Journal of Bone Oncology 34 (2022) 100424

Contents lists available at ScienceDirect

Journal of Bone Oncology

journal homepage: www.elsevier.com/locate/jbo

Research Paper

Postoperative outcomes of subaxial cervical spine metastasis: Comparison among the anterior, posterior, and combined approaches

Panya Luksanapruksa [a], Borriwat Santipas [a], Panupol Rajinda [b], Theera Chueaboonchai [b], Korpphong Chituaarikul [a], Patawut Bovonratwet [c], Sirichai Wilartratsami [a,*]

[a] Division of Spine Surgery, Department of Orthopaedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand
[b] Department of Orthopedic Surgery, Sunpasithiprasong Hospital, Ubon Ratchathani, Thailand
[c] Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, NY, USA

ARTICLE INFO

Article history:
Received 5 November 2021
Revised 17 March 2022
Accepted 17 March 2022
Available online 19 March 2022

Keywords:
Postoperative outcomes
Subaxial cervical spine metastasis
Anterior approach
Posterior approach
Combined approach
Thailand

ABSTRACT

Background: The incidence of subaxial spinal metastases increases due to longer life expectancy resulting from successful modern cancer treatments. The three most utilized approaches for surgical treatment include the anterior, posterior, and combined approaches. However, despite increasing surgical volume, data on the postoperative complication profiles of different operative approaches for this patient population is scarce.

Methods: The institutional databases of two large referral centers in Thailand were retrospectively reviewed. Patients with subaxial cervical spine metastasis who underwent cervical surgery during 2005 to 2015 were identified and enrolled. Clinical presentations, baseline characteristics, operative approach, perioperative complications, and postoperative outcomes, including pain, neurological recovery, and survival, were compared among the three surgical approaches.

Results: The 70 patients (44 with anterior approach, 14 with posterior approach, 12 with combined approach) were enrolled. There were no statistically significant differences in preoperative characteristics, including Charlson Comorbidity Index (CCI), Tomita score, and Revised Tokuhashi score, among the three groups. There were no significant differences among groups for medical complications, surgical complications, neurological recovery, verbal pain score improvement, survival time, or ambulatory status improvement. However, the combined approach did show a significantly higher rate of overall perioperative complications ($p = 0.01$), intraoperative blood loss ($p < 0.001$), and operative time ($p < 0.001$) compared to the other two approaches.

Conclusions: Patients in the combined approach group had the highest rates of perioperative complications. However, although the differences were not statistically significant, patients in the combined group tended to have better clinical outcomes after follow-up and the longest survival time.

1. Introduction

The incidence of cervical spine metastasis ranges from 10% to 15%, and it most often occurs in the subaxial cervical region [1,2]. Most patients present with axial neck pain (from tumor biology and cervical instability) and neurologic deficits – both of which are associated with a poor prognosis due to high-level disability [3–5]. Operative treatment may show benefit in patients who are not responsive to nonoperative treatment, who have intractable pain due to cervical instability, or who have progressive neurological deficits [6].

Decision-making regarding the operative approach depends on multiple factors. In most subaxial cervical spine metastasis cases, the anterior approach is recommended [7]. However, in certain situations, such as multiple consecutive tumor involvement, anterior surgical decompression can result in massive bleeding, which may make reconstruction difficult. In these types of cases, the posterior approach is more appropriate. Previous studies reported promising pain reduction and neurological recovery results without serious complications for the anterior and posterior surgical approaches [2–4,8,9]. However, no previous study has directly compared these two approaches' clinical outcomes and perioperative complications.

* Corresponding author at: Department of Orthopedic Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, 2 Wanglang Road, Bangkoknoi, Bangkok 10700, Thailand.
E-mail address: sirichai.wil@mahidol.edu (S. Wilartratsami).

https://doi.org/10.1016/j.jbo.2022.100424
2212-1374/

Accordingly, the purpose of the current study was to evaluate the perioperative complication profiles and postoperative outcomes of subaxial cervical spine metastasis treatment compared among the anterior, posterior, and combined surgical approaches.

2. Material and methods

This retrospective cohort comparison study evaluates postoperative outcomes following anterior, posterior, or combined surgical approaches in subaxial cervical spinal metastasis patients. This study received Institutional Review Board (IRB) approval by the Siriraj Institutional Review Board (SIRB) (COA no. 428/2558 (EC2)). All methods were carried out following relevant guidelines and regulations. Moreover, all authors confirmed that informed consent was obtained from all subjects. We reviewed the institutional databases of both participating centers for patients who underwent surgery for subaxial cervical metastasis from April 2005 to March 2015. The inclusion criteria were patients with spinal metastasis involving the subaxial cervical region (C3-C7), age at surgery from 20 to 90 years, and pathological report or radiographic study confirming metastatic disease. Exclusion criteria were previous surgery at the same level, loss to follow-up, and incomplete medical records.

