



Clinical significance of traditional clinical parameters and inflammatory biomarkers for the prognosis of patients with spinal chondrosarcoma: a retrospective study of 150 patients in a single center

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Abstract

Background To investigate the clinical significance of five inflammatory biomarkers and conventional clinical parameters in prognostic prediction of spinal chondrosarcoma.

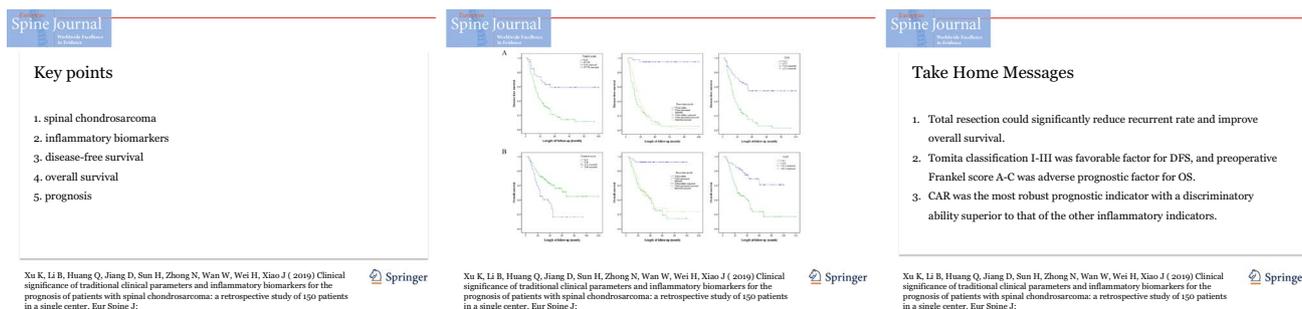
Methods Univariate and multivariate analyses were performed to investigate independent prognostic factors for recurrence and death of patients with spinal chondrosarcoma. Disease-free survival (DFS) and overall survival (OS) were estimated by Kaplan–Meier curve, and differences were analyzed by log-rank test. The optimal cutoff values for NLR, PLR, LMR, and CAR were determined by X-tile program.

Results The optimal cutoff value for NLR, PLR, LMR, AGR, and CAR was 2.7, 200, 3.0, 1.5, and 0.2, respectively. Of the 150 patients included, recurrence was detected in 105 patients, and death occurred in 78 patients. Multivariate analysis indicated that Tomita I–III, total resection, and CAR < 0.2 were significantly associated with longer DFS. Meanwhile, preoperative Frankel score D–E, total resection, and CAR < 0.2 were favorable prognostic factors for OS. Subtype analysis showed that only total resection was an independent prognostic factor for DFS of recurrent spinal chondrosarcoma.

Conclusion Total resection could significantly reduce the recurrence rate of spinal chondrosarcoma and improve OS of chondrosarcoma patients. Tomita classification I–III was a favorable factor for DFS, and preoperative Frankel score A–C was an adverse prognostic factor for OS. CAR was the most robust prognostic indicator with a discriminatory ability as compared with other inflammatory indicators.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



Kehan Xu, Bo Li, and Quan Huang have contributed equally to this work.

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Extended author information available on the last page of the article

Keywords Spinal chondrosarcoma · Inflammatory biomarkers · Disease-free survival · Overall survival · Prognosis

Abbreviations

DFS	Disease-free survival
OS	Overall survival
NLR	Neutrophil-to-lymphocyte ratio
PLR	Platelet-to-lymphocyte ratio
LMR	Lymphocyte-to-monocyte ratio
AGR	Albumin/globulin ratio
CAR	C-reactive protein-to-albumin ratio
HR	Hazard ratio
CI	Confidence interval

Introduction

Chondrosarcoma is the second most common primary malignant bone tumor characterized by production of a cartilaginous matrix without tumor osteoid [1, 2]. It is reported that the annual incidence of chondrosarcoma is 1 in 200,000 while only less than 10% of chondrosarcoma lesions occur in the spine [3, 4]. Chondrosarcoma can be classified as conventional, mesenchymal, and dedifferentiated according to the pathological features, the presence or absence of previous lesions, and histological grades [5]. This tumor can arise *de novo* in the normal bone or undergo malignant transformation from a preexisting cartilage lesion, such as osteochondrosarcoma and enchondrosarcoma [6, 7]. In spite of its rare occurrence in the spine, spinal chondrosarcoma exhibits local invasion, distant metastasis, and high potential of recurrence [8]. Because this neoplasm appears relatively resistant to chemotherapy and radiotherapy, radical gross total resection is recommended for standard treatment [9–11]. Due to its rarity and a lack of large series studies reported in the literature, it is difficult to extract exact information regarding the prognosis of spinal chondrosarcoma. In a previously published retrospective study of 98 cases in our bone tumor center [8], Yin et al. reported that total en bloc spondylectomy could significantly decrease the risk of recurrence and distant metastasis and improve overall survival (OS). Simultaneously, distant metastasis and a high pathological grade were considered adverse prognostic factors for OS.

