World Journal of Surgical Oncology

REVIEW

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Efficacy and safety of en-bloc resection versus debulking for spinal tumor: a systematic review and meta-analysis

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Abstract

Background This systematic review and meta-analysis aimed to consolidate the existing evidence regarding the comparison between en-bloc resection surgery and debulking surgery for spinal tumors, including both primary and metastatic tumors.

Materials and methods The databases of PubMed, Embase, Cochrane database, Web of Science, Scopus, Chinese National Knowledge Infrastructure (CNKI), Chongqing VIP Database (VIP), and Wan Fang Database was carried out and included all studies that directly compared en-bloc resection surgery with debulking surgery for spinal tumors in patients through March 2024. The primary outcomes included recurrence rate, postoperative metastasis rate, mortality rate, overall survival (OS), recurrence-free survival (RFS), complication, and so on. The statistical analysis was conducted using Review Manager 5.3.

Results We systematically reviewed 868 articles and included 27 studies involving 1135 patients who underwent either en-bloc resection surgery (37.89%) or debulking surgery (62.11%). Our meta-analysis demonstrated significant advantages of en-bloc resection over debulking surgery. Specifically, the en-bloc resection group had a lower recurrence rate (OR = 0.19, 95%CI: 0.13–0.28, $P < 0.00001$), lower postoperative metastasis rate ($P = 0.002$), and lower mortality rate ($P < 0.00001$). Additionally, en-bloc resection could improve OS and RFS (HR = 0.45, 95%CI: 0.32–0.62, $P < 0.00001$ and HR = 0.37, 95%CI: 0.17–0.80, $P = 0.01$, respectively). However, en-bloc resection required longer operative times and was associated with a higher overall complication rate compared to debulking surgery ($P = 0.0005$ and $P < 0.00001$, respectively).

Conclusion The current evidence indicates that en-bloc surgical resection can effectively control tumor recurrence and mortality, as well as improve RFS and OS for patients with spinal tumors. However, it is crucial not to overlook the potential risks of perioperative complications. Ultimately, these findings should undergo additional validation through multi-center, double-blind, and large-scale randomized controlled trials (RCTs).

Keywords Meta-analysis, En-bloc, Debulking, Spinal tumor

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Introduction

Spinal tumors can be categorized into primary tumors and metastatic tumors. The occurrence and prevalence of metastases, which are documented in 30%-50% of cancer patients, are on the rise, with 10% of cancer patients developing symptomatic spinal metastases [1, 2]. Primary tumors represent less than 5% of spinal column tumors [3, 4]. However, Spinal tumors often present with vertebral collapse, fractures, and bone pain. In severe cases, paralysis can occur, significantly reducing the patient's survival time and causing immense suffering [5]. Currently, available treatment options for spinal tumor are surgery, chemotherapy, radiotherapy, and conservative treatment [6]. Common surgical approaches for spinal tumors include curettage, piecemeal resection, and en-bloc resection, which can improve neurological function and overall survival. Tumor excision and spinal stabilization can help alleviate tumor-related pain [7–9].

In recent decades, debulking surgery (including curettage resection and piecemeal resection) have become the primary surgical techniques for treating spinal tumors. However, a notable drawback of debulking surgery is its elevated risk of local recurrence due to tumor cell contamination and residual tumor tissue [10, 11]. En-bloc resection is commonly employed for primary malignant spinal tumors, aggressive benign tumors, and rare isolated metastatic tumors. The main objective is to completely remove the diseased tissue, reconstruct the integrity and stability of the spinal structure. En-bloc resection is frequently utilized in the treatment of primary malignant spinal tumors, aggressive benign tumors, and rare isolated metastatic tumors. The primary objective is to thoroughly excise the diseased tissue, thereby lowering the local recurrence rate of spinal tumors and enhancing patient survival rates [12]. However, given its intricate anatomical structure and close proximity to major blood vessels, internal organs, the spinal cord, and nerves, the en-bloc resection technique for the spine is complex and challenging, resulting in elevated risks of complications and mortality [13, 14]. Therefore, our objective is to conduct a comprehensive systematic review and meta-analysis of existing literature to evaluate the comparative advantages and risks associated with en-bloc resection surgery in comparison to debulking surgery.

Material and methods

Search strategy

This study was conducted and reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines. The search encompassed various electronic databases up to March 2024, including PubMed (1946 to March 2024), Embase (1947 to March 2024), The Cochrane Database (searched March 2024), Web of Science (1985 to March 2024), Scopus (1946 to March 2024), CNKI (1915 to March 2024), and Wan Fang (1900) Database. The retrieval method adopted the combination of subject words and free words, and English retrieval words and Chinese versions include. The complete search strategy is available in Supplementary Table 1. Furthermore, the references of the included studies were meticulously reviewed to complement the relevant research findings.

Inclusion and exclusion criteria

Inclusion criteria: All citations were independently evaluated by two authors, while the remaining two authors reviewed the articles based on the inclusion and exclusion criteria. Studies were eligible for inclusion if they met the following criteria: 1) P: all patients were diagnosed with spinal tumors, including primary spinal tumors and spinal metastases. 2) I: the interventions included en-bloc resection. 3) C: the control method was debulking surgery, which involved procedures such as curettage resection and piecemeal resection. 4) O: the outcome measure was the availability of sufficient raw data. 5) S: the study design encompassed RCTs and retrospective studies.