Recorded variables included demographic and clinical data (gender, age at operation, comorbidities, and preoperative neurological status), operative data (surgical approach, level of decompression, reconstruction materials, type of instrumented fixation, operative time, and estimated blood loss [EBL]), and postoperative data (postoperative complications, length of hospital stay, neurological outcomes, ambulatory status, reoperation, and survival). The severity of comorbidity was calculated using the Charlson Comorbidity Index (CCI) [10]. Neurological status was classified by American Spinal Injury Association (ASIA) grading during the preoperative and postoperative periods [11]. Ambulatory status was classified as ambulator or non-ambulator. Preoperative predicted survival was calculated using the Revised Tokuhashi score (RTS) [12] and Tomita score [13]. Preoperative pain and postoperative pain were evaluated using a verbal numerical scale (VNS) that ranged from 0 (no pain) to 10 (most extreme pain). Pain assessment agreement between the visual analog scale (VAS) for pain and the VNS for pain was reported to be good [14].

The indications for surgery of our institution were intractable pain, patients who present with a neurological deficit which resulted in disability, impaired ambulatory status or bowel-bladder dysfunction, and patients who had SINS score of at least seven.

Anterior techniques included corpectomy at the compressive level and reconstruction with autologous bone graft, polymethyl methacrylate (PMMA), or metallic cage, combined with anterior cervical plate fixation (Fig. 1). Posterior techniques included laminectomy at the compressive level and stabilization with cervical pedicle screws or lateral mass screws and rod systems (Fig. 2). Combined surgery could be performed simultaneously or staged (Fig. 3).

The primary outcomes were perioperative complications classified as medical-related complications (pneumonia, urinary tract infection, myocardial infarction, deep vein thrombosis, and pulmonary embolism) and surgery-related complications (surgical wound infection, implant failure, reoperation). The secondary outcomes were improvement in VNS, neurological recovery, ambulatory status at the discharge date, and median survival time after surgery with the censoring date set as 31 May 2015.

2.1. Statistical analysis

Descriptive statistics were calculated and reported as mean ± standard deviations or median with interquartile range for quantitative data and frequency with percentage for categorical data. Chi-square test or Fisher's exact test were used to analyze categorical variables as appropriate. One-way analysis of variance (ANOVA) was used to analyze the verbal pain scale. Survival curves were created using the Kaplan-Meier method. Data were compiled and analyzed using SPSS Statistics version 18.0 (SPSS, Inc., Chicago, IL, USA). *P*-values of<0.05 were considered statistically significant.

3. Results

Seventy-two patients were identified; however, two of those patients were excluded – one for having previous surgery, and the other was lost to follow-up. The remaining 70 patients were enrolled (33 men and 37 women). The average follow-up duration was 17.80 ± 22.86 months. The average age was 58.3 ± 11.6 years. The mean duration of symptoms before surgery was 55 ± 40.26 d ays. Most patients (57/70, 81.42%) had neurological deficits before surgery. Primary tumors were classified according to the Revised Tokuhashi Score, as shown in Table 1.

There were no significant differences in preoperative demographic or clinical characteristics, including gender, duration of symptoms, CCI, Revised Tokuhashi Score, and Tomita score, among the three surgical approach groups. Additional demographic and comorbidity data are shown in Table 1.

Concerning operative data, the combined group had significantly greater intraoperative blood loss, longer operative time, and more perioperative complications (1,235.4 ± 689.00 ml, 333. 42 ± 80.11 min, and 58.3%, respectively [$p < 0.05$]) compared to the anterior and posterior approach groups.

3.1. Perioperative complications

The perioperative medical-related complication rate was 22.9%, and the surgical-related complication rate was 17.1%. Pneumonia was found in 6 patients (8.6%; 4 anterior approaches, 2 posterior approaches), and one patient in the posterior group expired due to severe obstructive pneumonia. Urinary tract infection was found in 8 patients (11.4%; 4 in anterior approach group, 2 in posterior approach group, and 2 in combined approach group). Patients with UTI will be administered empirical antibiotic therapy with Ceftriaxone and then adjusted following the urine culture and sensitivity results. One patient in the anterior group died from perioperative ST-elevation myocardial infarction (STEMI) and congestive heart failure. One patient in the combined group had deep vein thrombosis (DVT) and pulmonary embolism (PE) that required anticoagulant therapy. Surgical wound infection was found in 6 patients (1 anterior, 1 posterior, and 4 combined). Implant-related complications were found in 4 patients. Two patients in the anterior group had cement displacement during the postoperative period after receiving anterior reconstruction using PMMA without anterior plate fixation. Both of those patients underwent revision surgery with anterior cervical plate fixation after removing the cement from the previous surgery. One patient in the anterior group had implant failure 2 months after surgery but did not undergo revision surgery due to the progression of the disease. One patient in the posterior group had right C7 lateral mass screw malposition and underwent revision surgery. Dysphagia was found in 1 patient, but the improvement was observed during follow-up.

We compared perioperative complication occurrence between each range of Revised Tokuhashi score. 54 patients had the RTS in the range of 0–8, 15 patients had the RTS in the range of 9–11,

Fig. 1. Radiographic study of a 41-year-old woman (patient #3). (A) Plain radiograph lateral view of the cervical spine shows pathological C4 fracture with kyphosis. (B) T2-weighted magnetic resonance imaging (MRI) demonstrates spinal metastasis at the C4 vertebral body without significant pressure on the cervical cord. (C, D) Postoperative anteroposterior and lateral radiographs demonstrate anterior corpectomy of the C4 vertebral body with reconstruction using polymethylmethacrylate (PMMA) with K-wire augmentation, and stabilization with cervical plate.

