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Surgical Treatment of Chronic Infectious Cervicothoracic Spondylitis

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Abstract

Background. Chronic infectious spondylitis of the cervicothoracic spine represents an etiologically heterogeneous group of diseases characterized by vertebral destruction within the C6-T3 region. There is no common strategy for the surgical treatment of this cohort of patients.

The aim of the study was to analyze the technical features and long-term outcomes of surgical treatment for chronic infectious cervicothoracic spondylitis.

Methods. The cohort included 18 patients treated between 2018 and 2022. Considering the etiology, long-term outcomes were analyzed in 11 patients with chronic nonspecific spondylitis and 7 patients with tuberculous spondylitis. Clinical, radiological, and surgical parameters were assessed. Long-term results were evaluated at 6 and 12 months postoperatively.

Results. Chronic infectious spondylitis in the cohort was classified according to E. Pola (2017) as types B.3 (n = 10), C.2 (n = 4), C.3 (n = 1), and C.4 (n = 3). The mean age at the time of surgery was 48 years and 3 months (range 20-71). The groups were comparable in gender, age, and degree of local sagittal balance impairment. The etiology of chronic spondylitis influenced the extent of the destructive process (p = 0.009) and the severity of vertebrogenic pain syndrome (p = 0.028). Quality-of-life analysis revealed a greater degree of social maladaptation in tuberculous spondylitis group according to the NDI (p = 0.018) and SF-12 (p = 0.002) scales. Indications for various techniques of cervicothoracic reconstruction, including isolated ventral, isolated dorsal, and combined approaches, were determined.

Conclusions. Chronic infectious spondylitis of the cervicothoracic spine is a rare and poorly studied pathology. The etiology of spondylitis affects the clinical course of the disease and the incidence of postoperative complications in the long term. Analysis of available data and evaluation of the authors' experience allowed for the development of several tactical tools for planning surgical reconstruction, including an algorithm for selecting the surgical approach and determining the need for manubriotomy. Long-term surgical outcomes using the proposed tactical algorithm confirm its effectiveness and potential for further application.

Keywords: chronic infectious spondylitis, cervicothoracic spine, spinal surgery complications, revision spinal surgery.

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Хирургическое лечение хронических инфекционных спондилитов шейно-грудного отдела позвоночника

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Реферат

Введение. Хронические инфекционные спондилиты шейно-грудного отдела позвоночника представляют собой этиологически разнородную группу заболеваний с деструкцией позвонков в зоне C6–Th3. Единая стратегия хирургического лечения данной когорты пациентов отсутствует.

Цель исследования — изучить технические особенности и отдаленные результаты хирургического лечения хронических инфекционных спондилитов шейно-грудного отдела позвоночника.

Материал и методы. Когорту составили 18 пациентов (лечение с 2018 по 2022 г.). С учетом этиологии изучены отдаленные результаты операций у 11 пациентов с хроническим неспецифическим и 7 — с туберкулезным спондилитом. Оценены клинико-лучевые и операционные параметры. Отдаленные результаты изучены спустя 6 и 12 мес.

Результаты. Хронические инфекционные спондилиты в когорте классифицированы как типы B.3 ($n = 10$), C.2 ($n = 4$), C.3 ($n = 1$) и C.4 ($n = 3$) по E. Pola (2017). Средний возраст на момент операции составил 48 лет 3 мес. (20–71). Группы сопоставимы по полу, возрасту и степени нарушения параметров локального сагиттального баланса. Выявлено влияние этиологии хронического спондилита на распространенность деструктивного процесса ($p = 0,009$), на интенсивность вертеброгенного болевого синдрома ($p = 0,028$). Анализ качества жизни свидетельствует о большей степени социальной дезадаптации при туберкулезном спондилите по шкале NDI ($p = 0,018$) и SF-12 ($p = 0,002$). Определены показания к различным вариантам реконструкций шейно-грудного отдела, в т.ч. изолированной вентральной, изолированной дорсальной и комбинированной.

Заключение. Хронические инфекционные спондилиты шейно-грудного отдела представляют собой редкую и малоизученную патологию. Этиология спондилита оказывает влияние на клиническое течение заболевания и частоту осложнений в отдаленном послеоперационном периоде. Анализ существующей информации по рассматриваемому вопросу и оценка собственного накопленного опыта позволили предложить ряд тактических инструментов планирования хирургической реконструкции: алгоритм выбора варианта операции и траекторию хирургической доступности для определения необходимости манубриотомии. Отдаленные результаты вмешательств с применением тактического алгоритма позволяют констатировать его эффективность и перспективу дальнейшего использования.