Exclusion criteria: The number of studies and reasons for exclusion were as follows: 1) unavailable or incomplete/ inaccurate data that rendered the study unanalyzable; 2) duplicate reports; 3) other surgical interventions or drug use; 4) relevant outcome measures not reported; 5) animal studies, biomechanical studies, case reports, letters, technology notes, reviews, withdrawn trials, and meta-analyses.

Data extraction

According to the inclusion and exclusion criteria, two researchers independently reviewed the full text of potential studies. Discrepancies were resolved by consensus and were reviewed by a third investigator. The data extraction included the basic information of the study sample (such as year of publication, number of participants, age, interventions, control measures, etc.), follow-up time, tumor types, and lesions segment etc. Additionally, we extracted specific data from each selected study, including operation time, intraoperative blood loss, recurrence rate, mortality rate, postoperative metastasis rate, total complication rate, RFS, and OS. In cases where information was missing, we made efforts to contact the primary author via email for clarification or to consider excluding the study.

Risk of bias assessment

The Newcastle–Ottawa Scale (NOS) scores were used to evaluate observational studies [15]. Studies with scores of ≥ 6 were deemed as high-quality articles according to the NOS criteria for observational studies. Bias assessment was carried out independently by two researchers, while quality assessment was conducted by the same two reviewers. Any discrepancies between reviewers were resolved through discussion or, if needed, by involving a third reviewer for assessment.

Statistical analysis

Forest plots of comparative Odds Ratios (OR) and 95% confidence of primary efficacy and safety outcomes were calculated and pooled using the Mantel–Haenszel random effects model in Revman 5.3 software, while continuous outcomes were reported as Mean Differences (MD) with 95% CI. Time-to-event data from each study were summarized using Hazard Ratios (HR) with 95% CI. When HR was not reported by the trials, Tierney's method [16] was followed to extract HR from studies that reported Kaplan–Meier curves. Kaplan–Meier curve was interpreted with the Engauge Digitizer software 4.1. Chi-square test was used to test the heterogeneity of the included research results. If $P \geq 0.1$ and $I^2 \leq 50\%$, it showed that there was no heterogeneity among the research results, and a fixed-effect model was used. There was heterogeneity between studies if $P < 0.1$ or $I^2 > 50\%$, and a random effect model was used. Subgroup analyses were performed according to different tumor types. Sensitivity analyses were conducted to determine the robustness of the results by using the leave-one-out method. Publication bias was evaluated through funnel plot analysis.

Results

Search results

The initial search yielded 868 records, of which 348 duplicates were excluded. Following the review of titles, abstracts, and full-text articles, 27 potentially relevant studies were evaluated. Subsequently, after applying the inclusion criteria, a total of 24 studies [12, 14, 17–38] published in English and 3 studies [39–41] published in Chinese were included. Figure 1 illustrates the selection process, displaying the numbers of included and excluded studies. All titles, abstracts, and full texts underwent dual and independent review by the authors.

Study characteristic

This meta-analysis incorporated 27 studies focusing on the treatment of spinal tumors using TES surgery. There were 1135 patients (430 in the en-bloc resection group and 705 in the debulking group). Among those included studies, 22 studies [14, 17–19, 21, 22, 24–26, 28–38, 40, 41] reported primary spinal tumors, while 5 studies [12, 20, 23, 27, 39] focused on the spinal metastases. The main basic characteristics of the included literature were shown in Table 1.

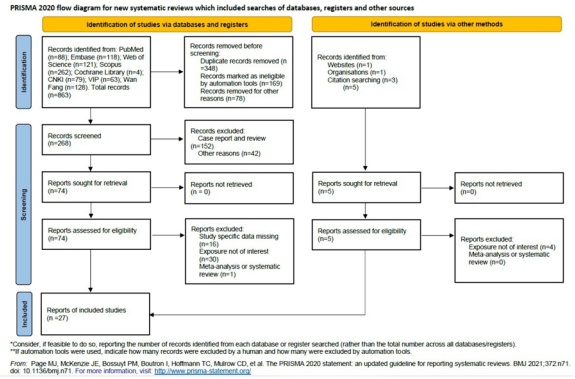

Fig. 1 The Flowchart of the Study

The bias risk assessment results of the included studies

In the retrospective analysis, the NOS scale was employed to assess bias risk. Most of the included studies fulfilled the quality assessment criteria, with 20 studies collectively achieving scores ≥ 6, suggesting a low bias risk. Nonetheless, six articles scored below 6 overall, indicating a high risk of bias. Detailed information can be found in Table 2.

Meta-analysis results

Recurrence rate

A total of 25 studies, including references [12, 17–24, 26–41], provided data on recurrence rate. The analysis revealed no significant heterogeneity ($P = 0.39$, $I^2 = 0\%$), indicating a consistent pattern among the studies. Consequently, a fixed effect model was employed to assess the data. The findings demonstrated that patients who underwent en-bloc resection had a significantly lower recurrence rate compared to those who underwent debulking surgery (OR = 0.19, 95%CI: 0.13–0.28, $P < 0.00001$, as shown in Fig. 2). Furthermore, subgroup analysis indicated that en-bloc resection is particularly effective in reducing recurrence rate for both primary spinal tumors and spinal metastases (respectively; $P < 0.00001$ and $P < 0.00001$).