Previous studies mostly used conventional clinicopathological parameters to identify prognostic factors for spinal chondrosarcoma [12, 13], but increasing evidence indicates that cancer progression and prognosis are associated not only with these conventional clinicopathological parameters but also with inflammatory responses [14, 15]. Cancer-related inflammation in the tumor microenvironment is a meaningful contributor to cancer progression by promoting proliferation, angiogenesis, and metastasis

and reducing response to anti-tumor therapies [16, 17]. Systemic inflammatory biomarkers such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), lymphocyte-to-monocyte ratio (LMR), albumin/globulin ratio (AGR), and C-reactive protein-to-albumin ratio (CAR) have shown potential for guiding the clinical management of cancer patients across a range of malignancies [18–20].

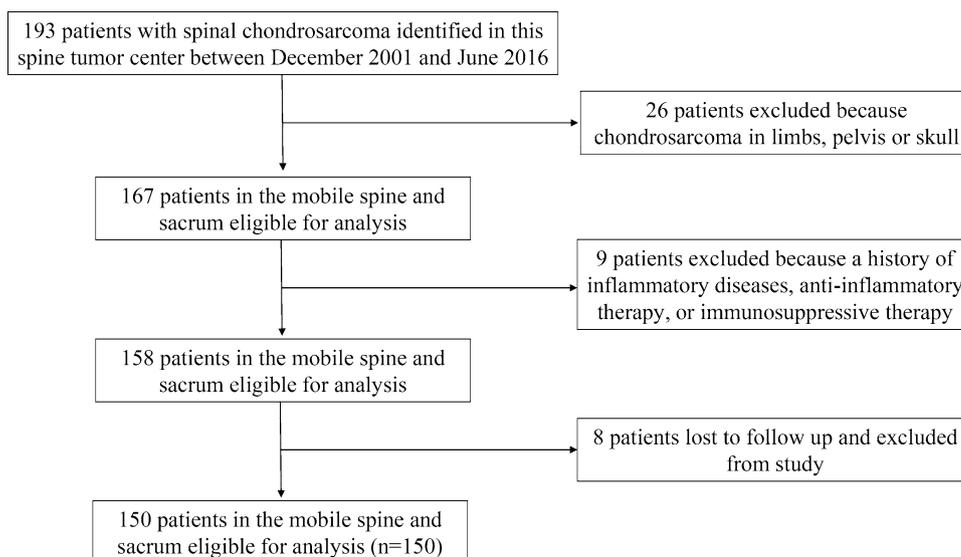
However, there is no published information regarding the prognostic significance of inflammatory biomarkers as prognostic factors for spinal chondrosarcoma. Meanwhile, prognostic significance of these inflammatory indicators was rarely evaluated and reported on primary malignant spine tumors. Therefore, the purpose of our study was to investigate the prognostic significance of five inflammatory biomarkers and conventional clinical parameters.

Materials and methods

Patients

A total of 193 patients with spinal chondrosarcoma who underwent surgical treatment between December 2001 and June 2016 were included in this retrospective study. All patients were diagnosed with spinal chondrosarcoma by biopsy and postoperative pathology. The patient inclusion criteria were as follows: (1) patients who were treated surgically on spinal lesions in our bone tumor center; (2) spinal chondrosarcoma was confirmed by biopsy and postoperative pathology; (3) patients who did not receive any anticancer treatment before surgery; (4) patients who had not used any anti-inflammatory medications or received immunosuppressive therapy including recent steroid exposure, or with chronic inflammatory diseases including autoimmune diseases and infections before operation; (5) surviving patients who were followed up for more than 24 months; and (6) patients with all laboratory data obtained before surgery. The flow diagram is shown in Fig. 1.

This retrospective study was approved by the Ethics Committee of Changzheng Hospital affiliated to the Navy Military Medical University (Shanghai, China). Informed consent was obtained from all living patients and family members of dead patients. Medical records of all patients were reviewed for clinical reports, radiographic images, and inflammatory biomarkers. The preoperative neurological status was evaluated according to the patient Frankel score [21]. The radiological imaging and therapeutic materials of one typical case are shown in Fig. 2. We focused

Fig. 1 Patient flow diagram

on disease-free survival (DFS) and OS. Event times were defined as the interval from the date of surgery to local recurrence, death, or until June 2016 for living patients. All patients were followed up on an outpatient basis at 3, 6, and 12 months after surgical treatment, every 6 months for the second year, and then annually for life.

Statistical method

Statistical analyses were performed with SPSS, version 22.0 (Chicago, Illinois, USA). Quantitative data were described by median (range), and qualitative data were described as counts and percentages. X-tile 3.6.1 software 20 (Yale University, New Haven, CT, USA) was used to determine the optimal cutoff values for NLR, PLR, LMR, and CAR. The optimal cutoff values for NLR, PLR, LMR, and CAR obtained by X-tile analysis of DFS were estimated as cutoff values for OS. Univariate and multivariate analyses were performed to identify the independent prognostic factors for DFS and OS. DFS and OS were calculated by the Kaplan–Meier method. Univariate analysis was performed by log-rank test. Possible prognostic factors <0.1 in the univariate analysis were submitted to multivariate analysis by Cox regression analysis. Factors with P value <0.05 were considered statistically significant.

