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Efficacy of the da Vinci robot versus thoracoscopic surgery for patients with mediastinal tumors of different body mass index: a multicenter propensity score-matched study

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Abstract

Background The purpose of the present study was to evaluate the efficacy and safety of da Vinci robot-assisted thoracoscopic surgery (RATS) versus video-assisted thoracoscopic surgery (VATS) for the treatment of patients with mediastinal tumors of different body mass indices (BMI).

Methods A retrospective cohort study was used to collect 260 patients with mediastinal tumors admitted to three medical centers in China from December 2020 to March 2024. These patients underwent mediastinal tumor resection by RATS ($n = 125$) or VATS ($n = 135$). Propensity score matching (PSM) analysis was performed for the both groups, and further, the patients were divided into the N-BMI group (18.5 kg/m^2 ≤ BMI < 25 kg/m^2) and the H-BMI group (BMI ≥ 25 kg/m^2) based on their BMI to compare patients' surgery-related information.

Results The RATS group had more advantages than the VATS group in terms of intraoperative blood loss, total postoperative drainage, postoperative drainage time, and postoperative hospital stay. As for hospitalization costs, the VATS group was more advantageous. In the H-BMI group, subgroup analysis showed a statistically significant difference in shorter operative time and lower incidence of postoperative complications in the RATS group.

Conclusion RATS has technical and short-term efficacy advantages in comparison with VATS, although it has the drawback of high costs associated with the treatment of mediastinal tumors. In the patients with mediastinal tumors of H-BMI, RATS can achieve better short-term outcomes and safety, especially in the reduction of the incidence of postoperative complications.

Keywords Mediastinal tumors, Robot-assisted thoracic surgery, Video-assisted thoracoscopic surgery, Body mass index, Multicenter retrospective study

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Introduction

Mediastinal tumors are ubiquitous in thoracic surgery, including thymomas, neurogenic tumors, teratomas and benign cysts. As usual, surgical treatment is generally preferred in clinical practice [1]. With the increasing development of the concept of accelerated rehabilitation surgery, minimally invasive surgery is becoming a primary choice for most surgeons and patients in order to minimize postoperative pain [2]. Several studies have demonstrated that video-assisted thoracoscopic surgery (VATS) has significant advantages over conventional surgery, such as shorter postoperative hospital stay, fewer complications and lesser pain, and has now become a major surgical modality in thoracic surgery [2, 3]. However, VATS has some inherent shortcomings, such as a two-dimensional field of view, inadequate handling in a confined space (especially for upper mediastinal and parietal pleural lesions) and more difficult operations (suturing and knotting) [4]. Given the above-mentioned shortcomings of thoracoscopy, robotic-assisted surgical systems emerged and have been widely employed in thoracic surgery in the recent decades.

With the improvement of living standards, the proportion of obesity and overweight population of China is increasing, and it now becomes the country with the largest obesity and overweight population in the world [5]. In clinical practice, we found that the patients with mediastinal tumors having high body mass index (H-BMI) is raising. Several previous studies have analyzed the perioperative outcomes of robot-assisted thoracoscopic surgery (RATS) versus VATS for lung cancer patients with different BMI [6–8]. However, the related study on the comparison of RATS versus VATS for patients with mediastinal tumors of different BMI is scarce until now. Therefore, in the present study, we finished the comparison of the short-term efficacy and safety of RATS versus VATS mediastinal tumor resection using propensity score matching (PSM) analysis and the subgroup analysis based on BMI on the basis of the retrospective analysis of the data from three medical centers in China.

Materials and methods

Clinical information

This study retrospectively analyzed 260 patients with mediastinal tumors admitted to three medical centers in China from December 2020 to March 2024. Related surgical procedures were performed according to the patients' financial conditions and wishes. Among them, there were 145 cases in Gansu Provincial Hospital (72 cases of RATS and 73 cases of VATS), 61 cases in the Second Hospital of Lanzhou University (29 cases of RATS and 32 cases of VATS) and 54 cases in Hebei Provincial Chest Hospital (24 cases of RATS and 30 cases of VATS).