Ключевые слова: хронический инфекционный спондилит, шейно-грудной отдел позвоночника, осложнения операций на позвоночнике, ревизионные операции на позвоночнике.

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INTRODUCTION

Cervicothoracic spine is a specific anatomical zone characterized by the combination of mobile cervical and rigid thoracic segments [1, 2]. From the perspective of surgical accessibility, C6-T3 motion segments are ventrally limited by the manubrium and the body of the sternum, as well as by the trachea and the organs of the posterior mediastinum [3, 4]. Reconstruction of this region via the isolated posterior approach is associated with a high risk of neurological complications, necessitating a combined approach to achieve three-column stability [5, 6].

In the overall structure of chronic infectious spondylitis, lesions of the cervicothoracic spine account for 3-5% and are associated with segmental instability and secondary orthopedic deformities due to their significant impact on the T1 slope (T1S) and cervical sagittal vertical axis (cSVA) [7, 8]. Indications for surgical treatment in this patient group include progressive neurological deficit, ineffective isolated antibacterial therapy, chronic vertebrogenic pain syndrome, and reduced quality of life due to sagittal balance disturbances [9, 10]. At the initial stage of treatment, trephine biopsy under fluoroscopic navigation is recommended, followed by molecular-genetic, bacteriological, and histological studies of the material. This is due to the low efficacy of empirical antibacterial therapy and the etiological heterogeneity of destructive lesions (nonspecific, granulomatous, including tuberculous, fungal, and parasitic lesions) [11, 12, 13, 14].

A special subset of patients comprises those with chronic infectious cervicothoracic spondylitis requiring revision operations [15, 16, 17]. Causes prompting revision in this cohort include infectious complications (superficial surgical site infections, deep implant-associated infections) and orthopedic complications (progressive deformity, segmental instability, pseudoarthrosis).

Current approaches to the surgical treatment of spondylitis are predominantly validated for acute processes with disease duration not exceeding two months. In cases of acute spondylitis and spondylodiscitis at the C6-T3 level, dorsal decompressive-stabilizing interventions are preferred. Though, when treating chronic forms of spondylitis, such interventions pose significant technical challenges [18, 19]. A preliminary review of the literature revealed limited information on this problem and formed the basis for the following research questions:

1) is it possible to algorithmize the surgical treatment of chronic infectious cervicothoracic spondylitis based on the extent of the lesion and previous surgical interventions?

2) what clinical and radiological factors influence the course and long-term outcomes of surgical treatment for chronic infectious cervicothoracic spondylitis?

The accumulated experience of the Spine Surgery Center at the Saint Petersburg State Research Institute of Phthisiopulmonology allowed us to present our clinical data and analyze long-term outcomes.

The aim of the study was to analyze the technical features and long-term outcomes of surgical treatment for chronic infectious cervicothoracic spondylitis.

METHODS

Study design: continuous single-center cohort study (class IIB).

The initial cohort included 31 patients treated at the Spine Surgery Center of the Saint Petersburg State Research Institute of Phthisiopulmonology between 2018 and 2022 for cervicothoracic spine destruction. After applying inclusion and exclusion criteria, the final cohort consisted of 18 consecutively operated patients with chronic infectious cervicothoracic spondylitis.

Inclusion criteria:

1) etiologically confirmed spondylitis with a therapeutic pause of ≥2 months and no effect from isolated antibacterial, including antitubercular chemotherapy, conducted according to the established regimens [20];

2) vertebral destruction within the C6-T3 zone;

3) reconstruction of the spine in 180° or 360° volume;

4) availability of complete radiographic archives;

5) follow-up of at least 12 months.

Exclusion criteria: types A.1-B.2 spondylitis according to the E. Pola et al. classification (6 cases) [21], inability to analyze long-term outcomes due to the loss of the contact with patient (4 cases), inability to perform standing radiography due to neurological deficits of types A-B by Frankel (3 cases).

Based on etiological verification, two patient groups were identified: 11 patients with nonspecific spondylitis (Group 1) and 7 patients with tuberculous chronic spondylitis (Group 2).

The preoperative examination protocol included lateral X-rays of the spine in a standing position, CT, and MRI of the spine covering C2-T6 segments, and the use of the Neck Disability Index (NDI), Short Form Health Survey (SF-12), Visual Analog Scale (VAS), and Frankel scale (functional classes A-E) questionnaires. The classification of spondylitis types was performed according to E. Pola et al.