Results

Patient baseline characteristics and cutoff values of inflammatory biomarkers

The characteristics of the 150 patients are presented in Table 1. The population comprised 87 males and 63

females with a mean age of 42.8 (median 42; range 12–82) years. Of them, 72 patients were admitted for primary lesions, and the remaining 78 patients were diagnosed with recurrent lesions after surgical treatment. Tumor lesions involved the cervical spine in 23 (15.3%) cases, thoracic spine in 78 (52%) cases, lumbar spine in 15 (10%) cases, and sacrum in 34 (22.7%) cases. The mean follow-up period was 36.3 (median 30.5; range 3–120) months. Of the 105 patients with recurrent spinal chondrosarcoma, 78 patients died during the follow-up periods. The mean time from surgery to recurrence was 26.2 (median 13; range 2–68) months, and the mean time from surgery to death was 36.4 (median 19 months; range 3–67) months.

The optimal cutoff value for NLR, PLR, LMR, and CAR was 2.7, 200, 3.0, and 0.2, respectively, as determined by X-tile program (Fig. 3). The cutoff value of AGR was 1.50, according to the standard value reported by the Clinical Laboratory Department in Changzheng Hospital. Thus, patients were stratified into two groups according to cutoff values of inflammatory biomarkers ($NLR < 2.7$ and $NLR \geq 2.7$; $PLR < 200$ and $PLR \geq 200$; $LMR < 3.0$ and $LMR \geq 3.0$; $CAR < 0.2$ and $CAR \geq 0.2$; $AGR < 1.5$ and $AGR \geq 1.5$). Kaplan–Meier survival analysis revealed that $NLR \geq 2.7$, $PLR \geq 200$, $LMR < 3.0$, and $AGR < 1.50$ were significantly associated with decreased DFS and OS ($P < 0.05$).

Univariate and multivariate analyses of prognostic factors for DFS

The overall postoperative DFS rate in patients with spinal chondrosarcoma was 30%, with a mean DFS of 26.2 (range 2–68) months. The results of univariate and multivariate analyses are given in Table 1. Potential prognostic factors

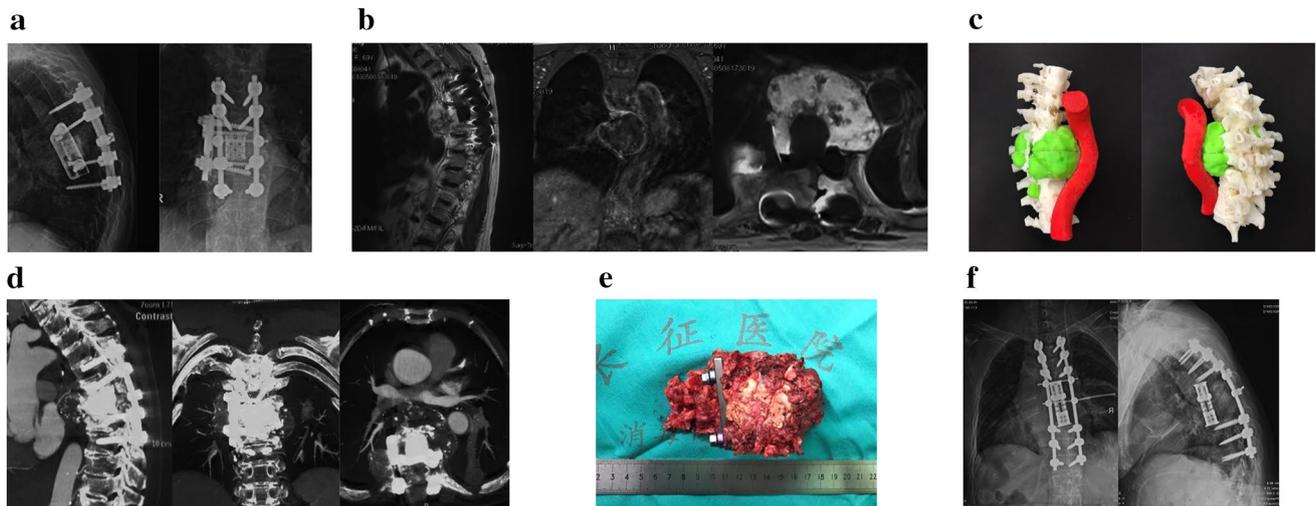


Fig. 2 A typical case underwent the removal of tumor by total en bloc spondylectomy in our center and was diagnosed as recurrent spinal chondrosarcoma. **a** Preoperative X-rays of anteroposterior and lateral spine demonstrated straightening of thoracic physiological curvature, osseous destruction from third thoracic spine to fifth thoracic spine. **b** Preoperative magnetic resonance imaging (MRI) indicated that the lesion showed low-intensity signal on T1-weighted image and high-intensity signal on T2-weighted image. **c** 3D model of thoracic tumor.

d Preoperative CT showed osteolytic destruction from third thoracic vertebrae to fifth thoracic vertebrae and its posterior elements, paravertebral soft tissue mass, and compression of spinal cord. *CT* computed tomography. **e** Gross total resection by en bloc spondylectomy was conducted, and tumor was removed. **f** The postoperative X-rays showed the third, fourth, and fifth thoracic spines were removed and replaced by artificial vertebral body, with solid internal fixation.

extracted by univariate analysis were submitted to Cox proportional hazards analysis. Patients with spinal chondrosarcoma classified as Tomita I–III had significantly longer DFS than those with tumors classified as Tomita IV–VI (HR 1.623; $P = 0.009$). Subtotal spondylectomy was performed in 46 patients, total piecemeal spondylectomy in 65 patients, and total en bloc spondylectomy in 39 patients. The statistical result revealed that the risk of recurrence was significantly decreased in patients receiving total piecemeal spondylectomy (HR 35.105; $P < 0.001$) versus total en bloc spondylectomy (HR 22.599; $P < 0.001$). Patients with $CAR < 0.2$ had longer DFS than those with $CAR \geq 0.2$ (HR 1.942; $P = 0.012$). The Kaplan–Meier curves of DFS for Tomita score, resection mode, and CAR for the 150 patients are presented in Fig. 4a.