Inclusion criteria: (i) preoperative CT or MRI should be performed to determine that the lesions are non-invasive, with clear borders, without obvious invasion of surrounding tissues or organs, without encircling large blood vessels or with distant metastases for the patients with mediastinal tumors treated by minimally invasive surgery [9]; (ii) preoperative cardiopulmonary function is basically normal without serious comorbidities, history of other thoracic surgery, history of tuberculosis, abscess chest and other related diseases that may cause extensive adhesions in the chest cavity [9]. Exclusion criteria: (i) simultaneous surgery for mediastinal tumors combined with lung disease [9]; (ii) patients who have undergone preoperative radiotherapy and chemotherapy [9]. This study has been reviewed by the Ethics Committee of Gansu Provincial Hospital, approval number: 2024−509. All patients signed the informed consent form for surgery before surgery.

Surgical methods

Three-hole, three-arm robotic surgery was used for all of the patients. Position: patients with anterior mediastinal tumors are placed in a 30-degree semi-supine position, exposing the ipsilateral axilla. On the other hand, patients with middle and posterior mediastinal tumors are placed in a lateral position with a slight forward tilt to reduce the interference of lung tissue [10]. Hole arrangement: for anterior mediastinal tumor, if the tumor is right-sided, the right thoracic approach is adopted, with the right anterior external body position, and the hole position is set as "5-3-5" method ("5" is the camera hole, at the 5th intercostal space in the anterior axillary line of the affected side; "3" is the operation hole of the ①arm, at the 3rd intercostal space in the anterior axillary line; "5" is the operation hole of the ② arm, at the 5th intercostal space in the mid-clavicular line) [10]. If the tumor is left-sided, the left thoracic approach is adopted, with the left anterior external body position, and the hole position is set as "5-3-5". The posterior mediastinal tumor orifice is set as "6-4-7" method ("6" is the camera hole, which is between the 6th ribs in the posterior axillary line of the affected side; "4" is the operation hole of the ② arm, which is between the 4th ribs in the anterior axillary line; "7" is the operation hole of the ① arm, which is between the 4th ribs in the posterior axillary line) [4]. Taking the posterior mediastinal tumor as an example, the mediastinal pleura was dissected during the operation, and the mediastinal mass was completely removed with tight hemostasis, as displayed in Fig. 1. The specimen was removed from the operation hole of arm ①.

A dual-port VATS is used for anterior mediastinal tumors: a 3-cm incision is made at the 2nd or 3rd intercostal space in the anterior axillary line as an auxiliary operating hole, and the 5th intercostal space in the