Evaluated sagittal balance parameters included:

1) local kyphosis angle (LK);
2) C2-C7 sagittal vertical axis (C2-C7 SVA);
3) T1 slope angle (T1S);
4) neck tilt angle (NTA) [22].

Following reconstructive interventions, local kyphosis and C2-C7 SVA parameters were analyzed. Assessment of T1S and NTA postop was not feasible due to resection of the T1 vertebral body during anterior cervicothoracic reconstruction. Radiographic balance parameters were calculated using Surgimap v. 2.3.2.1, with the prior anonymization of patient data.

Intraoperative data included blood loss volume (gravimetric method, combining losses in sponges and suction devices) and surgery duration. Long-term outcomes were assessed at 6 and 12 months, focusing on bone block formation on CT (5-point scale), sagittal balance parameters (standing lateral X-rays), vertebrogenic pain severity (VAS), quality of life (NDI, SF-12), and complication rates [23].

The clinical characteristics of the patients are presented in Table 1.

Surgical technique

Preoperative preparation and anesthetic management were performed in all cases according to established recommendations, without clinically significant tactical deviations [24]. The planning of the ventral stage of reconstruction was based on sagittal CT scans. The necessity for manubriotomy was determined by drawing a horizontal line along the upper edge of the manubrium to the vertebral bodies, thereby defining the surgical trajectory for the access to the cervicothoracic spine. The planning scheme is shown in Figure 1.

To access the anterior column of the spine at the C6-T3 level, a right-sided oblique approach along the medial edge of the sternocleidomastoid muscle was used. The inferior boundary of the incision was limited by the sternoclavicular joint (in cases where the surgical trajectory was not obstructed by the manubrium) or extended to the lower edge of the manubrium if manubriotomy was required.

Mobilization of the anterior surface of the vertebral bodies was performed using standard techniques. In cases requiring manubriotomy, the bone was transected along the midline, and a rake retractor was installed to expose the brachiocephalic trunk, right common carotid artery, right brachiocephalic vein, and medial wall of the trachea and esophagus. A "working window" was created between the vascular structures and hollow organs.

The first stage involved inserting pins of the Caspar distractor into the centers of adjacent intact vertebral bodies. Resection of the affected vertebrae was carried out under tension from the Caspar distractor. Abscess debridement and anterior decompression of the *dura mater* were performed using a high-speed drill, osteotomes, bone curettes, and Kerrison rongeurs. Pathologically altered vertebral bodies were resected within the boundaries of the adjacent intact endplates.

Final reclination and correction of kyphotic deformity of the cervicothoracic junction were performed by gradually expanding the arms of the Caspar distractor under fluoroscopic control. Anterior spinal fusion was carried out using a titanium block cage filled with autogenous bone material (fragments of the anterior superior iliac crest). Sternal osteosynthesis was completed by placing cerclage sutures.

When affecting the posterior support complex or during revision operations (previous decompressive laminectomy), 360° reconstruction was performed (6 cases). The first stage involved posterior instrumentation fixation, followed by repositioning the patient in the supine position for anterior column reconstruction using the aforementioned technique. Correction of local kyphotic deformity during the dorsal stage was achieved by mobili-zing the posterior support complex (Schwab grade 1 osteotomy) followed by a compression-reclination maneuver. Posterior instrumentation fixation was secured with rods