Univariate and multivariate analyses of prognostic factors for OS

A total of 78 patients died during the postoperative follow-up period, either directly related to spinal chondrosarcoma or surgical complications. The overall OS rate in our series was 46% (mean 36.4 months; range 3–67 months). Univariate and multivariate analyses of the prognostic factors affecting OS in patients with spinal chondrosarcoma are given in Table 2. All potential prognostic factors were

submitted for multivariate analysis, revealing that preoperative Frankel score D–E, total en bloc spondylectomy, and $CAR < 0.2$ were independent prognostic factors for OS (preoperative Frankel score: HR 0.590, $P = 0.034$; resection mode: HR 6.67, $P = 0.003$; CAR : HR 2.100, $P = 0.013$). In addition, the Kaplan–Meier curves of OS for preoperative Frankel score, resection mode, and CAR are presented in Fig. 4b.

Prognostic factors affecting DFS in patients with recurrent spinal chondrosarcoma

Of the 150 patients in our series, 78 patients underwent surgical treatment in our center after first surgery in our center or other institutions. Recurrence was confirmed by the clinical manifestations, radiological findings, and postoperative pathological results. In recurrent cases, the mean DFS was 26.3 (range 3–100) months. The conventional clinical parameters and inflammatory biomarkers were included to identify independent prognostic factors related to recurrence of recurrent spinal chondrosarcoma. Univariate and multivariate analyses indicated that patients who underwent total resection by either total piecemeal spondylectomy or total en bloc spondylectomy had significantly longer DFS than those who underwent subtotal spondylectomy (total piecemeal: HR 0.202, $P < 0.038$; total en bloc: HR 1.964, $P < 0.019$) (Table 3).

Table 1 Univariate and multivariate analysis of prognostic factors affecting disease-free survival for patients with spinal chondrosarcoma

Variables	Number	Disease-free survival			
		Univariate analysis		Multivariate analysis	
		Median time (months)	<i>P</i> value	HR (95% CI)	<i>P</i> value
Gender					
Male/female	87/63	17 versus 22	0.546		
Age					
< 30 years/≥ 30 years	40/110	19 versus 19	0.352		
Treatment history				1.000	
Primary/recurrent	72/78	24 versus 17	0.018*	1.070 (0.684–1.675)	0.776
Symptom duration					
< 1 year/≥ 1 year	100/50	17 versus 23.5	0.115		
Preoperative Frankel score				1.000	
A–C/D–E	49/101	12 versus 24	0.002*	0.855 (0.539–1.356)	0.506
Tumor location					
Cervical/thoracic/lumbar/sacrum	23/78/15/34	14 versus 17 versus 12 versus 22.5	0.987		
Involved segments					
Mono/multi-segments	86/64	21 versus 17	0.999		
Tomita score				1.000	
I–III/IV–VII	40/110	29.5 versus 17	< 0.001*	1.623 (0.913–2.886)	0.009 [†]
Surgical approach				1.000	
Anterior/posterior/combined	27/106/17	28/19/14	0.032*	1.031 (0.674–1.576)	0.888
Resection mode					
Subtotal spondylectomy				1.000	
Total piecemeal spondylectomy				35.105 (8.164–150.941)	< 0.001 [†]
Total en bloc spondylectomy	46/65/39	17 versus 12 versus 40	< 0.001*	22.599 (5.052–101.097)	< 0.001 [†]
Intraoperative chemotherapy				1.000	
Yes/no	49/101	23 versus 17	0.022*	1.434 (0.900–2.284)	0.130
NLR				1.000	
< 2.7/≥ 2.7	73/77	25 versus 14	< 0.001*	1.240 (0.776–1.981)	0.369
AGR					
< 1.5/≥ 1.5	83/67	15 versus 21	0.162		
PLR				1.000	
< 200/≥ 200	34/116	24.5 versus 17	0.03*	0.925 (0.527–1.624)	0.787
LMR					
< 3.0/≥ 3.0	75/75	17 versus 21	0.34		
CAR				1.000	
< 0.2/≥ 0.2	59/91	35 versus 14	< 0.001*	1.942 (1.159–3.253)	0.012 [†]

HR hazard ratio, CI confidence interval, NLR neutrophil-to-lymphocyte ratio, AGR albumin/globulin ratio, PLR platelet-to-lymphocyte ratio, LMR lymphocyte-to-monocyte ratio, CAR C-reactive protein-to-albumin ratio

