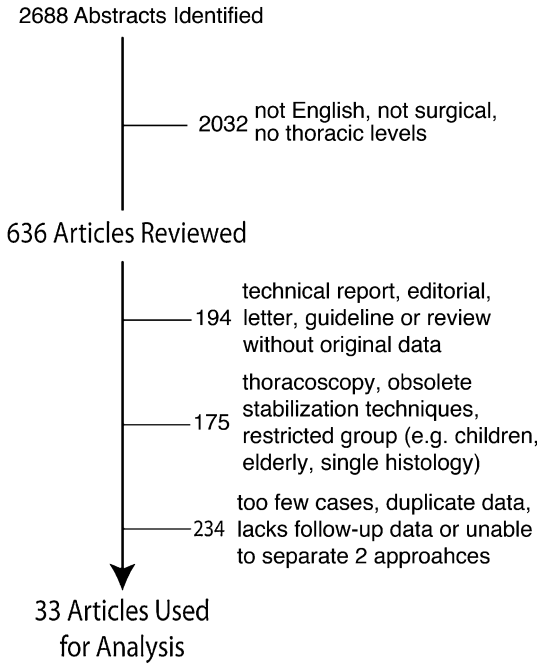


FIG. 2 Summary of the structured literature review performed showing numbers of abstracts reviewed, articles read, and used in our analysis, as well as reasons for rejection

The probabilities of various surgical outcomes are reported in Table 2. Differences in the number of patients at risk reflect the fact that not every article discussed the occurrence of every outcome. Table 3 reports the QOL associated with each outcome. When these values are plugged into the model and simulations are run, in subjects who are ambulatory before decompression, mean expected QOL after anterior decompression is 0.932 (SEM 0.017) and posterior decompression is 0.926 (SEM 0.018) ($p = 0.785$). For nonambulatory patients, mean expected QOL after anterior decompression is 0.774 (SEM 0.014) and posterior decompression is 0.783 (SEM 0.011) ($p = 0.610$). Our metaregression analysis demonstrated no change in outcomes over time for either approach.

DISCUSSION

We applied decision analysis to address the question of whether an anterior or posterior approach to circumferential decompression of the spinal canal in metastatic disease involving the thoracic spine yields a higher QOL and found no difference, regardless of preoperative ambulatory status.

Our results are consistent with those of previous case series. Lu et al.[38] found equivalent blood loss, operative time, and complication rates in patients undergoing a single-level transpedicular versus anterior-only corpectomies for trauma, metastases, and osteomyelitis. Significant differences in specific complications were not seen. In