Mortality rate

A total of 11 studies, referenced as [12, 18, 21–23, 27, 29, 33, 35, 38, 39], provided data on mortality rate. The analysis revealed no significant heterogeneity among

Table 1 Basic characteristics of the included literature

Name	Year	Age(I/C)	Region	Number (I/C)	Intervention group	Controlled group	Tumor types	Lesions segment	Enneking	Follow-up time
Boriani S	2012	30/30	Italy	13/36	En-bloc resection	Debulking (Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar	II-III	NA
Boriani S	2011	NA	Italy	10/7	En-bloc resection	Debulking (Intralesional piecemeal resection)	Primary (Ewing's sarcoma)	NA	IIB-IIIB	2-218 m (65 m)
Cao S	2022	59.46/58.69	China	26/26	Total en-bloc resection	Debulking (Separation surgery with stereotactic radiosurgery)	Isolated SM	Thoracic; Lumbar	NA	6-79 m (31.44 m)
Cao SL	2022	25.8/25.8	China	3/47	En-bloc resection	Debulking (Intralesional piecemeal resection; Intralesional curettage resection)	Primary (OB)	Cervical; Thoracic; Lumbar	II-III	24-160 m (50 m)
Chang SY	2019	45.1/45.1	Korea	17/12	Total en-bloc resection	Debulking (Total/subtotal piecemeal resection)	Primary (Sarcoma)	Cervical; Thoracic; Lumbar; Sacral	NA	12-255 m (36 m)
Demura S	2011	60.7/60.7	Japan	10/14	Total en-bloc resection	Debulking (Piecemeal resection; Curettage resection)	SM (Thyroid carcinoma)	NA	NA	12-180 m (55 m)
Fidler MW	2001	32/32	Netherlands	4/5	En-bloc resection	Debulking (Intralesional curettage resection)	Primary (GCT)	Thoracic	I-II	NA
Gao X	2019	54.5/54.5	China	23/24	En-bloc resection	Debulking (Piecemeal resection)	Primary (Chordoma)	Sacral	NA	12-87 m (41.3 m)
Jia Q	2019	15.9/15.9	China	4/27	Total en-bloc resection	Debulking (Intralesional total piecemeal resection; Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar; Sacral	I-III	12-221 m (85.1 m)
Kato S	2016	59.4/62.5	Japan	20/12	Total en-bloc resection	Debulking (Intralesional subtotal piecemeal resection; Intralesional curettage resection	SM (Thyroid carcinoma)	Cervical; Thoracic; Lumbar	NA	64.8 m
Lee SJ	2023	31.6/31.6	Korea	13/15	En-bloc resection	Debulking (Piecemeal resection)	Primary (GCT)	Cervical; Thoracic; Lumbar	I-III	15–189 m (90.5 m)
Leng A	2024	32.3/33.6	China	15/17	Total en-bloc resection	Debulking (Intralesional total piecemeal resection)	Primary (GCT)	Thoracic; Lumbar;	II-III	(41.9 m)
Li RY	2013	55.08/58	China	25/24	Total en-bloc resection	Debulking (Piecemeal resection; Curettage resection)	SMs	Thoracic; Lumbar	NA	3-17 m (18 m)
Li X	2014	19/19	China	7/20	En-bloc resection	Debulking (Piecemeal excision)	Primary (Ewing's sarcoma)	Cervical; Thoracic; Lumbar; Sacral	NA	36-144 m (80.4 m)

Table 1 (continued)

Name	Year	Age(I/C)	Region	Number (I/C)	Intervention group	Controlled group	Tumor types	Lesions segment	Enneking	Follow-up time
Martin C	2010	31/31	USA	13/8	En-bloc resection	Debulking (Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar; Sacral	NA	0-64 m (31.4 m)
Morin RC	2017	31.9/36.1	Canada	23/54	En-bloc resection	Debulking (Intralesional curettage resection)	Primary (GCT)	NA	NA	12-222 m (57.6 m)
Ou YHO	2017	33.4/33.4	China	9/64	Total en-bloc resection	Debulking (Intralesional piecemeal resection; Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar	NA	1-188 m (75.3 m)
Quraishi NA	2017	21.8/21.8	UK	12/69	En-bloc resection	Debulking (Intralesional piecemeal resection)	Primary (Osteoid osteoma)	Cervical; Thoracic; Lumbar	NA	1-174 m (32.4 m)
Schoenfeld AJ	2012	44/52	USA	8/13	En-bloc resection	Debulking (Intralesional piecemeal resection)	Primary (Chondrosarcoma)	Cervical; Thoracic; Lumbar	IIB	8.5–298.9 m (120.5 m)
Shi L	2013	34/34	China	4/13	En-bloc resection	Debulking (Curettage resection)	Primary (GCT)	Thoracic; Lumbar	NA	18-86 m (48 m)
Tomita K	2006	NA	Japan	64/70	Total en-bloc resection	Debulking (Piecemeal resection)	Primary	NA	II	NA
Tomita K	2001	57.7/57.7	Japan	28/13	En-bloc resection	Debulking (Subtotal piecemeal resection; Curettage resection)	SMs	Cervical; Thoracic; Lumbar	NA	5-84 m (40.8 m)
Wang QZ	2021	32.34/32.34	China	26/36	Total en-bloc resection	Debulking (Intralesional total piecemeal resection; Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar; Sacral	NA	(73.6 m)
Wang T	2020	42.9/37.1	China	17/10	En-bloc resection	Debulking (Intralesional piecemeal resection)	Primary (Recurrent chondrosarcoma)	Thoracic; Lumbar	NA	NA
Yin HB	2015	33/33	China	13/27	Total en-bloc resection	Debulking (Intralesional total piecemeal resection; Intralesional curettage resection)	Primary (GCT)	Cervical; Thoracic; Lumbar; Sacral	I-III	23–167 m (73.9 m)
Yokogawa N	2018	33/36	Japan	13/12	Total en-bloc resection	Debulking (Total piecemeal resection)	Primary (GCT)	Cervical; Thoracic; Lumbar	III	24-216 m (99 m)
Zhong NZ	2017	NA	China	10/30	Total en-bloc resection	Debulking (Total piecemeal excision)	Primary (Chordoma)	Cervical	I-III	NA