**P* value < 0.1; [†]*P* value < 0.05

Discussion

Spinal chondrosarcoma is the second primary malignant bone tumor with high potential of recurrence and distant metastasis [22, 23]. The complex anatomical structures of the spine pose a considerable challenge on the surgical treatment of spinal chondrosarcoma and increase the risk of recurrence [8, 24]. Preventing recurrence and increasing postoperative DFS and OS remain intractable issues

in spine surgery. The aim of this retrospective study was to identify possible prognostic factors for OS and DFS of spinal chondrosarcoma thorough combination of univariate and multivariate analyses with conventional clinical data and inflammatory biomarkers. The results showed that Tomita score, total resection by either total piecemeal spondylectomy or total en bloc spondylectomy, and CAR were significantly associated with DFS. Meanwhile, preoperative Frankel score, total resection, and CAR were independent

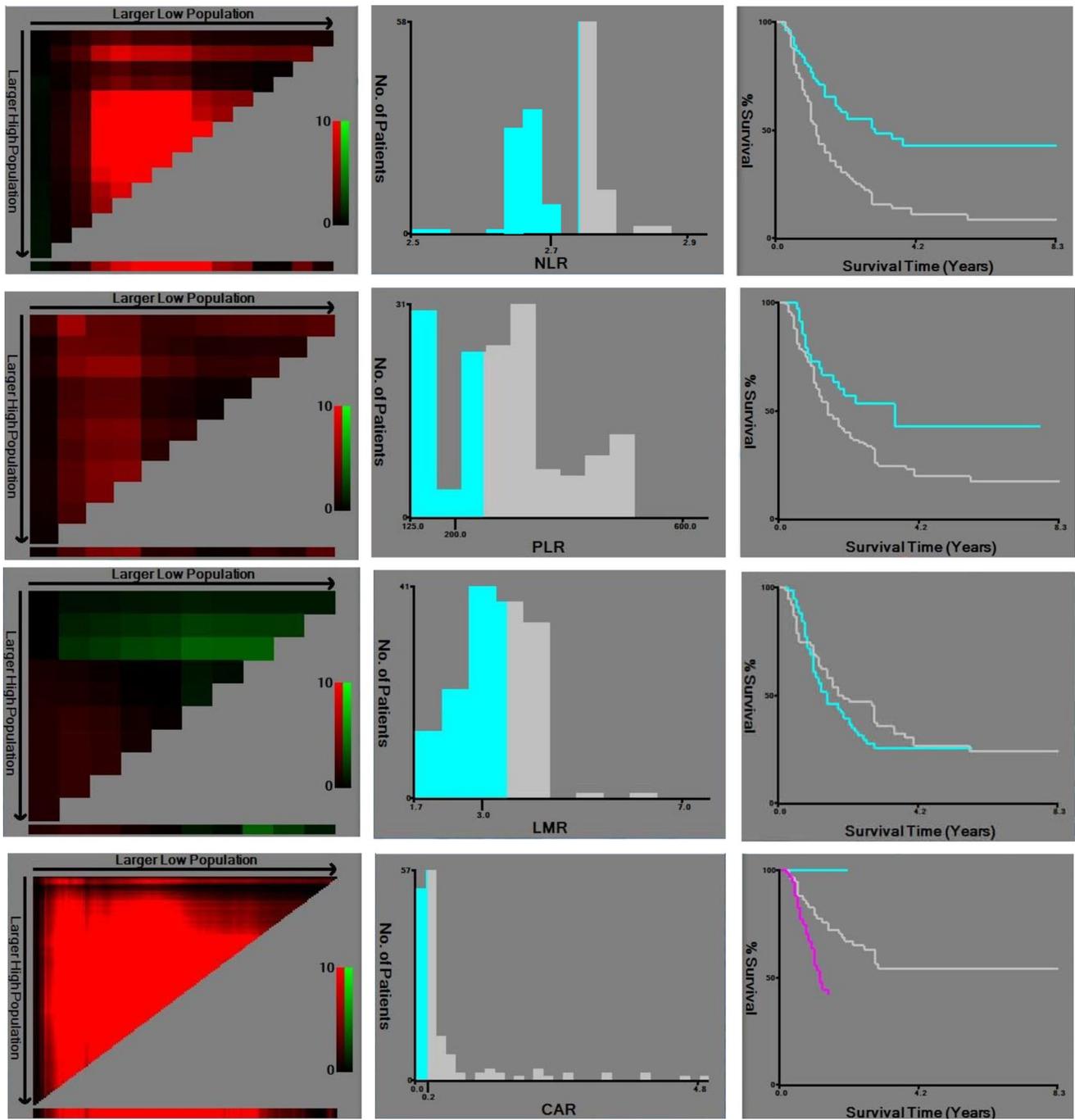


Fig. 3 X-tile analysis of DFS was performed using patients’ date to determine the optimal cutoff values for NLR, PLR, LMR, and CAR. The sample of patients with spinal chondrosarcoma was equally divided into training and validation sets. X-tile plots of training sets are shown in the left panels, with plots of matched validation sets shown in the small inset. The optimal cutoff values highlighted by

the black circles in left panels are shown in histograms of the entire cohort (middle panels), and Kaplan–Meier plots are displayed in right panels. *P* values were determined by using the cutoff values defined in training sets and applying them to validation sets. The optimal cutoff values for NLR, PLR, LMR, and CAR were 2.7, 200, 3.0, and 0.2, respectively

prognostic factors for OS. Subtype analysis indicated that total resection could significantly reduce the risk of recurrence of recurrent spinal chondrosarcoma.