Table 1

Characteristics of the patients included in the study

№	Gender / Age	Charlson Comorbidity Index	Level / E. Pola	Therapeutic pause, mos.	Kyphosis, ° according to Cobb	CSVA, cm / T1S, ° / NTA, °	VAS / NDI	Frankel		Reconstruction type	Operation duration, min / blood loss, ml	Complication/time of development, mos.
								before	after			
1	M/26	1	C7–T1/B.3	7	–	4.1/20.3/41.2	5/35	D	E	PIF + AD C5–T4	115/70	–
2	F/29	0	T1–3/C.2	10	38	5.7/49.6/46.8	5/35	D	E	PIF C5–T6, ACCF T1–3	315/250	–
3	M/42	8	C7–T1/B.3	3	7	3.1/34.9/40.7	6/38	D	E	ACCF C7–T2	120/100	–
4	F/44	8	C6–T2/B.3	8	14	3.8/47.2/73.5	6/42	C + POD	D + POD	PIF C4–T4 + AD C6–T2	125/50	Delayed deep SSI, stage 2 sacral pressure ulcer, wound revision, replacement of PIF supporting elements, NPWT / 3 months postop
5	M/45	7	C7–T1/B.3	4	23	4.2/18.2/39.7	7/37	D	E	ACCF C7–T1	105/60	Formation of pseudarthrosis in the anterior spinal fusion area by 12 months postop, without signs of infection recurrence, posterior instrumented fixation, Schwab 1 osteotomy, posterior spinal fusion
6	M/48	6	C6–T1/B.3	4	39	5.9/8.9/43.5	7/41	D	E	ACCF + AP C5–T1	145/300	–
7	F/57	1	C6–T1/C.4	11	35	5.4/2.6/61.6	6/38	C	D	ACCF + AP C5–T1	120/100	–
8	M/64	2	C6–T2/C.4	4	16	4.1/28.5/67.2	7/42	C	D	ACCF C6–7, T1–2	140/200	–
9	M/65	3	C6–T1/B.3	24	–	3.6/16.6/58.6	3/32	E	E	ACCF + AP C6–T1	95/50	–
10	M/70	4	C7–T1/B.3	5	47	6.4/38.1/65.3	5/36	D + POD	D + POD	ACCF C7–T1	135/100	Stage 2 sacral pressure ulcer, local therapy, defect closure / 14 days postop
11	F/71	3	C7–T1/C.2	5	35	5.5/4.6/76.6	6/33	E	E	PIF C5–T3, ACCF C6–T2	365/400	–
12	M/20	1	C7–T3/C.4	4	45	6.3/25/41.5	4/45	C + POD	E	PIF C5–T4 + ACCF C6–T2	300/400	–
13	M/27	2	C7–T2/C.3	3	5	4.1/26.8/35.4	4/34	D	E	ACCF C7–T2	80/90	MDR-TB, early deep SSI, revision, debridement, preservation of interbody implant / 10 days postop
14	F/45	0	C7–T1/C.2	7	31	5.1/10.9/60	5/41	D	E	ACCF C6–T1	135/80	–
15	F/46	6	T1–2/C.2	3	35	5.6/46.3/65.7	4/42	C	C	PIF C5–T4, ACCF T1–3	230/350	–
16	M/49	1	C7–T1/B.3	4	19	4.4/4.9/57.1	6/44	D	E	ACCF C7–T1	130/50	–
17	F/56	2	C6–T1/B.3	4	39	5.7/38.2/42.7	5/43	D	E	ACCF + AP C6–T1	145/100	–
18	F/67	3	C7–T1/B.3	3	15	3.9/7.6/48.3	3/45	D	E	ACCF C7–T2	90/100	–

POD — pelvic organ dysfunction; PIF — posterior instrumental fixation; ACCF — anterior cervical corpectomy fusion; MDR-TB — multidrug-resistant tuberculosis (*M. tuberculosis*); SSI — surgical site infection; NPWT — negative pressure wound therapy.

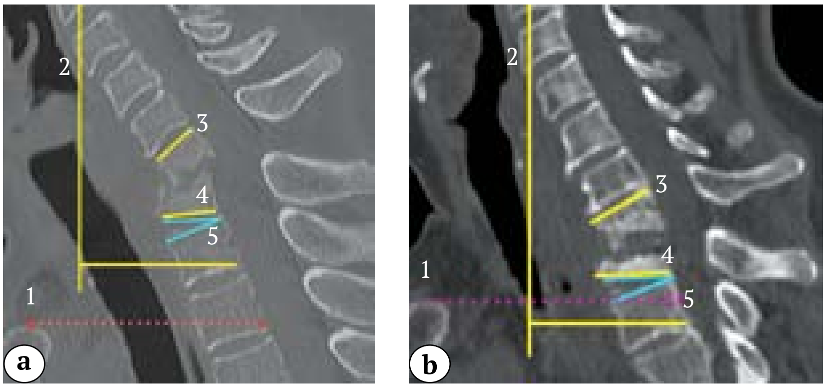


Figure 1. Reconstruction planning scheme: sagittal CT scan showing surgical trajectory (1), cervical sagittal vertical axis C2-C7 (cSVA, 2), local kyphosis (LK, 3), T1 slope (T1S, 4), and neutral thoracic angle (NTA, 5):
a — reconstruction without manubriotomy;
b — manubriotomy required

of 3.5 mm and 5.5 mm diameter connected via domino connectors.

All surgical interventions were performed by a single surgical team using a standardized surgical kit and power equipment. In all cases, intraoperative neuromonitoring was utilized.