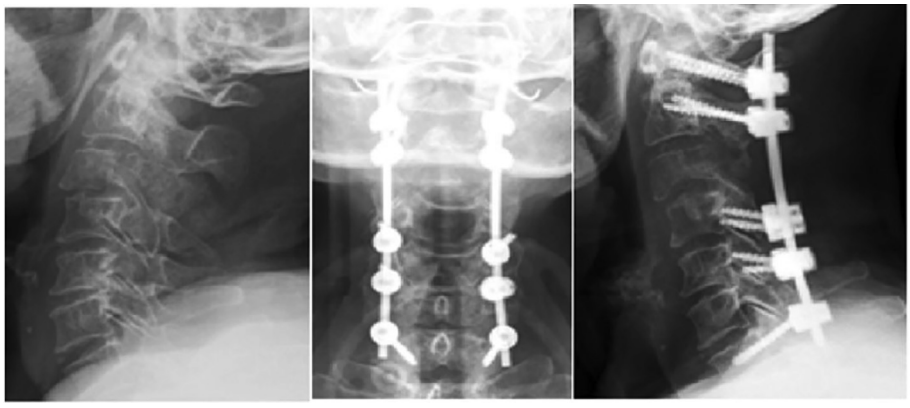

Fig. 2. Radiographic study of a 69-year-old woman (patient #30). (A) Plain radiograph lateral view of the cervical spine demonstrates spinal metastasis at the posterior part of the body, and at posterior elements of the C4 vertebra with anterior listhesis of C3 over C4. (B, C) Postoperative anteroposterior and lateral radiographs show decompressive laminectomy from partial C2 to C5 with cervical stabilization using lateral mass screw and pedicle screw systems.

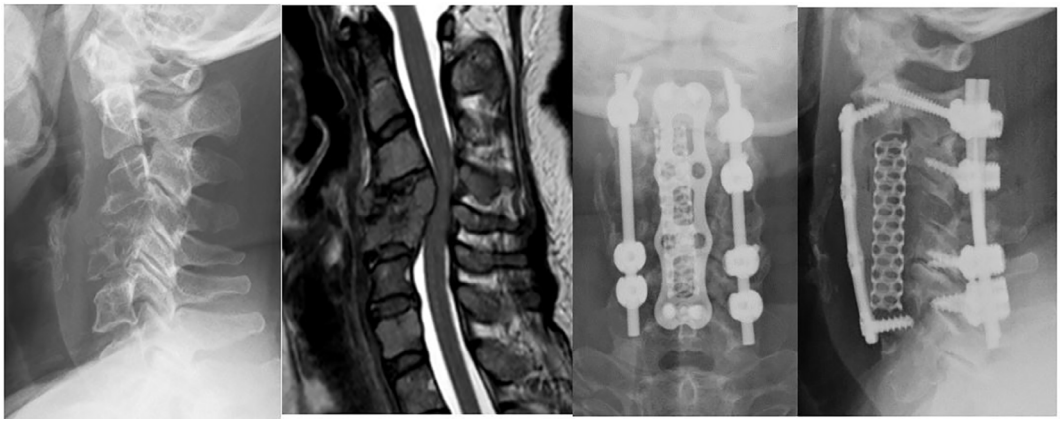

Fig. 3. Radiographic study of a 41-year-old woman (patient #39). (A) Plain radiograph lateral view of the cervical spine reveals pathological fracture of C4 with kyphosis. (B) T2-weighted magnetic resonance imaging (MRI) shows spinal metastasis at the C4 vertebral body and circumferential spinal cord compression caused by posterior elements. (C, D) Postoperative anteroposterior and lateral radiographs demonstrate anterior corpectomy of C3-C5 vertebral body and reconstruction using a titanium cage with polymethylmethacrylate (PMMA) augmentation, and stabilization with anterior cervical plate, lateral mass crew, and pedicle screw systems.

and 1 patient had the RTS in the range of 12–15. The majority of perioperative occurrence was found in the patients who had the RTS in the range of 0–8 (21 patients (38.9%) had medical-related complications, 10 patients (18.5%) had surgical-related complica-

Table 1
Demographic and clinical characteristics of the total cohort, and compared among approach groups.