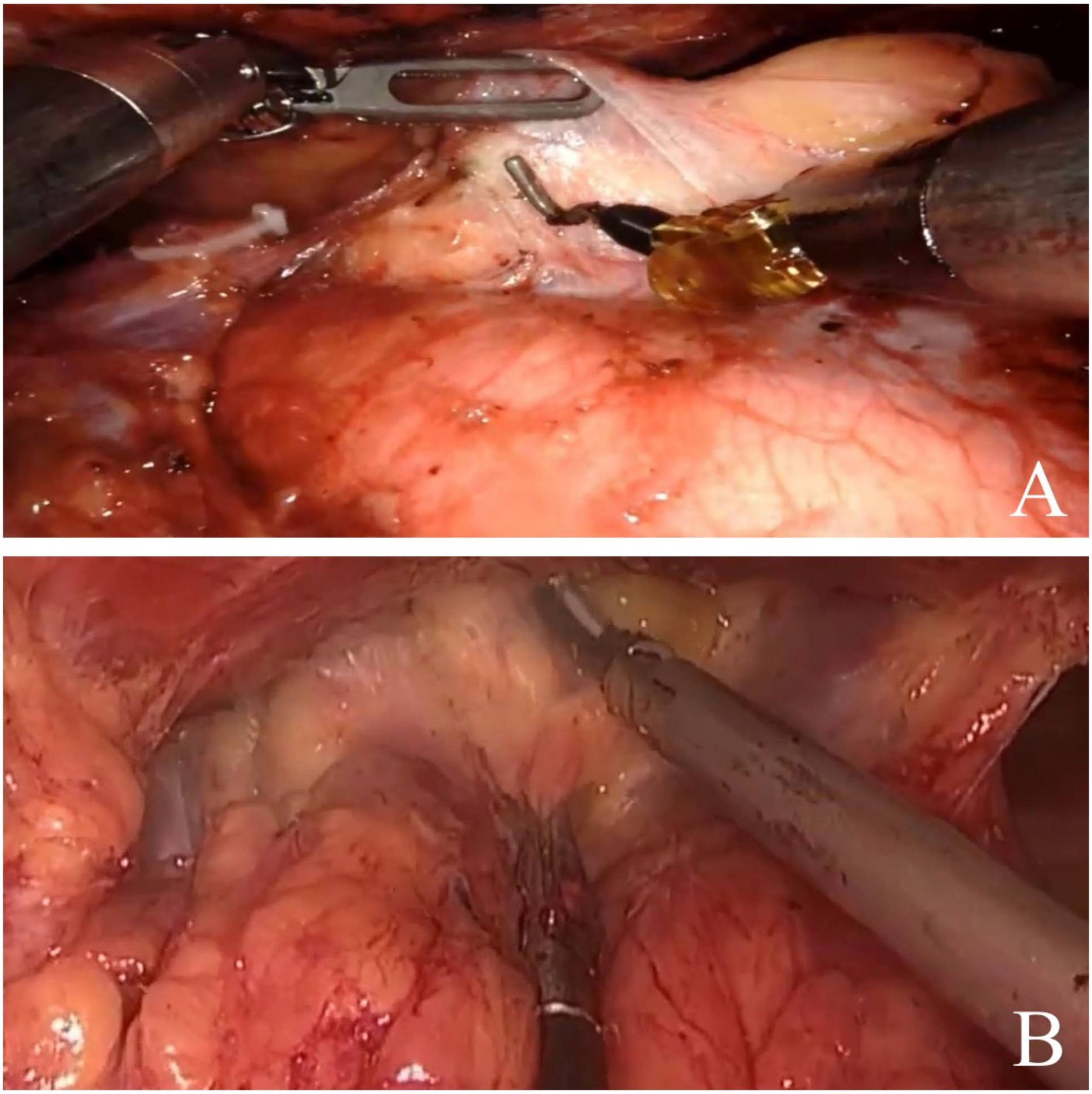

Fig. 1 **(A)**Intraoperative figure under RATS; **(B)** Intraoperative figure under VATS

mid-axillary line as a camera hole. For mid-posterior mediastinal tumors, a single-port VATS is performed with the port set at the 5th intercostal space between the mid-axillary and posterior axillary lines.

Observed indicators

Baseline information includes the aspects of sex, age, BMI, smoking history, underlying disease, tumor size, tumor location and pathological type. Perioperative indicators contains operative time, intraoperative blood loss, total postoperative drainage volume, postoperative chest drainage time, postoperative hospital stay, postoperative complications and hospitalization costs [9].

Statistical analysis

A 1:1 PSM analysis was performed using SPSS 27.0 software (SPSS Inc., Chicago, IL, USA), and the caliper value was set as 0.02 [11]. Matching factors involve sex, age, BMI, smoking history, underlying disease, tumor size, tumor location and pathological type [11]. Continuous variables were expressed as mean±standard deviation ($\bar{x}$ ± s), and two independent samples t-test were applied for

Table 1 Comparison of baseline information before and after propensity score matching between the two groups [cases (%)/$\bar{x}\pm s$]