Statistical analysis

Statistical analysis was conducted using the SPSS software, version 22.0 (SPSS Inc., Chicago, IL, USA). The normality of the distribution of quantitative parameters was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. For all parameters, a two-tailed significance level of $p<0.05$ was considered. The significance of intergroup differences in quantitative variables was assessed using the Mann-Whitney U test. Differences in quantitative parameters before and after surgery were evaluated using the Wilcoxon signed-rank test. The influence of sagittal balance parameters on NDI, SF-12, and VAS scores was assessed using the Spearman's correlation coefficient. Results were presented as M±SD and Me (min-max). Differences were considered statistically significant at a two-tailed significance level of $p<0.05$.

RESULTS

According to E. Pola's classification, the lesions of types B.3 (n = 10), C.2 (n = 4), C.3 (n = 1), and C.4 (n = 3) were identified. The average age of patients at the time of surgery was 48 years and 3 months ± 15 years and 7 months (range: 20-71). Of the patients, 10 (55.5%) were male and 8 (45.5%) were female. No significant differences were found between genders (p = 0.387) or ages (p = 0.536) regarding the etiology of chronic spondylitis.

The duration of therapeutic pause in patients with chronic nonspecific spondylitis was higher (p = 0.035), averaging 5 months (range: 3-24). There were no significant differences in the structure of comorbidities (p = 0.211), with a Charlson comorbidity index of 2.5 points (range: 0-8) for the cohort.

Etiological groups were comparable in preoperative parameters of local sagittal balance, including LK (p = 0.659), CSVA (p = 0.536), T1S (p = 0.930), and NTA (p = 0.479). Postoperatively, statistically significant correction of segmental kyphosis (p = 0.001) and C2-C7 sagittal vertical axis (p = 0.038) was achieved in both groups, with no significant loss of correction at 6 and 12 months. The summary parameters of local sagittal balance are presented in Table 2.

The etiology of the process influenced the extent of destruction. Patients with chronic nonspecific spondylitis showed more frequent polysegmental destruction involving two or more motion segments (p = 0.009). The intensity of vertebrogenic pain syndrome was higher in these patients: 5.7±1.2 (range: 4.9-6.5) compared to 4.4±1.0 (range: 3.5-5.3) in patients with tuberculous spondylitis (p = 0.028).

Quality-of-life analysis revealed a trend toward greater social maladaptation in patients with tuberculous spondylitis. Preoperative NDI scores were 43.0±3.8 (range: 34-45) versus 37.0±3.4 (range: 33-42) in patients with nonspecific spondylitis (p = 0.018). Similar results were observed in SF-12 physical and mental component scores, which were 19.0±1.7 (range:

Table 2

Summary parameters of local sagittal balance

Etiology	Before surgery	After surgery	p
Chronic nonspecific spondylitis			
LK	23 (9-47)	2.4 (-5-4.5)	0.001
CSVA	4.2 (3.1-6.4)	3.7 (1.2-4.6)	0.048
T1S	20.3 (2.6-49.5)	–	–
NTA	58.6 (39.7-76.6)	–	–
Tuberculous spondylitis			
LK	31 (5-45)	2.1 (-9.0-3.5)	0.001
CSVA	5.1 (3.9-6.3)	3.4 (1.2-4.3)	0.032
T1S	25 (4.9-46.3)	–	–
NTA	48.3 (35.4-65.7)	–	–
The mean			
LK	27 (9-47)	2.2 (-9.0-4.5)	0.001
CSVA	4.8 (3.1-6.4)	3.5 (1.2-4.6)	0.038
T1S	22.6 (2.6-49.5)	–	–
NTA	52.7 (35.4-76.6)	–	–

LK – local kyphosis; CSVA – cervical sagittal vertical axis; T1S – T1 slope; NTA – neck tilt angle; an intergroup two-tailed significance level p was calculated using the Mann-Whitney U test; a two-tailed significance level p for pre- and postoperative parameters was calculated using the Wilcoxon signed-rank test.

18-23) and 20.0±1.6 (range: 18-22) respectively for tuberculous spondylitis (p = 0.002).

Postoperatively, the quality of life improved in Group 1 (nonspecific spondylitis): NDI 16.2±0.7 (range: 13-21), SF-12 physical component 45.6±2.4 (range: 34.8-63.0), and SF-12 mental component 47.7±2.7 (range: 29.2-63.0). In Group 2 (tuberculous spondylitis): NDI 17.0±1.1 (range: 12-19), SF-12 physical component 42.2±1.9 (range: 31.2-47.1), and SF-12 mental component 44.7±1.3 (range: 39.2-49.6). No significant intergroup differences were observed postoperatively in NDI (p = 0.927), SF-12 mental (p = 0.415), or SF-12 physical (p = 0.239) scores.