Characteristics	Total (N = 70)	Anterior (n = 44)	Posterior (n = 14)	Combined (n = 12)	*p*-value
Males gender	33 (47.1%)	19 (43.2%)	7 (50.0%)	7 (58.3%)	0.629
Average age (years)	58.33 ± 11.56	58.82 ± 11.45	57.79 ± 13.76	57.17 ± 9.95	0.894
Average duration of symptom (days)	55.00 ± 40.26	47.68 ± 34.07	75.86 ± 49.39	57.50 ± 44.40	0.119
Average Charlson Comorbidity Index	8.93 ± 1.77	8.91 ± 1.55	9.07 ± 2.20	8.83 ± 2.23	0.868
Average Revised Tokuhashi score	6.44 ± 2.79	6.52 ± 2.44	6.71 ± 3.63	5.38 ± 3.07	0.696
Average Tomita score	6.90 ± 2.28	6.90 ± 2.00	6.85 ± 2.76	6.91 ± 2.77	0.995
Tumor type					
- Lung, osteosarcoma, stomach, bladder, esophagus, pancreas	17	9	5	3	
- Liver, gallbladder, unidentified	30	24	2	4	
- Others	5	3	0	2	
- Kidney, uterus	0	0	0	0	
- Rectum	1	1	0	0	
- Thyroid, breast, prostate, carcinoid tumor	17	7	7	3	
ASA class					0.825
I	3 (4.3%)	2 (4.5%)	0 (0.0%)	1 (8.3%)	
II	18 (25.7%)	11 (25.0%)	4 (28.6%)	3 (25.0%)	
III	36 (51.4%)	23 (52.3%)	6 (42.9%)	7 (58.3%)	
IV	13 (18.6%)	8 (18.2%)	4 (28.6%)	1 (8.3%)	
V	0	0	0	0	
Preoperative ASIA grade					
A	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
B	3 (4.3%)	2 (4.5%)	0 (0.0%)	1 (8.3%)	
C	17 (24.3%)	11 (25.0%)	3 (21.4%)	3 (25.0%)	
D	36 (51.4%)	22 (50.0%)	7 (50.0%)	7 (58.3%)	
E	14 (20%)	9 (20.4%)	4 (28.6%)	1 (8.3%)	
Postoperative ASIA grade					
A	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
B	1 (1.4%)	1 (2.3%)	0 (0.0%)	0 (0.0%)	
C	9 (12.8%)	5 (11.4%)	3 (21.4%)	1 (8.3%)	
D	42 (60.0%)	30 (68.2%)	7 (50.0%)	5 (41.7%)	
E	18 (25.7%)	8 (18.2%)	4 (28.6%)	6 (50.0%)	

Data presented as number and percentage or mean ± standard deviation.
p-value < 0.05 indicates statistical significance.
Abbreviations: ASA, American Society of Anesthesiologists; ASIA, American Spinal Injury Association.

tions, and 2 patients (3.7%) experienced worsening neurological status). We found a statistically significant difference in surgical-related complication occurrence among groups (p = 0.014). The details are shown in Table 3.

Regarding patients' physical status and comorbidity, we found no statistically significant difference in complication occurrence between each ASA classification. Patients with CCI of less than 8 had statistically significantly greater surgical-related complications occurrence (p = 0.019) and implant failure (p = 0.042) when compared with patients who had CCI at least 8. The details of the bivariate analysis are shown in Table 4.

3.2. Clinical outcomes

The mean overall preoperative VNS was 5.64, and the average postoperative VNS was 3.14. The mean preoperative VNS was 6.04, 4.28, and 5.75 in the anterior group, posterior group, and combined group, respectively. The mean postoperative VNS in the same groups were 3.43, 2.78, and 2.50, respectively. Improvement in VNS was found in more than 75% of patients in all 3 groups.

Neurological recovery rate and ambulatory status improvement were both poor (22.7–33.3% and 11.4–33.3%, respectively). Neurological improvement was found in only 18 of 70 patients, with the best improvement observed in the combined group and the least improvement observed in the anterior group. Twelve of 70 patients became ambulatory after treatment (Table 2). These results are also reported in Fig. 4.

3.3. Survival

The overall mortality rate was 84.28%. Thirty-one patients (77.5%) had expired – 2 patients due to postoperative complications, and 29 patients due to disease progression. Analysis of mortality by the group revealed that 15 patients were in the anterior group, 12 in the posterior group, and 4 in the combined group. Mean and median survival times are shown in Table 2. Kaplan-Meier survival analysis showed the median survival time in the anterior, posterior, and combined approach groups to be 6.03, 6.76, and 27.93 months, respectively (Fig. 5).

4. Discussion

Subaxial cervical metastases are known to have a poorer prognosis than metastases to the thoracic or lumbar regions [15]. Despite the potential complications, operative treatment for subaxial cervical metastasis is more effective than nonoperative treatment for relieving pain and may also reverse neurologic deficits and improve ambulatory function [16,17]. Operative treatment options in this region include the anterior approach, the posterior approach, or the combined anterior and posterior approach. Fehlings *et al.* conducted a systematic review and recommended the anterior approach for most subaxial cervical spine metastases and the posterior approach for most craniovertebral metastases [7]. The combined anterior and posterior approach is recommended in circumferential tumor involvement and poor bone quality [7]. However, data on the perioperative complication profiles of these three approaches is lacking. Therefore, the purpose of the current study was to compare the clinical results among these three standard approaches. This information may help to

Table 2
Operative data and clinical outcomes compared among the anterior, posterior, and combined approach groups.