GCT Giant cell tumor, *OB* Osteoblastoma, *SM* Spinal metastases, *NA* Not available

Table 2 Results of quality assessment using Newcastle–Ottawa scale for cohort studies

Study selection	Representativeness of the exposed cohort	Selection of the nonexposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	follow-up long enough for outcomes to occur	Adequacy of follow-up of cohorts	Quality score
Boriani S 2011 [17]	1	1	1	1	0	1	0	0	5
Boriani S 2012 [18]	1	1	1	1	0	1	1	1	7
Cao S 2022 [19]	1	1	1	1	1	1	1	1	8
Cao SL 2022 [20]	1	1	0	1	0	0	1	1	5
Chang SY 2019 [21]	1	1	0	1	0	1	1	1	6
Demura S 2011 [23]	1	1	1	0	0	1	1	1	6
Fidler MW 2001 [24]	1	1	1	1	0	0	1	0	5
Gao X 2019 [25]	1	1	0	1	0	0	1	1	5
Jia Q 2019 [26]	1	1	1	1	0	0	1	1	6
Kato S 2016 [27]	1	1	1	1	1	1	1	1	8
Lee SJ 2023 [28]	1	1	1	1	0	1	1	1	7
Leng A 2024 [29]	1	1	1	1	1	1	1	1	8
Li RY 2013 [39]	1	1	1	1	1	1	1	1	8
Li X 2014 [40]	1	1	1	1	0	1	1	1	7
Martin C 2010 [30]	1	1	1	0	0	1	1	0	5
Morin RC 2017 [22]	1	1	1	1	0	1	1	0	6
Ou YHO 2017	1	1	1	1	1	1	1	0	7
Quraishi NA 2017 [32]	1	1	0	1	0	1	1	1	6
Schoenfeld AJ 2012 [33]	1	1	0	1	0	1	1	1	6
Shi L 2013 [41]	1	1	1	1	0	0	1	1	6
Tomita K 2001 [12]	1	1	0	1	0	1	1	1	6
Tomita K 2006 [14]	1	1	0	1	0	1	1	0	5
Wang QZ 2021 [34]	1	1	1	1	1	1	1	1	8
Wang T 2020 [35]	1	1	1	1	1	1	1	1	8
Yin HB 2015 [36]	1	1	1	1	0	1	1	0	6
Yokogawa N 2018 [37]	1	1	1	1	1	1	1	1	8
Zhong NZ 2017 [38]	1	1	0	1	0	1	1	0	5

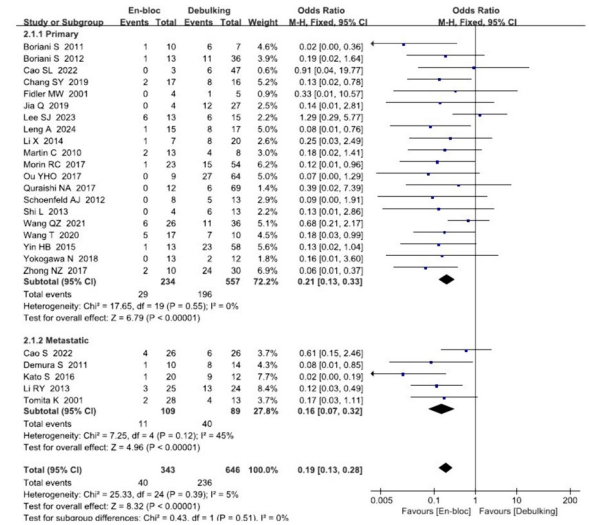

Fig. 2 A forest plot of recurrence rate

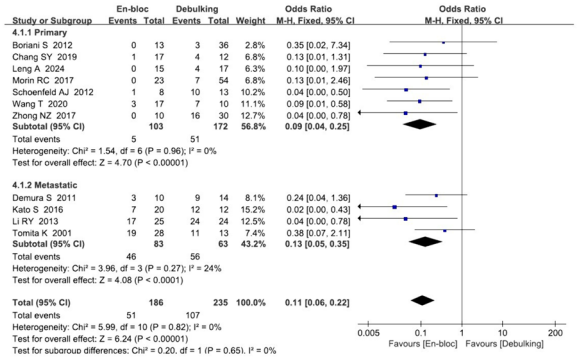

Fig. 3 A forest plot of mortality rate

the studies ($P=0.82$, $I^2=0\%$). Therefore, a fixed effect model was applied to analyze the data. The results indicated that patients who underwent en-bloc resection had a significantly lower mortality rate compared to those who underwent debulking surgery (OR = 0.11, 95%CI: 0.06–0.22, $P<0.00001$, as shown in Fig. 3). Furthermore, our subgroup analysis highlighted that en-bloc resection was associated with reduced mortality rate for both primary spinal tumors and spinal metastases (respectively; $P<0.00001$ and $P<0.00001$).