The duration of surgery (p = 0.956) and blood loss (p = 0.819) were comparable between the groups. Data are presented in Table 3.

The dynamics of bone block formation in the anterior spinal fusion zone demonstrated a stable positive trend at the control follow-ups. At 6 months postoperatively, a bone block rated 4 points on a 5-point scale was observed in 66.7% of cases, increasing to 94.4% at 12 months. One patient (case no. 5) underwent posterior fixation combined with spinal fusion due to pseudarthrosis of the anterior column without signs of infection recurrence.

Postoperative complications were more frequent in patients with nonspecific spondylitis (n = 3; 27.2%) compared to tuberculous spondylitis (n = 1; 9.1%) (p = 0.518). Management of complications depended on their timing and severity. Early deep SSI (case no. 13) required revision and wound debridement using an ultrasonic cavitation while preserving the supporting construct elements. For delayed deep SSI (case no. 4), revision and ultrasonic cavitation of the wound were followed by construct

Table 3

Summary operation parameters

Parameter	Etiology		p	The mean for both groups
	Chronic nonspecific spondylitis	Tuberculous spondylitis		
Operation duration	2 h 40 min ± 1 h 28 min (1 h 40 min – 3 h 41 min)	2 h 35 min ± 1 h 19 min (1 h 25 min – 3 h 52 min)	0.956	2 h 38 min ± 1 h 23 min (1 h 58 min – 3 h 21 min)
Blood loss	152±35 ml (73-232)	167±54 ml (50-300)	0.819	158±29 ml (96-220)

replacement and NPWT application above the aponeurotic layer for 12 days with dressing changes every 4 days until negative culture results were achieved (initial flora: MRSE). A stage 2 sacral pressure ulcer (case no. 10) was treated with NPWT for 15 days, with dressing changes every 3 days (initial flora: *E. coli*). In all cases of infectious complications, pathogen-directed antibiotic therapy was administered for at least 6 weeks.

DISCUSSION

Currently, there is no common approach to the surgical treatment of chronic infectious spondylitis in the cervicothoracic region. On the one hand, factors such as the extent of destruction, the degree of involvement of paravertebral tissues, the severity of local sagittal balance impairment, and the angle of segmental kyphosis are critical criteria for selecting a surgical method [7, 8, 9, 10, 11, 25]. On the other hand, the diversity of stabilization systems and the possibility of correcting pathological changes via various surgical approaches necessitate a critical analysis of long-term outcomes of such interventions.

An essential aspect of understanding the infectious-destructive process in this region is the etiology of spondylitis. Its verification is achieved through diagnostic biopsy under fluoroscopy. This step is emphasized as critical by all authors [11].

A common trend noted in the reviewed literature was the necessity of manubriotomy for reconstructing the cervicothoracic junction. However, none of the publications provide clear prognostic criteria for determining the need for this procedure [3, 6, 26, 27, 28, 29]. In our opinion, the trajectory of surgical accessibility, defined as a horizontal line drawn along the upper edge of the manubrium to the vertebral bodies, can serve as a universal tool for the preoperative planning of C6-T3 reconstruction in cases of chronic infectious spondylitis. This approach has consistently allowed for accurate prediction of the necessity for manubriotomy. A comparable tool is the cervicothoracic angle developed by H. Teng et al. However, its use is limited in case of infection due to the typical spread of paravertebral soft tissue components (abscesses and granulomas) requiring caudal mobilization of the anterior column, even for lesions in zones A and B [18].

Our analysis of both our own clinical data and the literature has enabled the systematization of criteria for selecting surgical reconstruction methods. For monosegmental lesions, isolated ventral reconstruction is advisable. In the presence of rigid kyphosis, a 360° combined approach is warranted. For multisegmental destructions, favorable long-term outcomes have been achieved with 360° combined reconstructions, where the ventral stage is performed first [17, 30]. Revision reconstructions of the cervicothoracic junction represent a distinct cohort, in which the use of an isolated anterior approach does not ensure stable results and is associated with pseudoarthrosis formation and loss of correction [15]. The specific feature of combined revision reconstructions is that the dorsal stabilization is performed at the first stage, followed by the ventral stage [16]. Systematizing our clinical experience and literature data (Table 4), we developed a tactical scheme for selecting the type of surgical intervention for primary and revision procedures, presented in Figure 2.