Data and outcomes	Anterior (n = 44)	Posterior (n = 14)	Combined (n = 12)	*p*-value
Number of decompression levels				
0	0 (0.0%)	2 (14.3%)	0 (0.0%)	***<0.001***
1	32 (72.7%)	1 (7.1%)	2 (16.7%)	
2	12 (27.3%)	2 (14.3%)	4 (33.3%)	
3	0 (0.0%)	7 (50.0%)	4 (33.3%)	
4	0 (0.0%)	2 (14.3%)	2 (16.7%)	
Average blood loss (ml)	287.50 ± 199.56	780.00 ± 702.79	1,235.40 ± 689.00	***<0.001***
Average operative time (minutes)	130.41 ± 56.98	242.86 ± 62.93	333.42 ± 80.11	***<0.001***
Postoperative outcomes				
Preoperative verbal pain score	6.04 ± 2.36	4.280 ± 2.97	5.75 ± 1.54	0.105
Postoperative verbal pain score	3.43 ± 1.53	2.78 ± 2.25	2.50 ± 1.56	***0.008***
Change in verbal pain score				0.06
Increment	1 (2.3%)	3 (21.4%)	0 (0.0%)	
No change	3 (6.8%)	0 (0.0%)	1 (8.3%)	
Decrement	40 (90.9%)	11 (78.6%)	11 (91.7%)	
Postoperative ASIA grade				
A	0 (0.0%)	0 (0.0%)	0 (0.0%)	
B	1 (2.3%)	0 (0.0%)	0 (0.0%)	
C	5 (11.4%)	3 (21.4%)	1 (8.3%)	
D	30 (68.2%)	7 (50.0%)	5 (41.7%)	
E	8 (18.2%)	4 (28.6%)	6 (50.0%)	
Neurological recovery (ASIA improved greater than 1 grade)	10 (22.7%)	4 (28.6%)	4 (33.3%)	0.73
Ambulatory improvement (non-ambulate to ambulate)	5 (11.4%)	3 (21.4%)	4 (33.3%)	0.18
Perioperative complications	11 (25%)	7 (50.0%)	7 (58.3%)	***0.01***
Medical complications	7 (15.9%)	5 (35.7%)	4 (33.3%)	0.328
Urinary tract infection	4 (9.1%)	2 (14.3%)	2 (16.7%)	
Myocardial infarction	1 (2.3%)	0 (0.0%)	0 (0.0%)	
Pneumonia	4 (9.1%)	2 (14.3%)	0 (0.0%)	
Deep vein thrombosis / pulmonary embolism	0 (0.0%)	0 (0.0%)	1 (8.3%)	
Electrolyte imbalance	1 (2.3%)	0 (0.0%)	1 (8.3%)	
Surgical complication	6 (13.6%)	2 (14.2%)	4 (33.3%)	0.177
Wound infection	1 (2.3%)	1 (7.1%)	4 (33.3%)	
Implant failure	3 (6.8%)	1 (7.1%)	0 (0.0%)	
Reoperation	3 (6.8%)	1 (7.1%)	0 (0.0%)	
Neurological deficit	2 (4.5%)	0 (0.0%)	0 (0.0%)	
Dysphagia	1 (2.3%)	0 (0.0%)	0 (0.0%)	
Average length of stay (days)	19.7 ± 13.7	31.8 ± 28.2	26.2 ± 12.7	***<0.001***
Median survival (months)	6.03	6.76	27.93	0.08

Data presented as number and percentage, mean ± standard deviation, or median.
A *p*-value < 0.05 indicates statistical significance.
Abbreviation: ASIA, American Spinal Injury Association.

Table 3
Comparison of *peri*-operative complication occurrence between each range of revised Tokuhashi score.

Data and outcomes	**Tokuhashi score 0–8(n = 54)**	**Tokuhashi score 9–11(n = 15)**	**Tokuhashi score 12–15(n = 1)**	***p*-value**
Medical complications	21 (38.9%)	5 (33.3%)	1 (100%)	0.413
Surgical complication	10 (18.5%)	0 (0%)	1 (100%)	**0.014**
Neurological deficit	2 (3.7%)	0 (0%)	0 (0%)	0.737

Pearson Chi-Square

Table 4
Comparison of *peri*-operative complication occurrence among ASA classification and Charlson comorbidity index.

Comparison of peri-operative complication	**ASA Classification***					**CCI****		
	ASA I (n = 3)	**ASA II (n = 18)**	**ASA III (n = 36)**	**ASA IV (n = 13)**	***p*-value**	**<8 (n = 17)**	**≥ 8 (n = 53)**	***p*-value**
Medical complications	0 (0%)	8 (44.4%)	15 (41.7%)	4 (30.8%)	0.453	9 (52.9%)	18 (34.0%)	0.252
Urinary tract infection	0 (0%)	4 (22.2%)	4 (11.1%)	0 (0%)	0.247	0 (0%)	8 (15.1%)	0.185
Myocardial infarction	0 (0%)	0 (0%)	1 (2.8%)	0 (0%)	0.811	0 (0%)	1 (1.9%)	1.000
Pneumonia	0 (0%)	2 (11.1%)	3 (8.3%)	1 (7.7%)	0.931	1 (5.9%)	5 (9.4%)	1.000
Deep vein thrombosis / pulmonary embolism	0 (0%)	1 (5.6%)	0 (0%)	0 (0%)	0.402	1 (5.9%)	0 (0%)	1.000
Surgical complication	0 (0%)	2 (11.1%)	6 (16.7%)	3 (23.1%)	0.705	6 (35.3%)	5 (9.4%)	**0.019**
Wound infection	0 (0%)	1 (5.6%)	3 (8.3%)	2 (15.4%)	0.738	3 (17.6%)	3 (5.7%)	0.149
Implant failure	0 (0%)	1 (5.6%)	2 (5.6%)	1 (7.7%)	0.964	3 (17.6%)	1 (1.9%)	**0.042**
Reoperation	0 (0%)	1 (5.6%)	3 (8.3%)	0 (0%)	0.699	2 (11.8%)	2 (3.8%)	0.246
Neurological deficit	0 (0%)	1 (5.6%)	0 (0%)	1 (7.7%)	0.438	0 (0%)	2 (3.8%)	1.000
Dysphagia	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0.217	0 (0%)	1 (1.9%)	1.000

* ASA = American association of Anesthesiologist, ** CCI = Charlson comorbidity index.