Characteristic	Before PSM			After PSM		
	RATS group (*n* = 125)	VATS group (*n* = 135)	*P* value	RATS group (*n* = 113)	VATS group (*n* = 113)	*P* value
Sex			0.465			0.287
Male	61(48.8)	72(53.3)		51(45.1)	59(52.2)	
Female	64(51.2)	63(46.7)		62(54.9)	54(47.8)	
Age (years)	50.16 ± 3.43	50.65 ± 3.53	0.256	50.91 ± 5.24	50.41 ± 2.67	0.362
BMI (kg/m^2)	24.53 ± 1.65	24.25 ± 1.83	0.189	24.31 ± 1.53	24.15 ± 1.46	0.415
Smoking history			0.792			0.749
Yes	27(21.6)	31(23.0)		24(21.2)	26(23.0)	
No	98(78.4)	104(77.0)		89(78.8)	87(77.0)	
Basic Diseases			0.739			0.679
Yes	46(36.8)	47(34.8)		43(38.1)	40(35.4)	
No	79(63.2)	88(65.2)		70(61.9)	73(64.6)	
Tumor size (cm)	3.28 ± 0.63	3.39 ± 0.62	0.175	3.27 ± 0.62	3.24 ± 0.60	0.770
Tumor location			0.031			0.188
Front	67(53.6)	90(66.7)		65(57.5)	75(66.4)	
Middle	15(12.0)	18(13.3)		13(11.5)	15(13.3)	
Posterior	43(34.4)	27(20.0)		35(31.0)	23(20.3)	
Type of pathology			0.110			0.725
Thymoma	32(25.6)	50(37.1)		31(27.3)	38(33.6)	
Benign cysts	39(31.2)	47(34.8)		38(33.6)	41(36.2)	
Teratoma	3(2.4)	3(2.2)		2(1.8)	3(2.7)	
Thymic hyperplasia	3(2.4)	5(3.7)		3(2.7)	2(1.8)	
Neurogenic tumor	43(34.4)	27(20.0)		36(31.9)	26(23.0)	
Other	5(4.0)	3(2.2)		3(2.7)	3(2.7)	

BMI, body mass index.

Table 2 Surgical data of patients [cases (%)/$\bar{x} \pm s$]

Characteristic	RATS group (*n* = 113)	VATS group (*n* = 113)	*P* value
Operative time (min)	84.91 ± 19.41	89.74 ± 18.81	0.059
Intraoperative blood loss (mL)	45.97 ± 12.46	55.09 ± 12.99	< 0.001
Total postoperative drainage volume (mL)	203.36 ± 42.54	282.74 ± 33.44	< 0.001
Duration of postoperative drainage (d)	2.24 ± 0.66	3.48 ± 0.81	0.002
Postoperative hospital stay (d)	4.31 ± 1.43	6.12 ± 1.17	< 0.001
Postoperative complications			0.065
Pneumonia	4(3.5)	6(5.3)	
Pulmonary atelectasis	2(1.8)	6(5.3)	
Arrhythmia	2(1.8)	3(2.7)	
Pleural effusion	1(0.9)	3(2.7)	
Total cost of hospitalization ($)	7302.17 ± 430.47	5297.98 ± 821.25	< 0.001

$ dollars

comparison between the different groups [11]. Categorical variables were expressed as frequencies and percentages (%), and group comparisons were made using the chi-square test or Fisher test [11]. $P<0.05$ was considered to be statistically significant difference.

Results

Propensity score matching

The differences in tumor location between the two groups of patients prior to propensity score matching (PSM) were statistically significant. Factors such as sex, age, BMI, smoking history, underlying diseases, tumor size, tumor location and pathological type were incorporated into the PSM process. After a 1:1 match, 113 patients in the RATS group and 113 patients in the VATS group were successfully paired, resulting in no statistically significant differences in the confounding variables. Table 1 lists the comparison of baseline information before and after propensity score matching between the two groups.

Surgical results

The surgical data from the two groups of patients after PSM are detailedly showed in Table 2. In terms of intraoperative blood loss [(45.97±12.46) mL vs. (55.09±12.99) mL], total postoperative drainage volume [(203.36±42.54) mL vs. (282.74±33.44) mL], postoperative drainage time [(2.24±0.66) days vs. (3.48±0.81) days] and postoperative hospital stay [(4.31±1.43) days vs. (6.12±1.17) days] were more advantageous in the RATS group, with statistically significant differences. In the light of the hospitalization costs [($5297.98±821.25) vs. (\$7302.17±430.47)], the VATS group was more advantageous and the difference was statistically significant. There was no statistically significant difference between the two groups in terms of operative time [(84.91±19.41) min vs. (89.74±18.81) min] and postoperative complications.