Postoperative metastasis rate

A total of 7 studies, referenced as [18, 21, 23, 33, 35, 38, 40], provided data on postoperative metastasis rate. The analysis revealed no significant heterogeneity among the studies ($P=0.93$, $I^2=0\%$). Consequently, a fixed effect model was utilized for the analysis. The meta-analysis results indicated that patients who underwent en-bloc resection had a lower postoperative metastasis rate compared to those who underwent debulking surgery (OR = 0.30, 95%CI: 0.14–0.64, $P=0.002$, as shown in Fig. 4). Subgroup analysis further revealed that en-bloc resection was associated with a lower postoperative metastasis rate for primary spinal tumors; however, when considering metastatic tumors specifically, en-bloc resection did not demonstrate superiority over debulking surgery in reducing postoperative metastasis rate (respectively; $P=0.007$ and $P=0.11$).

Recurrence-free survival

A total of 9 studies, referenced as [18, 20, 25, 26, 28, 29, 35, 37, 38], provided data on RFS. The analysis revealed no significant heterogeneity among the studies ($P=0.36$, $I^2=9\%$). Consequently, a fixed effects model was utilized for the analysis. The meta-analysis results indicated that patients who underwent en-bloc resection had a higher RFS compared to those who underwent debulking surgery (HR = 0.37, 95%CI: 0.17–0.80, $P=0.01$, as shown in Fig. 5). Subgroup analysis further revealed that en-bloc resection was associated with a higher RFS for primary spinal tumors; however, when considering metastatic tumors specifically, en-bloc resection did not demonstrate superiority over debulking surgery in reducing RFS (respectively; $P=0.02$ and $P=0.24$).

Overall survival

A total of 10 studies, referenced as [12, 14, 20, 23, 25, 27, 33, 35, 38, 39], provided data on the OS of patients undergoing en-bloc resection for spinal tumors. The analysis revealed no significant heterogeneity among the studies ($P=0.94$, $I^2=0\%$), leading to the utilization of a fixed-effect model for the analysis. The pooled analysis indicated a clear superiority in OS for patients who underwent en-bloc resection (HR = 0.45, 95%CI: 0.32–0.62, $P<0.00001$, as shown in Fig. 6), suggesting that en-bloc resection was more effective than debulking surgery in improving overall survival. Furthermore, a subgroup analysis was conducted which demonstrated that en-bloc resection resulted in higher OS for both primary spinal tumors and spinal metastases (respectively; $P=0.007$ and $P<0.0001$).

1-year RFS and 5-year RFS

A total of 10 studies [18, 20, 23, 25, 26, 28, 29, 35, 37, 38] provided data on 1-year RFS. The analysis indicated that en-bloc resection resulted in significantly higher 1-year RFS compared to debulking surgery (OR = 6.49, 95%CI: 2.85–14.77, $P<0.00001$, refer to supplementary file: Figure S1). Subgroup analysis highlighted that en-bloc resection was particularly effective in improving 1-year RFS for primary spinal tumors; however, it did not show superiority over debulking surgery for spinal metastases.