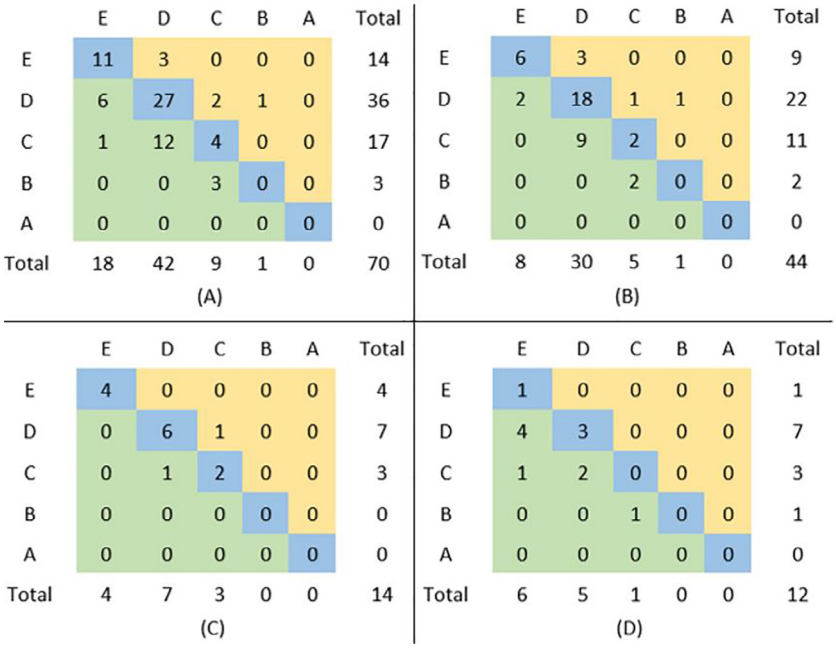

Fig. 4. American Spinal Injury Association (ASIA) grading in (A) all patients, (B) the anterior group, (C) the posterior group, and (D) the combined group.

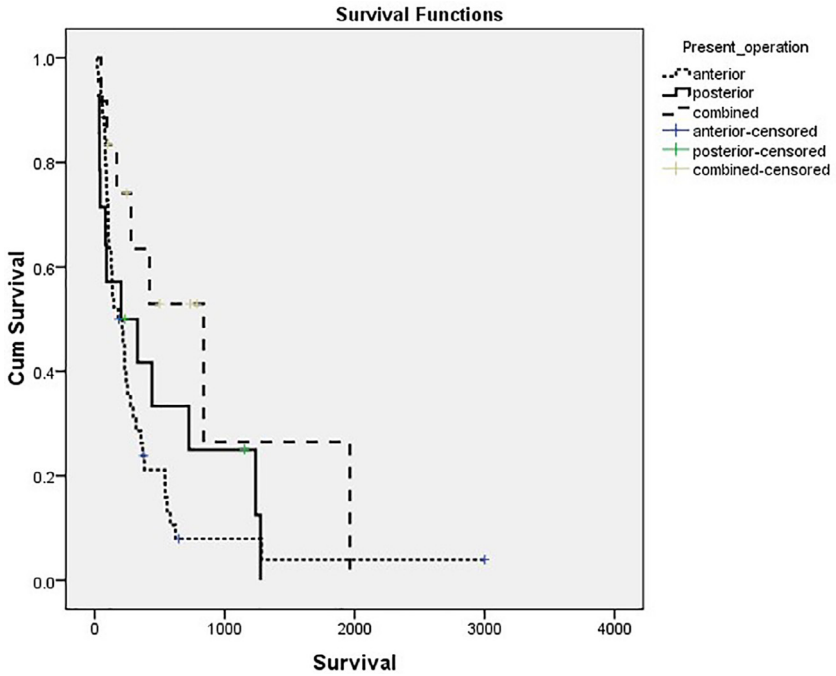

Fig. 5. Kaplan-Meier survival curves compared among groups.

guide decision-making for surgical treatment of subaxial cervical spine metastases.

Previous studies reported low complication rates for the anterior surgical approach [2–4,8,9]. Jonsson *et al.* reported complications, such as dysphagia, reversible vocal cord paralysis, and a postoperative mortality rate of about 2% [3]. Heidecke *et al.* reported complications in 62 patients, including reversible vocal cord paralysis (8%), early instrumentation failure (4.8%), thrombosis and embolism (4.8%), wound infection (3.2%), and neurological deterioration (6.5%) [2]. Oda *et al.* reported results from 32 patients (25 for posterior fixation alone and 7 for combined approach). They found an overall complications rate of 19% [Radiculopathy from screw malposition (3%), deep wound infection (3%), postoperative hematoma (3%), cerebrospinal leakage (3%), and one patient in combined group (14%) had a displacement of an anterior strut and required revision surgery]. In the current study, the overall perioperative complication rate was slightly higher because more types of complications were included in our analysis. Even though there was no difference in preoperative patient characteristics among groups, the perioperative complication rate was highest in the combined approach group (75%) for the subgroup analysis. This may be because the combined approach is the most extensive surgical approach, and it has the longest operative time and the most blood loss.