Subgroup analysis

Subgroup analysis of perioperative outcomes was conducted according to the BMI range. Patients were divided into two groups including the N-BMI group (18.5 kg/m^2≤BMI<25 kg/m^2) and the H-BMI group (BMI≥25 kg/m^2) according to the World Health Organization BMI classification. Furthermore, the subgroup comparisons of perioperative outcomes in the RATS and VATS groups are showed in Table 3. For the patients in the H-BMI group, in addition to obtaining similar findings as before the subgroup analysis, the RATS group has an advantage over the VATS group in terms of operative time [(86.39±18.77) min vs. (95.30±14.47) min] and postoperative complications with a statistically significant difference.

Discussion

The installed base of da Vinci robots worldwide has grown rapidly in recent years. Although the overall efficacy of RATS versus VATS in the treatment of mediastinal tumors has been investigated, few studies have analyzed the short-term efficacy and safety of the two procedures in patients with different BMI [9, 10]. Therefore, we included data from three medical centers to compare the short-term efficacy and safety of RATS versus VATS in the treatment of mediastinal tumors, whereas the short-term efficacy and safety of patients with different BMI have rarely been investigated.

In surgical procedures, excessive visceral fat can make it difficult to separate organs and blood vessels, thereby increasing the difficulty of surgical manipulation [12]. Obesity and overweight are considered manifestations of sub-health in the body. In surgical procedures, excessive visceral fat can make it difficult to separate organs and blood vessels, thereby increasing the difficulty of surgical manipulation [12]. In addition, the thicker the fat layer, the higher the probability of liquefaction, which can affect the healing of the surgical incision and the overall recovery after surgery [12]. The number of patients with mediastinal tumors with H-BMI increased significantly in recent years, and thoracic surgeons encounter enormous challenges when operating on patients with H-BMI. In this study, the difference in operative time between the RATS and VATS groups was not statistically significant, but after analysis based on BMI subgroups, we found that patients in the H-BMI group have longer operative time than those in the N-BMI group. Due to the higher body fat content in the H-BMI group of mediastinal tumor patients, the surgical procedure may be more complex. This is because the fatty tissue may cover or envelop the surgical area, and the surgical space may also be narrower, limiting the manipulation of surgical instruments, thereby increasing the duration of the surgery. The patients in the H-BMI group, the operative time was shorter in the RATS group than in the VATS group, and the difference between the two groups was statistically significant. In patients with mediastinal tumors with H-BMI, the operation time will be longer because of the large amount of fat accumulation, and the anatomical level is often poorly identified during VATS operation due to the difficulty in exposing the surgical field. RATS has a 3D field of view and high-definition imaging with 10–15 times magnification for easy field exposure and surgical manipulation, so the operative time is shorter than VATS in patients in the H-BMI group. In addition, the operation time of RATS can be significantly reduced because of the experience of the operator and the skillful cooperation of the robotic team.

In this study, the total postoperative drainage in the RATS group was lesser than that in the VATS group. Some related studies have analyzed the difference in

Table 3 Subgroup analysis based on BMI [cases (%)/$\bar{x}\pm s$]

Characteristic	*N*-BMI group			H-BMI group		
	RATS group (*n*=58)	VATS group (*n*=60)	*P* value	RATS group (*n*=55)	VATS group (*n*=53)	*P* value
Operative time (min)	82.84±19.60	85.00±19.70	0.553	86.39±18.77	95.30±14.47	0.022
Intraoperative blood loss (mL)	43.19±10.63	51.08±15.79	0.002	47.78±10.62	59.55±11.07	<0.001
Total postoperative drainage flow (mL)	197.59±32.14	275.67±33.33	<0.001	207.96±41.73	285.76±24.11	<0.001
Duration of postoperative drainage (d)	1.93±0.70	3.15±1.00	0.001	2.60±0.71	3.73±0.80	0.005
Postoperative hospital stay (d)	4.03±1.04	5.72±1.26	<0.001	4.63±1.28	6.33±1.02	<0.001
Postoperative complications			0.373			0.004
Pneumonia	2(3.4)	2(3.3)		2(3.6)	4(7.5)	
Pulmonary atelectasis	1(1.7)	3(5.0)		1(1.8)	3(5.7)	
Arrhythmia	1(1.7)	1(1.7)		1(1.8)	2(3.8)	
Pleural effusion	0	1(1.7)		1(1.8)	2(3.8)	
Total cost of hospitalization (\$)	7216.93±324.96	5225.82±814.30	<0.001	7352.05±463.61	5356.54±766.74	<0.001