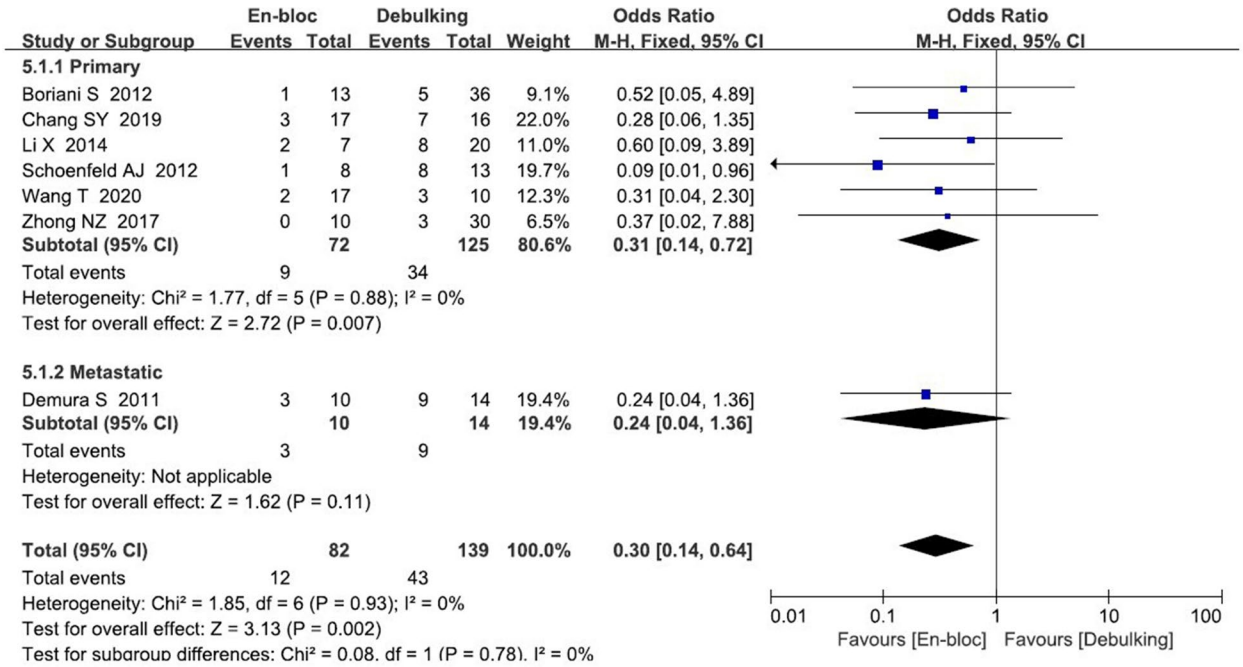

Fig. 4 A forest plot of postoperative metastasis rate

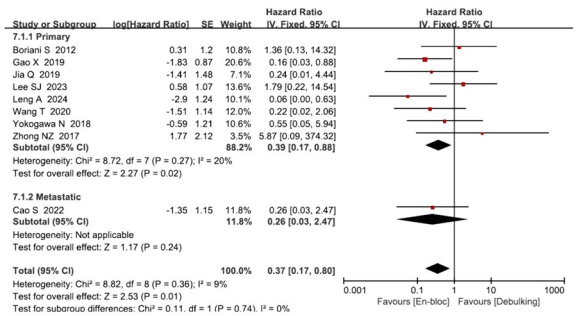

Fig. 5 A forest plot of RFS

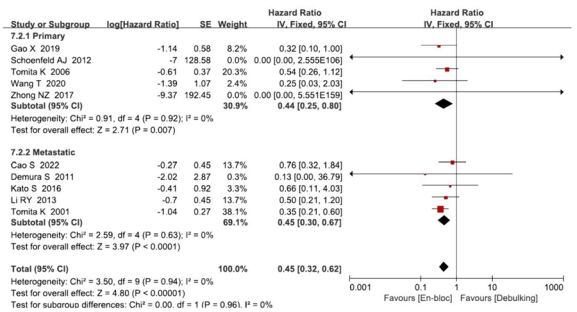

Fig. 6 A forest plot of OS

Similarly, a total of 9 studies [18, 23, 25, 26, 28, 29, 35, 37, 38] reported data on 5-year RFS. The analysis revealed that en-bloc resection led to notably higher 5-year RFS compared to debulking surgery (OR = 8.33, 95%CI: 4.44–15.64, $P < 0.00001$, refer to supplementary file: Figure S2). Subgroup analysis further emphasized that en-bloc resection was linked to improved 5-year RFS for primary spinal tumors; nevertheless, it did not demonstrate superiority over debulking surgery for spinal metastases.

Operative time and intraoperative blood loss

A total of 4 studies [20, 29, 35, 39] reported data on operative time. The analysis revealed that en-bloc resection required a significantly longer operative time compared to debulking surgery (MD = 55.42 min, 95%CI: 22.46–86.39, $P = 0.0005$, refer to supplementary file: Figure S3). However, there was no significant difference in intraoperative blood loss between en-bloc resection and debulking surgery based on the data from these 5 studies [20, 29, 35, 36, 39] (MD = 60.28 ml, 95%CI: -573.86–694.42, $P = 0.85$, refer to supplementary file: Figure S4).

Complication

A total of 11 studies [19, 20, 23, 29, 30, 32, 33, 35, 37–39] provided data on total complication rate included in the study. The analysis showed no significant heterogeneity among the studies ($P = 0.61$, $I^2 = 0\%$), leading to the

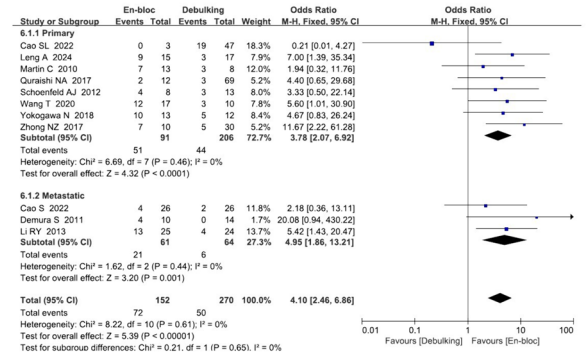

Fig. 7 A forest plot of complication rate

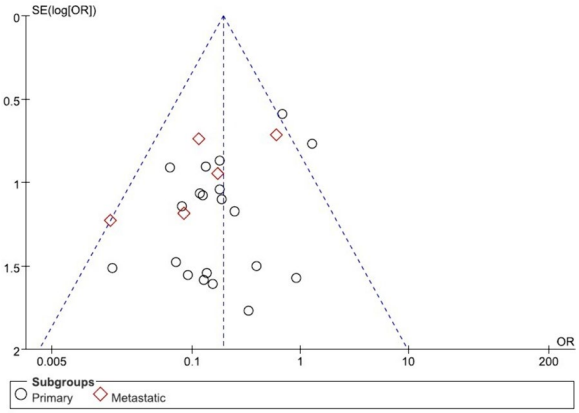

Fig. 8 A funnel plot of complication rate

utilization of a fixed-effect model for the analysis. The results revealed that en-bloc resection was associated with a higher total complication rate compared to debulking surgery (OR = 4.10, 95% CI: 2.46–6.86, $P < 0.00001$, as shown in Fig. 7). Subgroup analysis further confirmed that en-bloc resection resulted in a higher rate of complications for both primary spinal tumors and spinal metastases.