TABLE 1 Case series used in the analysis

Study	Year	Approach	No. of cases	Ambulating before surgery, %	Mortality, %	Losing ambulation, %	Other complications, %	Reoperation required, %	Regaining ambulation, %
Abel[34]	2008	Posterior	34	9.1	2.9	33.3	21.2	3.0	13.3
Akeyson[28]	1996	Posterior	25	52.0	0.0	0.0	4.0	4.0	41.7
Bauer[68]	1997	Posterior	67	61.2	0.0	0.0	16.4	9.0	61.5
Bilsky[30]	2000	Posterior	25	100.0	12.0	4.5	9.1	9.1	NR
Cappelletto[69]	1998	Posterior	21	50.0	4.8	0.0	20.0	0.0	50.0
Chen[70]	2000	Anterior	60	55.0	0.0	0.0	5.0	NR	40.7
Chen[71]	2004	Posterior	70	42.4	5.7	0.0	12.1	3.0	39.5
Chen[72]	2007	Posterior	27	29.6	0.0	0.0	22.2	14.8	68.4
Cho[31]	2009	Posterior	21	61.9	0.0	0.0	9.5	14.3	37.5
Cooper[73]	1993	Anterior	33	75.8	0.0	0.0	18.2	0.0	50.0
Di Martino[74]	2009	Posterior	32	34.4	0.0	0.0	28.1	0.0	42.9
Gokaslan[2]	1998	Anterior	72	81.4	2.8	0.0	30.0	4.3	76.9
Hall[49]	1991	Anterior	10	14.3	30.0	NR	NR	NR	83.3
Harrington[1]	1993	Anterior	77	0.0	14.3	NR	NR	NR	9.1
Hertlein [75]	1992	Anterior	41	48.8	0.0	0.0	4.9	0.0	38.1
Hirabayashi[76]	2003	Posterior	81	39.7	3.7	0.0	14.1	11.5	57.4
Hofstetter[77]	2011	Posterior	67	59.7	0.0	5.0	3.0	7.5	44.4
Huang[78]	2006	Anterior	17	NR	0.0	NR	17.6	0.0	NR
Jansson[79]	2006	Posterior	282	43.7	13.1	4.7	6.9	4.9	72.5
Jonsson[80]	1996	Posterior	51	15.7	0.0	25.0	7.8	0.0	34.9
Klekamp[81]	1998	Posterior	101	53.4	12.9	4.3	11.4	2.3	22.0
Kocialkowski[82]	1992	Anterior	70	34.3	0.0	0.0	NR	0.0	56.5
Lu[38]	2010	Posterior	54	66.0	1.9	5.7	15.1	1.9	61.1
Muhlbauer[29]	2000	Posterior	17	41.2	0.0	0.0	23.5	0.0	70.0
Rompe[83]	1993	Posterior	50	71.4	2.0	5.7	18.4	4.1	57.1
Street[84]	2007	Posterior	42	75.6	2.4	0.0	0.0	26.8	30.0
Timlin[85]	1995	Anterior	28	88.5	7.1	0.0	11.5	0.0	0.0
Villavicencio[86]	2005	Anterior	58	NR	3.4	NR	21.4	0.0	NR
Viswanathan[87]	2011	Anterior	95	84.0	1.1	0.0	14.9	3.2	13.3
Walsh[88]	1997	Anterior	61	71.4	8.2	0.0	23.2	5.4	75.0
Wang[32]	2004	Posterior	140	93.6	0.0	0.8	7.9	11.4	88.9
Wiggins[89]	2001	Posterior	29	57.1	3.4	12.5	39.3	0.0	8.3
Xu[39]	2009	Anterior	22	NR	0.0	NR	109.1	22.7	NR
Xu[39]	2009	Posterior	45	71.1	0.0	0.0	73.3	4.4	15.4
Yen[90]	2002	Anterior	27	59.3	0.0	0.0	33.3	0.0	54.5

NR not reported

patients with metastatic disease only, Xu et al.[39] reported a higher rate of wound infection and deep vein thrombosis associated with a posterior approach, and a higher incidence of pneumothorax associated with an anterior approach. We identified similar trends in our study.

Decision analysis is a useful tool for clinical decision making that has previously been used in the neurosurgical literature.[45,46] Because it allows one to simulate thousands of clinical trials, it is particularly helpful in situations where the procedure or outcome of interest is rare. In addition to determining the morbidity and mortality associated with each procedure, decision analysis allows one to calculate the predicted QOL associated with each treatment, determined by weighting the risk of each possible outcome by its desirability. This is important because health-related QOL, or the subjective impact of a health

TABLE 2 Outcome probabilities after decompression for thoracic metastases

Outcome	Anterior decompression			Posterior decompression		
	No. at risk	Mean	SD	No. at risk	Mean	SD
Perioperative mortality	671	.059	.007	1,281	0.052	0.006
Nonfatal complications						
Pain	253	0.043	0.013	461	0.009	0.004
Wound[a]	572	0.024	0.006	1,107	0.076	0.008
Sepsis	512	0.006	0.003	1,215	0.006	0.002
Respiratory[b]	512	0.111	0.014	1,174	0.024	0.004
Deep vein thrombosis	512	0.018	0.006	1,174	0.016	0.004
Pulmonary emboli	512	0.012	0.005	1,141	0.007	0.002
Ambulation						
Preoperative rate	671	0.686	0.018	1,281	0.522	0.014
Lost[c]	389	0.009	0.004	669	0.030	0.007
Regained[d]	211	0.502	0.034	546	0.500	0.021
Reoperation[e]	433	0.032	0.008	942	0.084	0.009