thoracic drainage between RATS and VATS during mediastinal tumor surgery. RATS allows for more precise surgical operations, enabling surgeons to avoid damaging surrounding tissues and organs, leading to less total postoperative drainage volume. Besides, differences in the energy devices used in RATS versus VATS may also have a non-negligible impact on postoperative drainage volume. Our results showed that the RATS group has shorter postoperative drainage time, lower intraoperative blood loss and shorter postoperative hospital stay in comparison with the VATS group, as previously reported by Li et al. [13] and Alvarado et al. [14]. However, although the difference in intraoperative blood loss between the RATS and VATS groups was statistically significant ($P<0.001$), the difference was only about 10 mL, which may not have clinical significance.

There was no significant difference between the RATS and VATS groups in the postoperative complications, but a subgroup analysis based on BMI showed that the rate of postoperative complications was higher in the VATS group than in the RATS group among patients in the H-BMI group, and the difference was statistically significant. This is probably attributed to the following causes: (1) H-BMI patients have more fat accumulation around blood vessels and more brittle tissues, which can easily lead to tissue damage during surgery if not handled properly; (2) the two-dimensional field of view of thoracoscopy is not three-dimensional, and hand tremors caused by prolonged operation result in unstable field of view and operation, increasing the damage; (3) thoracoscopic instruments operating in reverse with Trocar as the fulcrum in fatty hypertrophic mediastinal tumors Surgery is extremely unstable and easily brings about increased postoperative complications [15]. In contrast, RATS is easier to perform precise resection and flexible suture tying in a small space, and clear visualization of the nerve, especially when the surgical anatomical level is unclear due to H-BMI, allowing the operator to identify local micro nerve structures and reduce the occurrence of medically induced injuries [16].

A previously retrospective study showed better inpatient surgical outcomes and fewer long-term complications and higher survival rates in patients with H-BMI [17]. Possible reasons for the relatively better perioperative prognosis of patients with H-BMI are due to : 1.BMI does not reflect body fat content and muscle content, and patients with H-BMI may have higher body muscle content [18]; 2. patients with H-BMI may have better nutritional status and tolerate surgery more easily [19]. Consequently, more studies are indispensable to explore the long-term efficacy of RATS versus VATS in treating patients with H-BMI mediastinal tumors in the future work.

There are some limitations and shortcomings of our present study: firstly, despite the application of PSM to control for confounding factors between groups, the potential selection bias was not completely eliminated; secondly, the sample size of this study was limited. After PSM, there is still a difference of 10 cases in the number of cases with neurogenic tumors between the two groups, which may introduce some bias into the results of the study; thirdly, this study lacks long-term survival analysis and it is proposed to further refine the data by follow-up.

Conclusion

In summary, despite the disadvantage of high cost associated with RATS, RATS offers technical and short-term efficacy advantages for the treatment of mediastinal tumors. In patients with mediastinal tumors of H-BMI, RATS can achieve better short-term outcomes and safety, especially in terms of reducing the incidence of postoperative complications.

Abbreviations

RATS Robot	assisted thoracoscopic surgery
VATS Video	assisted thoracoscopic surgery
BMI	Body mass index
PSM	Propensity score matching
$	Dollars

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Not applicable.

Author contributions
Qing Liu, Ziqiang Hong and Yunjiu Gou: conception and design and administrative support; Haochi Li and Wei Cao: provision of study materials or patients; Qing Liu, Wei Cao and Xiaoyang He: collection and assembly of the data; Jinlong Zhang and Dacheng Jin: data analysis and interpretation; manuscript writing: all authors. The authors read and approved the final manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study has been reviewed by the Ethics Committee of Gansu Provincial Hospital, approval number: 2024 – 509. All patients signed the informed consent form for surgery before surgery.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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