The mean age of the 150 patients in our series was 42.8 years with males predominating. The peak incidence was between 30 and 60 years of age, which is consistent with previous reports [8, 13, 25]. The male-to-female ratio

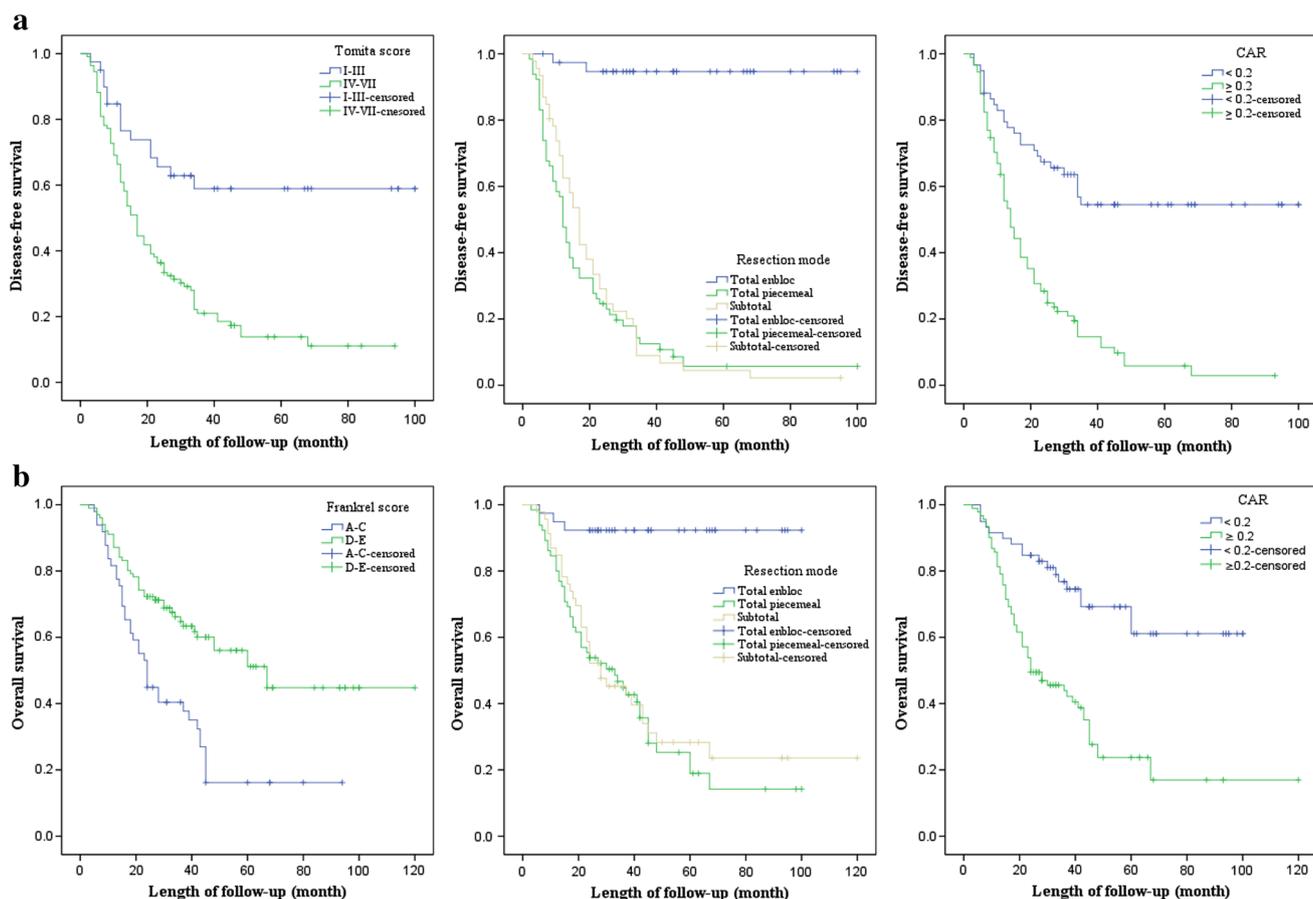


Fig. 4 **a** Kaplan–Meier curves of disease-free survival for Tomita score, resection mode, and CAR. **b** Kaplan–Meier curves of overall survival for preoperative Frankel score, resection mode, and CAR

in our series is 1.4:1 versus 1.8:1 reported by Boriani et al. [26] and 2.1:1 reported by Yin et al. [8]. However, Song et al. [27] reported that the male-to-female ratio was 1.38:1, which is similar to our finding. They also found that patients aged ≥ 60 years were associated with poorer prognosis. In our study, we failed to identify age as a significant prognostic factor for DFS and OS of patients with spinal chondrosarcoma. The possible reason may be that we chose 40 years as the cutoff value based on our clinical experience, while the peak incidence of the disease is usually between 30 and 60 years.