Patients with spinal metastasis experience three main types of pain. An expanding tumor can cause periosteal 'stretching,' which leads to constant localized pain and compression of nerve roots, leading to radicular pain. Axial pain is associated with pathological vertebral body fractures that cause spinal instability [18]. Surgical treatment can reduce the tumor size and stabilize the vertebral column, which results in pain reduction. Previous studies reported decreased pain as measured by pain scale after surgical treatment. Cho *et al.* analyzed the results of 46 patients treated with surgery for cervical spine metastasis and reported reduced pain in 37 of 44 patients (84.1%). They found that the mean visual analog scale (VAS) for pain decreased from a preoperative 7.86 ± 1.05 points to a postoperative 4.48 ± 2.09 points, representing a decrease of 3.39 ± 2.14 points (p = 0.001). The only factor that influenced pain improvement was neural foramina invasion by preoperative MRI [19]. Rao *et al.* reported on a series of 11 patients who underwent surgical treatment for symptomatic cervical spinal metastasis (5 in anterior approach group, 4 in posterior approach group, and 2 in combined approach group). According to patient postoperative VAS scores, all patients experienced reduced axial neck pain at the 1-month follow-up after surgery [20]. The current study found greater than 75% improvement in the VNS in all approaches, with the most remarkable improvement in pain observed in the combined approach group (87.5%). Due to extensive soft tissue dissection, the combined approach provides more decompression and stability than the two other approaches, which may explain this group's greater decrease in pain. Gallazzi, *et al.* reported a case series that treated thirty cervical spinal metastasis patients using posterior-only laminectomy and posterior stabilization. Their results showed a significant improvement in pain scores (5.5 ± 1.8 to 2.1 ± 1.0, $p < 0.00001$). After an average follow-up of 13.7 ± 14.8 months, fifteen (50%) patients died, 2 (6.9%) had a surgical-site infection that required reoperation, and no mechanical failures were reported [21].

Cho *et al.* reported neurological improvement in 75.7% (28/37) of preoperative neurological deficit patients [19]. In the current study, neurological recovery was highest in the combined approach group (33.3%), resulting from adequate decompression. However, preoperative neurological status could have confounded the high rate of neurological recovery in the combined group. Most patients in the combined group were ASIA class D (75%) compared to 55.6% in the anterior group and 42.9% in the posterior group. The overall neurological recovery rate in our study was relatively low compared to the rate reported by Cho *et al.*; however, this difference between studies may be because our follow-up period was shorter.

Regarding ambulatory status improvement, Denaro *et al.* reported improvement in 5 of 18 (27.8%) nonambulatory patients (Frankel B/C) who later became ambulatory (Frankel D) after surgery [22]. In the current study, 12 of 70 nonambulatory patients (17.1%) became ambulatory, with the highest rate of improvement in the combined group (33.3%). This result may be related to the better neurological recovery rate observed in the combined group. Heidecke *et al.* reported survival after surgery of 58% and 21% at 1 year and 2 years, respectively, after surgery [2]. Cho *et al.* found primary tumor growth rate, preoperative Tomita score, radiotherapy (RT), the timing of RT, and postoperative adjuvant treatment related to longer survival [19]. In the current study, despite the statistically similar preoperative Tomita score among the three approaches, the median survival time was the longest in the combined group.

4.1. Limitations

This study's primary limitation is its retrospective design, which rendered it vulnerable to missing or incomplete data in some cases. Another notable limitation is that our relatively small study population was recruited from only two centers. This could limit the generalizability of our findings to other care settings, and the small sample size may have impeded our ability to statistically reveal all existing differences and associations among the 3 evaluated surgical approaches. Third and last, the relatively short follow-up time could have prevented us from uncovering the advantages or disadvantages of one approach over the other that may emerge over time. A prospective multi-center study with a more extended follow-up period is warranted to confirm this study's findings and identify additional information that may enhance surgical approach-related decision-making in this patient population.

5. Conclusion

The results of this study do not reveal any clear superiority among the three main surgical approaches used to treat subaxial cervical spine metastasis. Patients in the combined approach group had the highest rates of perioperative complications. However, although the differences were not statistically significant, patients in the combined group tended to have better clinical outcomes, including neurological recovery and ambulatory improvement, after follow-up, and they also had the longest survival time.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosures

Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interesting connection with the submitted article

CRediT authorship contribution statement

Panya Luksanapruksa: Conceptualization, Data curation, Writing - original draft, Writing - review & editing. **Borriwat Santipas:** Project administration, Formal analysis, Writing - review & editing. **Panupol Rajinda:** Data curation, Writing - review & editing. **Theera Chueaboonchai:** Formal analysis, Writing - review & editing. **Korpphong Chituaarikul:** Conceptualization, Data curation, Writing - original draft, Writing - review & editing. **Patawut Bovonratwet:** Methodology, Validation. **Sirichai Wilartratsami:** Conceptualization, Supervision, Writing - original draft, Writing - review & editing.

Acknowledgement

The authors gratefully thank Miss Nhathita Panatreswas and Miss Supani Duangkaew for her assistance with statistical analysis, manuscript preparation, and journal submission process.