[a] Infection/dehiscence

[b] Failure, pneumonia, effusion, collapsed lung

[c] Ambulatory before surgery

[d] Nonambulatory before surgery

[e] Only ambulatory patients

state, is increasingly recognized as being an essential measurement of outcome.[47]

The comparable estimated QOL yielded by both approaches suggests that surgical decision making for metastatic disease of the thoracic spine should be based on other factors. Theoretical advantages of anterior approaches include more direct access to the vertebral body, easier ligation of tumor feeding vessels, and reduced blood loss due to lower pressures in the lateral decubitus compared to the prone position.[2,39] However, these procedures are associated with higher rates of pulmonary complications.[2,28,48–53] Posterior approaches allow for earlier identification of the spinal canal, the ability to address disease in the posterior elements, and more facile correction of imbalance in the sagittal, coronal, and axial planes.[35] They may be preferred in patients who cannot tolerate a transcavitary approach or who need long segmental fixation, but they are associated with higher rates of wound infection, persistent cerebrospinal fluid leakage, graft dislodgement, blood loss, unintentional durotomies, and infections.[2,20,39]

Disease factors may influence the selected approach. For instance, in very vascular tumors, blood loss might be more easily minimized using a combined anterioposterior approach.[54–58] The risk of wound dehiscence with previously irradiated fields may also be a factor in choosing an anterior approach.[59]

Patient characteristics must also be considered carefully. For instance, it may be preferable to avoid a thoracotomy in patients with significant lung disease.[48,60] Some authors have argued that anterior approaches require a higher level of patient fitness, but others maintain that these procedures are generally well tolerated.[36,59] In patients with a poor prognosis, palliative surgery involving posterior decompression and stabilization or laminectomy may be preferred.[61,62]

The anatomy of the disease may also guide approach. Lesions isolated to the posterior elements may be best approached posteriorly or posterolaterally, the anterior part of the verterbral body may be most easily approached anteriorly, and a combined approach may be optimal for lesions involving the posterior part of the vertebral body.[63] Anterior approaches are required when the vertebral tumor is growing outside the anterior circumference of the vertebral body and involves the segmental vessels. Tumors in the T1–4 region, especially T3–4, are generally obscured by the great vessels and therefore difficult to reach anteriorly.[59,60,64] Fourney and Gokaslan [4] argue that disease of one or two contiguous levels is best addressed anteriorly, as anterior prostheses allow for the best reconstruction of the weight-bearing capacity of the spine. However, posterior reconstruction of the anterior elements can be performed with an expandable cage polymethylmethacrylate and a chest tube or Steinman pins, or polyetheretherketone cages, and supplemented with simultaneous posterior fixation. Posterior stabilization may be required in cases of significant kyphosis, junctional zone disease, chest wall reconstruction, corpectomy spanning two or more levels, spondylectomy, and poor bone integrity.[28,38,59,60,65,66]

There are several limitations to our study. First, because data were taken from case series, it is subject to significant selection bias for each approach. Second, our model does not take into account the effects of metastatic disease at other sites or mortality beyond the perioperative period. Although important in determining patients' QOL, it is unlikely that these factors would differentially affect groups receiving a particular surgical approach, and accounting for them would be exceedingly difficulty given our methodology. Third, the number of articles reporting on the posterior approach was nearly double that of the anterior approach, although it is unlikely this difference would significantly affect the results. Fourth, several articles reported the results of a particular procedure on patients with metastatic disease in all spinal segments. Such articles were only included if more than 60 % of cases were thoracic, but the representativeness of data from these series is limited. Fifth, some authors may avoid anterior approaches in patients deemed to be less fit, and therefore it is possible that the morbidity and mortality