It is now increasingly recognized that the systematic inflammatory response plays an important role in the development and progression of cancers [28, 29]. The prognostic significance of several inflammatory indicators including NLR, PLR, AGR, LMR, and CAR has been reported to be associated with various cancer types. All these inflammatory biomarkers have been identified in Ewing's sarcoma, bone giant cell tumor, and osteosarcoma [30–32]. However, there is no published information regarding the prognostic significance of inflammatory

indicators in spinal chondrosarcoma. The result of multivariate analysis in the present study showed that CAR could serve as a novel and promising inflammatory prognostic indicator in chondrosarcoma and has a discriminatory ability even superior to that of other inflammatory indicators including NLR, PLR, AGR, and LMR. CAR is the C-reactive protein-to-albumin ratio based on two protein components. CRP level, which is often associated with a decreased serum Alb concentration, is used to indicate an impaired nutritional status and increased mortality [33]. Neutrophils interact with tumor cells via secreting cytokines, promoting tumor development [34]. Lymphocytes play a crucial role in mediating the immunologic destruction of cancer cells [35]. Platelets were also reported to serve as chemoattractants, contributing to the migration of tumor cells [36]. These inflammatory theoretic backgrounds lead to the emerging of several inflammation-based prognostic indicators in cancer patients. Multivariate analysis revealed that CAR was an independent prognostic factor for spinal chondrosarcoma. In addition, CAR was also reported to have favorable prognostic

Table 2 Univariate and multivariate analysis of prognostic factors affecting overall survival for patients with spinal chondrosarcoma

Variables	Number	Overall survival			
		Univariate analysis		Multivariate analysis	
		Median time (months)	<i>P</i> value	HR (95% CI)	<i>P</i> value
Gender					
Male/female	87/63	32 versus 32	0.402		
Age					
< 30 years/≥ 30 years	40/110	29 versus 31	0.747		
Treatment history				1.000	
Primary/recurrent	72/78	33.5 versus 27.5	0.023*	1.265 (0.759–2.108)	0.368
Symptom duration					
< 1 year/≥ 1 year	100/50	29 versus 32.5	0.254		
Preoperative Frankel score				1.000	
A–C/D–E	49/101	24 versus 33	< 0.001*	0.590 (0.363–0.96)	0.034 [†]
Tumor location					
Cervical/thoracic/lumbar/sacrum	23/78/15/34	26 versus 30.5 versus 28 versus 41.5	0.539		
Involved segments					
Mono/multi-segments	86/64	31 versus 28	0.704		
Tomita score				1.000	
I–III/IV–VII	40/110	33.5 versus 28	0.068*	0.881 (0.494–1.570)	0.667
Surgical approach					
Anterior/posterior/combined	27/106/17	28/33/21	0.153		
Resection mode					
Subtotal spondylectomy				1.000	
Total spondylectomy				10.682 (3.151–36.214)	< 0.001 [†]
Total en bloc spondylectomy	46/65/39	27.5 versus 26 versus 40	< 0.001*	6.67 (1.885–23.604)	0.003 [†]
Intraoperative chemotherapy				1.000	
Yes/no	49/101	31 versus 30	0.065*	1.244 (0.729–2.120)	0.423
NLR				1.000	
< 2.7/≥ 2.7	73/77	33 versus 27	0.002*	1.175 (0.686–2.014)	0.557
AGR					
< 1.5/≥ 1.5	83/67	28 versus 33	0.532		
PLR					
< 200/≥ 200	34/116	27 versus 32	0.699		
LMR					
< 3.0/≥ 3.0	75/75	28 versus 33	0.424		
CAR				1.000	
< 0.2/≥ 0.2	59/91	45 versus 24	< 0.001*	2.100 (1.170–3.770)	0.013 [†]

HR hazard ratio, CI confidence interval, NLR neutrophil-to-lymphocyte ratio, AGR albumin/globulin ratio, PLR platelet-to-lymphocyte ratio, LMR lymphocyte-to-monocyte ratio, CAR C-reactive protein-to-albumin ratio

**P* value < 0.1; [†]*P* value < 0.05

significance for Ewing's sarcoma, which was superior to NLR, PLR, and LMR for prognostic prediction [30, 37]. The results of our study imply that inflammatory-related protein parameters may be more reliable than the cellular parameters in predicting prognosis.

Surgery is the standard treatment strategy for spinal chondrosarcoma, with the aim to preserve or even improve functionality, relieve pain, control local recurrence, and prolong patient survival. Spinal chondrosarcomas always

exhibit invasive growth with irregular bony destruction, ill-defined margins, periosteal reaction, and soft tissue masses with involvement of multiple vertebral levels. Due to the anatomical complexity, surgical management of spinal chondrosarcoma is challenging and total en bloc spondylectomy is difficult to perform. The result of our study suggests that total resection by either total piecemeal spondylectomy or total en bloc spondylectomy can significantly reduce the recurrence rate and improve OS, which is

Table 3 Univariate and multivariate analysis of prognostic factors affecting disease-free survival for patients with recurrent spinal chondrosarcoma