References

[1] V. Bartanusz, F. Porchet, Current strategies in the management of spinal metastatic disease, Swiss Surg. 9 (2) (2003) 55–62.
[2] V. Heidecke, N.G. Rainov, W. Burkert, Results and outcome of neurosurgical treatment for extradural metastases in the cervical spine, Acta Neurochir. 145 (10) (2003) 873–881.
[3] B. Jonsson, H. Jonsson Jr., G. Karlstrom, L. Sjostrom, Surgery of cervical spine metastases: a retrospective study, Eur. Spine J. 3 (2) (1994) 76–83.
[4] G.M. Quan, J.M. Vital, V. Pointillart, Outcomes of palliative surgery in metastatic disease of the cervical and cervicothoracic spine, J. Neurosurg Spine 14 (5) (2011) 612–618.

[5] S. Rao, K. Badani, T. Schildhauer, M. Borges, Metastatic malignancy of the cervical spine: a nonoperative history, Spine 17 (Supplement) (1992) S407–S412.
[6] V. Denaro, G. Gulino, N. Papapietro, L. Denaro, Treatment of metastases of the cervical spine, Chir. Organi Mov. 83 (1–2) (1998) 127–137.
[7] M.G. Fehlings, K.S. David, L. Vialle, E. Vialle, M. Setzer, F.D. Vrionis, Decision making in the surgical treatment of cervical spine metastases, Spine (Phila Pa 1976) 34 (22 Suppl) (2009) S108–S117.
[8] J. Qian, Y. Tian, J.H. Hu, G.X. Qiu, Surgical treatment for subaxial cervical spine metastatic tumor, Zhonghua Yi Xue Za Zhi 90 (17) (2010) 1200–1203.
[9] I. Omeis, K. Bekelis, A. Gregory, M. McGirt, D. Sciubba, A. Bydon, J.P. Wolinsky, Z. Gokaslan, T. Witham, The use of expandable cages in patients undergoing multilevel corpectomies for metastatic tumors in the cervical spine, Orthopedics 33 (2) (2010) 87–92.
[10] M.E. Charlson, P. Pompei, K.L. Ales, C.R. MacKenzie, A new method of classifying prognostic comorbidity in longitudinal studies: development and validation, J. Chronic Dis. 40 (5) (1987) 373–383.
[11] H.L. Frankel, D.O. Hancock, G. Hyslop, J. Melzak, L.S. Michaelis, G.H. Ungar, J.D. Vernon, J.J. Walsh, The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia, I, Paraplegia 7 (3) (1969) 179–192.
[12] Y. Tokuhashi, H. Matsuzaki, H. Oda, M. Oshima, J. Ryu, A revised scoring system for preoperative evaluation of metastatic spine tumor prognosis, Spine (Phila Pa 1976) 30 (19) (2005) 2186–2191.
[13] K. Tomita, N. Kawahara, T. Kobayashi, A. Yoshida, H. Murakami, T. Akamaru, Surgical strategy for spinal metastases, Spine (Phila Pa 1976) 26 (3) (2001) 298–306.
[14] F. Diez Buron, J.M. Marcos Vidal, P.M. Baticon Escudero, A. Montes Armenteros, J.C. Bermejo Lopez, M. Merino Garcia, Agreement between verbal numerical scale and visual analog scale assessments in monitoring acute postoperative pain, Rev. Esp. Anestesiol. Reanim. 58 (5) (2011) 279–282.
[15] C. Mazel, L. Balabaud, S. Bennis, S. Hansen, Cervical and thoracic spine tumor management: surgical indications, techniques, and outcomes, Orthop. Clin. North Am. 40 (1) (2009) 75–92.
[16] K.W. Hammerberg, Surgical treatment of metastatic spine disease, Spine (Phila Pa 1976) 17 (10) (1992) 1148–1153.
[17] H. Katagiri, M. Takahashi, J. Inagaki, H. Kobayashi, H. Sugiura, S. Yamamura, H. Iwata, Clinical results of nonsurgical treatment for spinal metastases, Int. J. Radiat. Oncol. Biol. Phys. 42 (5) (1998) 1127–1132.
[18] R.H. Kassamali, A. Ganeshan, E.T. Hoey, P.M. Crowe, H. Douis, J. Henderson, Pain management in spinal metastases: the role of percutaneous vertebral augmentation, Ann. Oncol. 22 (4) (2011) 782–786.
[19] W. Cho, U.-K. Chang, Neurological and survival outcomes after surgical management of subaxial cervical spine metastases, Spine (Phila Pa 1976) 37 (16) (2012) E969–E977.
[20] J. Rao, R. Tiruchelvarayan, L. Lee, Palliative surgery for cervical spine metastasis, Singapore Med. J. 55 (11) (2014) 569–573.
[21] E. Gallazzi, L. Cannavo, G.G. Perrucchini, I. Morelli, A.D. Luzzati, C. Zoccali, G. Scotto, Is the posterior-only approach sufficient for treating cervical spine metastases?, The Evidence from a Case Series, World Neurosurg 122 (2019) e783–e789
[22] V. Denaro, A. Di Martino, R. Papalia, L. Denaro, Patients with cervical metastasis and neoplastic pachymeningitis are less likely to improve neurologically after surgery, Clin. Orthop. Relat. Res. 469 (3) (2011) 708–714.