A total of 7 studies [12, 18, 24, 25, 33, 39, 40] reported on postoperative neurological function remission. The findings indicated that en-bloc resection resulted in superior postoperative neurological function remission compared to debulking surgery (OR = 2.49, 95% CI: 1.28–4.85, $P = 0.007$, refer to supplementary file: Figure S5). However, en-bloc resection was associated with a higher rate of pleural tears rate compared to debulking surgery based on data from 3 studies [23, 35, 39] (OR = 18.56, 95% CI: 3.30–104.29, $P = 0.0009$, refer to supplementary file: Figure S6). Additionally, results from a total of 6 studies [20, 33, 35, 37–39] indicated no significant difference in wound infection rate between en-bloc resection and debulking surgery (OR = 0.89, 95% CI: 0.31–2.57, $P = 0.83$, refer to supplementary file: Figure S7).

Publication bias

In the evaluation of recurrence rate studies, the funnel plot displayed asymmetry (as shown in Fig. 8), indicating a potential publication bias. Furthermore, publication bias was identified in the analysis of total complication rate, mortality rate (refer to supplementary file: Figure S8 and Figure S9), postoperative metastasis rate, and RFS (refer to supplementary file: Figure S10 and Figure S11). However, it is noteworthy that the funnel plots for these factors exhibited symmetry, suggesting that there was no evidence of publication bias in these particular analyses.

Discuss

Spinal tumors include primary spinal tumors and secondary malignant tumors that have metastasized to the spine. Primary tumors originate from the spinal cord, cauda equina, nerve roots, and meninges of the spinal cord. Compared to secondary malignant tumors in the spine, primary spinal tumors are relatively rare, accounting for less than 10% of all spinal tumors [42]. The treatment of the vast majority of spinal tumors is considered palliative, aiming to alleviate pain, maintain or improve neurological function, and restore mechanical stability. However, for patients with primary malignant tumor (stage I or II), aggressive benign tumor (stage III), and isolated metastasis, the treatment intent is usually radical resection to achieve control of recurrence and improve survival rates [43, 14].

This meta-analysis has shown that en-bloc resection is associated with a lower recurrence rate compared to debulking surgery. The primary reason is that en-bloc resection ensures complete removal of the tumor, thereby decreasing local recurrence and postoperative tumor metastasis [44]. As the survival rate of patients is influenced by the presence of visceral metastases and effective control of primary lesions, patients with visceral metastases continue to bear a substantial tumor burden, significantly impacting their overall health. Some study indicates that en-bloc resection surgery for spinal tumors greatly improves the prognosis of patients by reducing tumor recurrence and metastasis [45]. Yamazaki et al. [46], it is strongly recommended that intralesional resection may significantly increase the risk of tumor recurrence. Luca Amendola et al [47]. study demonstrated that marginal and intralesional resections are independent predictors of local recurrence rate (HR = 9.45, 95%CI, 1.06–84.47 and HR = 38.62, 95%CI, 4.67–319.21, respectively, compared with wide en-bloc resection) and tumor-related mortality rate (HR = 17.10, 95%CI, 3.80–77.04 for intralesional resection compared with the wide en-bloc resection). Therefore, tumor recurrence and metastases significantly contribute to mortality. Several studies [46, 48] have reported mortality

rates ranging from 0–7% in patients undergoing en-bloc resection for primary spinal tumors. Our subgroup analysis revealed a mortality rate of 4.9% for en-bloc resection in primary spinal tumor cases, while the mortality rate for metastatic spinal tumors was 55.42%. Despite the higher mortality associated with metastatic spinal tumors, en-bloc resection remains superior to debulking surgery. For patients in good physical condition, whether dealing with primary spinal tumors or spinal metastases, aggressive surgical intervention may lead to long-term survival [13, 14].

For certain well-defined and localized spinal tumors, en-bloc resection is commonly favored. This surgical approach, as opposed to conventional debulking surgery, aims to enhance survival rates by minimizing the presence of residual tumor cells and effectively managing tumor recurrence and metastasis. However, while some reports have shown no statistically significant difference in survival rates between en-bloc resection and debulking surgery [49, 50], this study consolidates existing evidence to highlight that en-bloc resection yields superior results in terms of RFS and OS compared to debulking surgery (with respective P values of 0.01 and < 0.00001). This corroborates previous research indicating that en-bloc resection can enhance RFS and OS, with instances where even isolated metastases have been successfully treated [13, 49, 51]. For example, Druschel et al. reported a case of en-bloc resection for a recurrent thoracolumbar lesion with no observed local recurrence or metastasis during an 8-month follow-up period [52]. Similarly, Kawahara et al. documented a two-level total excision of a recurrent chondrosarcoma, resulting in the patient being disease-free for 15 years [53]. En-bloc resection surgery is strategically designed to achieve complete tumor removal externally, thereby controlling local recurrence rates and potentially extending survival prospects [54, 55]. In contrast, debulking surgery, characterized by intracapsular resection, poses a higher risk of tumor contamination and often leads to incomplete tumor removal, consequently increasing the likelihood of local recurrence and diminishing OS [11]. However, a subgroup analysis for different types of metastatic tumors was analyzed. In terms of overall survival, we found that en-bloc resection surgery was no better than debulking surgery for thyroid metastases. Therefore, the author believes that the tumor type of patients should be considered for patients with different metastatic tumors. However, few studies have been included so far, and the types of metastatic tumors were not introduced in three studies.