Variables	Number	Disease-free survival			
		Univariate analysis		Multivariate analysis	
		Median time (months)	<i>P</i> value	HR (95% CI)	<i>P</i> value
Gender					
Male/female	44/34	16 versus 16	0.706		
Age					
< 30 years/≥ 30 years	18/56	14 versus 19	0.943		
Symptom duration					
< 1 year/≥ 1 year	61/17	15 versus 17	0.743		
Preoperative Frankel score					
A–C/D–E	32/46	12 versus 21.5	0.004*	1.000 0.693 (0.0.379–1.266)	0.233
Tumor location					
Cervical/thoracic/lumbar/sacrum	12/48/10/8	10 versus 18 versus 14.5 versus 17.5	0.736		
Involved segments					
Mono/multi-segments	48/26	19 versus 16	0.123		
Tomita score					
I–III/IV–VII	21/57	27 versus 14	0.001*	1.000 1.663 (0.804–3.440)	0.170
Surgical approach					
Anterior/posterior/combined	8/59/11	24/17/10	0.088*	1.000 1.369 (0.799–2.346)	0.253
Resection mode					
Subtotal spondylectomy					
Total piecemeal spondylectomy				1.000 0.202 (0.045–0.917)	0.038 [†]
Total en bloc spondylectomy	32/32/14	17 versus 12 versus 33	0.001*	1.964 (1.116–3.459)	0.019 [†]
Intraoperative chemotherapy					
Yes/no	19/61	12 versus 17	0.761		
NLR					
< 2.7/≥ 2.7	21/57	22 versus 11	0.056*	1.000 1.268 (0.646–2.489)	0.491
AGR					
< 1.5/≥ 1.5	47/27	14 versus 19	0.544		
PLR					
< 200/≥ 200	20/58	17 versus 16	0.447		
LMR					
< 3.0/≥ 3.0	33/45	15 versus 17	0.619		
CAR					
< 0.2/≥ 0.2	28/50	17 versus 12.5	< 0.001*	1.000 1.819 (0.906–3.652)	0.092

HR hazard ratio, CI confidence interval, NLR neutrophil-to-lymphocyte ratio, AGR albumin/globulin ratio, PLR platelet-to-lymphocyte ratio, LMR lymphocyte-to-monocyte ratio, CAR C-reactive protein-to-albumin ratio

**P* value < 0.1; [†]*P* value < 0.05

similar to the result reported by Yin et al. [8], Schoenfeld et al. [25] and Boriani et al. [26]. Recurrent spinal chondrosarcomas can exacerbate the neurological defects and increase the difficulty of surgery, which is a big challenge in spine surgery. However, the result of our subtype analysis suggested that total resection was the only prognostic factor for DFS and OS in recurrent patients. Thus, the first surgical opportunity is precious for patients with spinal chondrosarcoma. Multidisciplinary treatment including

surgery, chemotherapy, and radiotherapy has been used to achieve local control of spinal chondrosarcoma, aiming to improve the prognosis [8, 38, 39]. However, there are controversies over the effectiveness of neoadjuvant therapy and therefore further investigation is required. This study mainly evaluated prognostic factors of inflammatory indicators, without considering the prognostic significance of neoadjuvant therapies.

Tomita classification was developed to evaluate the involvement of spinal tumors and help design individualized treatment strategies [40]. It was found in our study that patients with lesions classified as Tomita I–III seemed to have obviously longer DFS than those classified as Tomita IV–VII. Multiple studies have demonstrated that the preoperative condition assessed by Frankel score is an independent prognostic factor for survival of bone tumor patients [41, 42]. It was found in our study that patients with preoperative Frankel score D–E had significantly longer OS than those with preoperative Frankel score A–C.

According to the histological outcome, chondrosarcoma is classified as conventional, secondary, dedifferentiated, clear cell, periosteal, and mesenchymal types [43]. Srimanth et al. [44] reported that the dedifferentiated type had the worst outcome, while the clear cell type had the best outcome. But as the main purpose of the present study was to explore the prognostic significance of inflammatory indicators and the resection mode, histological classification was not our main consideration.

To the best of our knowledge, this is the largest study series on spinal chondrosarcoma. Nevertheless, some limitations also exist. First, it is a retrospective study with intrinsic limitations. In addition, we only focused on patients undergoing surgical treatment. Finally, the follow-up duration was not long enough.

Conclusion

Total spondylectomy, either by total piecemeal spondylectomy or total en bloc spondylectomy, could significantly reduce the recurrence rate and improve OS of patients with spinal chondrosarcoma. Tomita classification I–III is a favorable factor for DFS, and preoperative Frankel score A–C is an adverse prognostic factor for OS. Simultaneously, our finding demonstrated that CAR is a novel and promising inflammation-based prognostic indicator in patients with spinal chondrosarcoma.

Authors' contributions JX offered the research direction regarding the prognostic role of preoperative D-dimer and inflammatory biomarkers in spinal ESFTs. WF and WW designed the study and gave us several meaningful suggestions. JL, HS, and NZ reviewed and collected the medical records. QH and BL analyzed and interpreted the patient data. KX was a contributor in writing the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest No conflict of interest exists in the submission of this manuscript, and manuscript is approved by all authors for publication. I would like to declare on behalf of my co-authors that the work

described was original research that has not been published previously, and not under consideration for publication elsewhere, in whole or in part.

Ethical approval All procedures involving human participants performed in studies were approved by Changzheng Hospital Ethics Committee, and informed consents were obtained from all patients or their legal guardians.

Consent for publication Patients or their legal guardians know and approve the publication.

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