Among the factors influencing the clinical course of chronic spondylitis, the etiology of the process should be highlighted. Its nonspecific nature contributes to the development of multilevel destructions, while a granulomatous nature leads to a decline in both mental and physical components of the quality of life. A significant reduction in the quality of life across all evaluation scales among patients with chronic tuberculous spondylitis can be associated with more pronounced impairments of local sagittal balance parameters, as confirmed by our findings and those of other researchers [17, 19, 23, 26]. Of the 124 patients described in the literature, 122 cases (98%) involved tuberculous spondylitis, making our accumulated data a priority for patients with chronic nonspecific spondylitis.

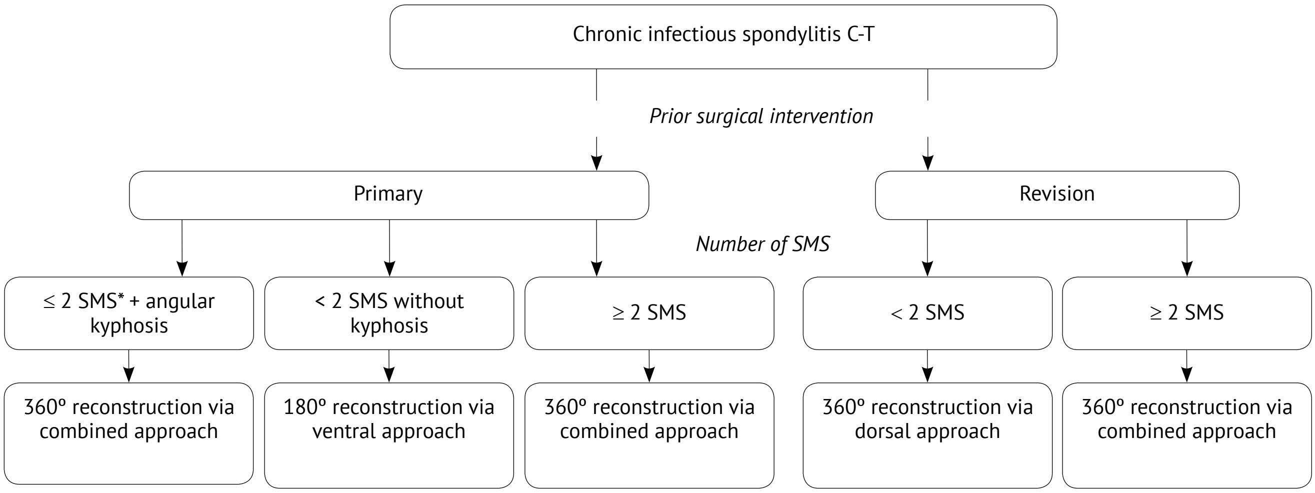
The complication rate in our cohort was 22.2%, with the majority being early and delayed complications of class IIIB according to the Clavien-Dindo classification. Most published studies report dysphagia in operated patients due to recurrent laryngeal nerve injury, as well as durotomy with subsequent cerebrospinal fluid leakage, necessitating lumbar drainage until the dural defect is closed [12, 19, 29].