TABLE 3 Outcomes and associated QOL

Complication	*n*	Associated QOL	SD	Scale	Study
Uneventful outcome	NA	1	NA	Consensus	Sox HC Jr, Blatt MA, Higgins MC, Marton KI. *Medical Decision Making*. Philadelphia: American College of Physicians; 2007
Deep vein thrombosis[91]	NA	0.95	–	Expert opinion	Danish SF, Burnett MG, Ong JG, Sonnad SS, Maloney-Wilensky E, Stein SC. Prophylaxis for deep venous thrombosis in craniotomy patients: a decision analysis. *Neurosurgery*. 2005;56:1286–94
Wound infection/ dehiscence[45]	45	0.928	0.179	SG	Lega BC, Danish SF, Malhotra NR, Sonnad SS, Stein SC. Choosing the best operation for chronic subdural hematoma: a decision analysis. *J Neurosurg*. 2010;113:615–21
Sepsis[45]	45	0.928	0.154	SG	Lega BC, Danish SF, Malhotra NR, et al. Choosing the best operation for chronic subdural hematoma: a decision analysis. *J Neurosurg*. 2010;113:615–21
Pulmonary embolus[45]	45	0.926	0.156	SG	Lega BC, Danish SF, Malhotra NR, et al. Choosing the best operation for chronic subdural hematoma: a decision analysis. *J Neurosurg*. 2010;113:615–21
Respiratory complications[45]	45	0.915	0.160	SG	Lega BC, Danish SF, Malhotra NR, et al. Choosing the best operation for chronic subdural hematoma: a decision analysis. *J Neurosurg*. 2010;113:615–21
Reoperation[45]	45	0.915	0.122	SG	Lega BC, Danish SF, Malhotra NR, et al. Choosing the best operation for chronic subdural hematoma: a decision analysis. *J Neurosurg*. 2010;113:615–21
Severe postoperative pain[92]	94	0.695	0.28	VAS	Sarna L, Cooley ME, Brown JK, Chernecky C, Elashoff D, Kotlerman J. Symptom severity 1–4 months after thoracotomy for lung cancer. *Am J Crit Care*. 2008;17:455–67
Lost ambulation[93]	17	0.67	0.13	EQ-5D	Gautschi OP, Seule MA, Cadosch D, Gores M, Ewelt C, Hildebrandt G, Heilbronner R. Health-related quality of life following spinal cordectomy for syringomyelia. *Acta Neurochir* (*Wien*). 2011;153:575–9
Perioperative death	NA	0	NA	Consensus	Sox HC Jr, Blatt MA, Higgins MC, Marton KI. *Medical Decision Making*. Philadelphia: American College of Physicians; 2007

QOL quality of life, *EQ-5D* EuroQol questionnaire, *NA* not appropriate, *SG* standard gamble

rates calculated for this approach underestimate what might be expected for the population at large.[36] Sixth, we did not include simultaneous anterioposterior approaches in our model, although there are cases in which these approaches may be preferred, including patients with significant thoracic metastatic disease burden, considerable instability, and marked deformity.[67] Combined approaches were excluded because such procedures are generally performed out of necessity; therefore, limited clinical equipoise exists between a combined approach and either a posterior or anterior approach. Additionally, as other authors have found, few studies report data for combined approach cohorts alone, which significantly limits the ability compare this technique to isolated anterior or posterior approaches.[64] Finally, several surgical outcomes including operative time, blood loss, and length of hospital stay were not included in this analysis. These factors, although important to surgeons and hospitals, have little impact on a patient's overall QOL. Fusion rates, which may indirectly affect QOL, were not reported frequently enough to be included in this study, although they are reflected in reoperation rates. The effect of radiotherapy and chemotherapy on wound healing as a function of approach is also beyond the scope of this study, but it likely contributes to infection rates.

The results of this decision analysis suggest that circumferential decompression of the thoracic spine for metastatic disease may be treated using either an anterior or posterior approach with an equal effect on QOL. At present, decisions regarding which approach to use should be made by considering surgeon comfort level, tumor characteristics, anatomy of the lesion, patient-related factors, and goals of treatment. In the future, larger randomized, prospective studies may provide more information regarding whether either approach yields better results.

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