En-bloc resection is a surgical procedure aimed at fully excising spinal tumors by removing the entire vertebra containing the tumor, along with en bloc laminectomy, en bloc corpectomy, and bilateral pediculotomy [56]. This procedure involves intricate anatomical maneuvers around critical structures such as the spinal cord, nerve roots, and major blood vessels, adding complexity and requiring meticulous care to ensure thorough tumor removal while safeguarding surrounding tissues. Moreover, the spine region harbors a dense network of blood vessels, necessitating meticulous vessel handling during en-bloc surgery to prevent significant bleeding or injury to vital structures, potentially leading to heightened intraoperative blood loss [12, 57]. Consequently, en-bloc resection surgeries typically entail longer operating times and increased intraoperative blood loss. However, debulking surgery aims to remove as much of the tumor mass as feasible, albeit without complete excision. This simpler procedure may result in shorter operation times and potentially lesser intraoperative blood loss [11]. Our study further revealed that en-bloc resection surgery exhibited a significantly longer operation duration ($P = 0.0005$) compared to Debulking surgery. However, when considering intraoperative blood loss,en-bloc resection did not demonstrate superiority over Debulking surgery. It is important to note that the findings from our analysis were based on a limited number of studies [20, 29, 35, 36, 39], underscoring the necessity for additional research to enhance the reliability and validity of these results.

The successful surgical management of spinal tumors hinges on the prevention and prompt treatment of surgical complications. Given the longer operation time and increased intraoperative blood loss associated with en-bloc resection, this approach often presents a higher incidence of surgical complications. While prior studies have highlighted that proper surgical techniques and an understanding of anatomical changes can help mitigate intraoperative complications (such as neurological issues, cerebrospinal fluid leaks, vascular injuries, and visceral organ damage) in spinal tumor surgeries [43], our analysis revealed that en-bloc resection was associated with a higher complication rate (47.37%) compared to Debulking surgery (18.52%, $P < 0.00001$). Consistent with these findings, other studies have reported complication rates around 43% for en-bloc resection [48, 24, 58]. A systematic review by Li Zhehuang et al [59]. delved into the complications of en-bloc surgery for spinal tumors, unveiling an overall complication rate of 58.3% (560 out of 961 cases). The study identified common complications including neurological damage (12.7%), dural tears (10.6%), wound-related issues (7.6%), as well as vascular injuries and bleeding (7.3%). While en-bloc resection is an effective strategy for treating spinal tumors, it is crucial not to overlook the potential risks of perioperative complications inherent to this approach.

However, there are also a few disadvantages and limitations for our study: 1) Some pooled results from

included studies were strongly subjective. 2) The included studies were retrospective studies, which have a great impact on the experimental results. 3) Inclusion and exclusion criteria of some studies are different, especially in tumor type. 4) Heterogeneity among the included studies was unavoidable because of racial differences, age difference, mode of anesthesia, and type of devices. 5) Etiology of the primary tumor, as well as the subtype, should be taken into account at the time of the indication and the final survival result. However, most publications are not usually included this information. Therefore, physicians around the world should be careful to interpret our results in clinical practice.

Conclusion

The current evidence indicates that en-bloc surgical resection can effectively control tumor recurrence and mortality, as well as improve RFS and OS for patients with spinal tumors. However, en-bloc surgical resection of spinal tumors presents certain surgical challenges, with longer operation times and higher rates of complication. Ultimately, these findings should undergo additional validation through multi-center, double-blind, and large-scale randomized controlled trials (RCTs).

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12957-024-03494-3.

Supplementary Material 1: Supplementary Table 1. Index and Keyword Terms Used in the Databases. Figure S1. A forest plot showing the 1-year RFS. Figure S2. A forest plot showing the 5-year RFS. Figure S3. A forest plot showing the operative time. Figure S4. A forest plot showing the intraoperative blood loss. Figure S5. A forest plot showing the postoperative neurological function remission. Figure S6. A forest plot showing the pleural tears rate. Figure S7. A forest plot showing the wound infection rate. Figure S8. A funnel plot showing publication bias of total complication rate. Figure S9. A funnel plot showing publication bias of mortality rate. Figure S10. A funnel plot showing publication bias of postoperative metastasis rate. Figure S11. A funnel plot showing publication bias of RFS.

Acknowledgements
No applicable

Authors' contributions
All authors contributed to the article and approved the submitted version. ZK designed the study, ZK and ZQZ searched the literature, and evaluated and extracted the data from each study. LD and ZG evaluated the bias of studies. ZG and ZK drafting of the manuscript. The authors read and approved the final manuscript.

Funding
Project of Southwest Medical University [grant number 2023QN072].

Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Meta-analyses do not involve human subjects and do not require IRB review (J Grad Med Educ. 2011 March; 3 (1): 5–6.).

Consent for publication
This article does not contain any studies with human or animal subjects performed by the any of the authors.

Competing interests
The authors declare no competing interests.

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Received: 10 May 2024 Accepted: 28 July 2024
Published online: 03 August 2024

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