Table 4

Characteristics of the studies included in the literature review

Author/year	Patients	Clinical picture, treatment tactics, long-term outcomes
Acosta F.L. 2006 [2]	1/NCS	50 years old, Frankel D, 55° angular kyphosis. 360° reconstruction, manubriotomy, corpectomy, C4-T2 anterior spinal fusion, posterior instrumental fixation. Follow-up — 35 months, relief of vertebrogenic pain syndrome, preservation of achieved kyphoses correction
Lan X., 2017 [4]	3/TBS	M = 33 years old, angular kyphoses, vertebrogenic pain syndrome. Stage 1 — Halo-traction for 1 week; Stage 2 – posterior instrumental fixation, abscess debridement of the anterior column, laminectomy. Follow-up — 26 months, stable supporting elements, no signs of recurrence
Chen Y., 2017 [5]	10/TBS	M = 33 years old, angular kyphoses, neurological deficit (Frankel C — 3; D — 5). 360° reconstruction via dorsal approach: corpectomy, anterior spinal fusion with autograft, posterior instrumental fixation. Follow-up — 53 months, kyphoses correction, successful spinal fusion, partial recovery of neurological deficit (Frankel C — 1; D — 4; E — 3)
Wu W.J., 2020 [6]	74/TBS	M = 24 years old, angular kyphoses, neurological deficit, pain syndrome. 180° reconstruction via ventral approach (n = 33): manubriotomy, abscessotomy, corpectomy, anterior spinal fusion with a titanium block-mesh cage and a locking plate (≤ 2 motion segments). 360° reconstruction via dorsal approach (n = 16): posterior instrumental fixation, costotransversectomy, anterior column debridement, anterior spinal fusion with autograft (≤ 2 motion segments, preceded by debridement via ventral approach). 360° reconstruction via combined approach (n = 25): posterior instrumental fixation, abscessotomy, corpectomy, anterior spinal fusion with a titanium block-mesh cage and a locking plate (> 2 motion segments, revisions, rigid angular kyphoses). Follow-up — 39 months: comparable correction of deformity, relief of pain syndrome. Complications: transient dysphagia (2 cases), durotomy with postoperative CSF leak (2 cases), lower limb monoparesis (1 case)
Rathod T.N., 2022 [8]	11/TBS	M = 25 years old, neurological deficit (Frankel A — 1, B — 2, C — 4, D — 4), angular kyphosis. 180° reconstruction via ventral approach (n = 8): corpectomy, abscess debridement, anterior spinal fusion with a titanium mesh and locking plate. 360° reconstruction: corpectomy, anterior spinal fusion with autograft, posterior instrumental fixation. Follow-up — 24 months: kyphosis correction, successful spinal fusion, partial recovery of neurological deficit (Frankel B — 1, C — 2, D — 4, E — 4)
Li Z., 2020 [19]	7/TBS	M = 46 years old, neurological deficit (Frankel A — 4, B — 2, C — 1), angular kyphosis. 180° reconstruction via ventral approach: manubrio/sternotomy, abscess debridement, corpectomy, anterior spinal fusion with a titanium mesh and locking plate. Follow-up — 24 months: stable implant, postoperative CSF leak requiring revision surgery (1 patient)
Zhang H.Q., 2015 [25]	15/TBS	M = 40 years old, kyphoses, neurological deficit, vertebrogenic pain syndrome. 360° reconstruction: corpectomy, anterior spinal fusion with autograft, posterior instrumental fixation. Follow-up — 27 months: kyphosis correction, successful spinal fusion, partial recovery of neurological deficit (Frankel C — 1, D — 4, E — 10)
Issa M., 2023 [26]	2/TBS, NCS	M = 36 years old, instability, pain syndrome. 180° reconstruction via ventral approach: manubriotomy, corpectomy, anterior spinal fusion with a titanium mesh and locking plate (TBS). 180° reconstruction via ventral approach: manubriotomy, corpectomy, anterior spinal fusion with a titanium mesh, posterior instrumental fixation (NCS). Follow-up — 1.5 months: transient recurrent laryngeal nerve dysfunction (1 case)
Chen Y.H., 2013 [30]	1/TBS	21 years old, lower paraplegia with POD, prevertebral, paravertebral, and epidural abscesses. Stage 1 – anterior decompression, abscess debridement, Halo-traction; Stage 2 – posterior instrumental fixation, laminectomy, posterior spondylodesis. Follow-up — 28 months: restoration of motor function in the lower limbs

NCS — nonspecific chronic spondylitis; TBS — tuberculous spondylitis.



* — spinal motion segment.

Figure 2. Tactical scheme for selecting the type of surgical intervention in chronic spondylitis of the cervicothoracic junction

Limitations of the study

The retrospective design of the study and the small sample size highlight the need for further accumulation of clinical data, including the use of a multicenter approach. At the same time, the scheme of the selection of surgical intervention we proposed is of a pilot nature and undoubtedly requires prospective validation.

CONCLUSIONS

Chronic infectious spondylitis of the cervicothoracic spine is a rare and poorly studied pathology. The etiology of spondylitis affects the clinical course of the disease and the incidence of postoperative complications in the long term. The analysis of available data and the evaluation of the authors' experience allowed for the development of several tactical tools for planning surgical reconstruction, including an algorithm for selecting the surgical approach and determining the need for manubriotomy. Long-term surgical outcomes using the proposed tactical algorithm allowed us to confirm its effectiveness and potential for further application.

DISCLAIMERS

Author contribution

Naumov D.G. — study concept and design, drafting and editing the manuscript.

Tkach S.G. — data acquisition, data analysis and interpretation, drafting the manuscript.

Aliev G.B. — literature search and review, statistical data processing, data analysis and interpretation.

Vishnevsky A.A. — literature search and review, editing the manuscript.

Yablonsky P.K. — study concept and design, editing the manuscript.

All authors have read and approved the final version of the manuscript of the article. All authors agree to bear responsibility for all aspects of the study to ensure proper consideration and resolution of all possible issues related to the correctness and reliability of any part of the work.

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