Original Article
https://doi.org/10.17816/2311-2905-7445

Long-term Outcomes and Effectiveness of Treatment Methods for Vertebral Osteomyelitis With Different Types of Lesions According to the E. Pola Classification

Alexander Yu. Bazarov[1,2], Konstantin S. Sergeev[2], Aleksandra K. Tsvetkova[2]

[1] *Tyumen Regional Hospital No 2, Tyumen, Russia*

[2] *Tyumen State Medical University, Tyumen, Russia*

Abstract

Background. Treatment of vertebral osteomyelitis (VO) is accompanied by a number of organizational and tactical problems related to the multidisciplinary nature of the disease. Therefore, the use of classifications determining treatment tactics is necessary. The evaluation of treatment outcomes and efficacy should be conducted in accordance with the classification type of the lesion and decisions made based on the tactical algorithm.

Aim of the study — to identify the dependence of long-term treatment outcomes of vertebral osteomyelitis on the type of lesion according to the modified Russian version of the E. Pola classification and the methods of treatment used.

Methods. The study analyzed the treatment results of 266 patients with vertebral osteomyelitis from 2006 to 2019. Type A lesions accounted for 24.1% (n = 64), type B — 47.0% (n = 125), type C — 26.3% (n = 70), and lesions of vertebral processes — 2.6% (n = 7). Neurological disorders were detected in 53 observations (type C). Conservative treatment, debridement, and reconstructive surgeries were performed. The evaluation of results was carried out a year or more after discharge.

Results. The maximum effectiveness of conservative treatment was noted in uncomplicated courses and minor bone destruction. Conservative treatment of type A lesions led to recovery in 97.4% of cases compared to reconstructive operations ($p = 0.002$) and recurrences ($p = 0.034$). Mortality was higher after reconstructive interventions ($p = 0.001$). The highest number of fatal outcomes after debridement of the focus was observed in type B lesions — 15.8% ($p = 0.022$). Analysis of type C lesions did not reveal significant differences between the methods of treatment used. The maximum number of unsatisfactory results was registered in patients with sepsis: mortality was 17.4%, and in its absence — 4.9% ($p = 0.039$), recurrences — 21.7% versus 7.8% ($p = 0.043$), recovery — 56.6% versus 83.5% ($p = 0.004$), respectively. There were no significant differences in the assessments according to the ODI, NDI, SF-36 scales in the long term. The overall survival rate was 84.4%, and the long-term one was 90.4%, which increased with conservative treatment compared to reconstructive interventions ($p = 0.045$).

Conclusion. Conservative treatment and extra-focal fixation of the spine showed maximum effectiveness in low-destructive and uncomplicated lesions (type A). Reconstructive interventions lead to an increase in the number of recurrences and fatal outcomes. Debridement of the focus in septic course of type B lesions leads to an increase in hospital mortality. There were no statistically significant differences between the results of different treatment methods for type C lesions.

Keywords: vertebral osteomyelitis, spondylitis, spondylodiscitis, classification of vertebral osteomyelitis.

Cite as: Bazarov A.Yu., Sergeev K.S., Tsvetkova A.K. Long-term Outcomes and Effectiveness of Treatment Methods for Vertebral Osteomyelitis With Different Types of Lesions According to the E. Pola Classification. *Traumatology and Orthopedics of Russia*. 2023;29(2):7-17. (In Russian). https://doi.org/10.17816/2311-2905-7445.

✉ *Alexander Yu. Bazarov*; e-mail: tyumen_trauma@mail.ru

Submitted: 28.02.2023. Accepted: 27.04.2023. Published Online: 17.05.2023.

Научная статья
УДК 616.711-018.46-002-08
https://doi.org/10.17816/2311-2905-7445

Отдаленные результаты и оценка эффективности методов лечения остеомиелита позвоночника при различных типах поражений по классификации E. Pola

А.Ю. Базаров [1,2], К.С. Сергеев [2], А.К. Цветкова [2]

[1] *ГБУЗ ТО «Областная клиническая больница № 2, г. Тюмень, Россия*

[2] *ФГБОУ ВО «Тюменский государственный медицинский университет» Минздрава России, г. Тюмень, Россия*

Реферат

Актуальность. Лечение гематогенного остеомиелита позвоночника (ГОП) сопровождается рядом организационных и тактических проблем, связанных с мультидисциплинарным характером заболевания. При этом абсолютно необходимо использование классификаций, определяющих тактику лечения. Оценку результатов и эффективности методов лечения целесообразно проводить в соответствии с классификационным типом поражения и решениями, принятыми на основании тактического алгоритма.

Цель исследования — выявить зависимость отдаленных результатов лечения гематогенного остеомиелита позвоночника от типа поражения по модифицированной русскоязычной версии классификации E. Pola и использованных методов лечения.

Материал и методы. Выполнен анализ результатов лечения 266 больных гематогенным остеомиелитом позвоночника за 2006–2019 гг. Поражения типа A составили 24,1% (n = 64), B — 47,0% (n = 125), C — 26,3% (n = 70), поражения отростков позвонков — 2,6% (n = 7). Неврологические нарушения выявлены в 53 наблюдениях (тип C). Выполнялись консервативное лечение, санирующие, стабилизирующие и реконструктивные вмешательства. Оценка результатов проводилась через год и более после выписки.

Результаты. Отмечена максимальная эффективность консервативного метода при неосложненном течении и незначительной костной деструкции. Консервативное лечение поражений A привело к выздоровлению в 97,4% наблюдений в сравнении с реконструктивными операциями (p = 0,002) и рецидивами (p = 0,034). Летальность была выше после реконструктивных вмешательств (p = 0,001). При поражениях типа B отмечено максимальное количество летальных исходов после санации очага — 15,8% (p = 0,022). Анализ поражений типа C не выявил значимых различий между использованными методами лечения. Максимальное количество неудовлетворительных результатов зарегистрировано у больных с сепсисом: летальность составила 17,4%, а при его отсутствии — 4,9% (p = 0,039), рецидивы — 21,7% против 7,8% (p = 0,043), выздоровления — 56,6% против 83,5% (p = 0,004) соответственно. Различий в оценках по шкалам ODI, NDI, SF-36 в отдаленном периоде не выявлено. Общая выживаемость составила 84,4%, отдаленная — 90,4% с ее повышением при консервативном лечении в сравнении с реконструктивными вмешательствами (p = 0,045).

Заключение. Консервативное лечение и внеочаговая фиксация позвоночника показали максимальную эффективность при малодеструктивных и неосложненных поражениях (тип A). Реконструктивные вмешательства приводят к повышению количества рецидивов и летальных исходов. Санация очага при септическом течении поражений типа B приводит к увеличению госпитальной летальности. Не выявлено статистически значимых различий между результатами различных методов лечения поражений типа C различными методами лечения.

Ключевые слова: остеомиелит позвоночника, спондилит, спондилодисцит, классификация остеомиелита позвоночника.

Для цитирования: Базаров А.Ю., Сергеев К.С., Цветкова А.К. Отдаленные результаты и оценка эффективности методов лечения остеомиелита позвоночника при различных типах поражений по классификации E. Pola. *Травматология и ортопедия России*. 2023;29(2):7-17. https://doi.org/10.17816/2311-2905-7445.

Базаров Александр Юрьевич; e-mail: tyumen_trauma@mail.ru

Рукопись получена: 28.02.2023. Рукопись одобрена: 27.04.2023. Статья опубликована онлайн: 17.05.2023.

BACKGROUND

Increasing life expectancy, the presence of comorbidities in the older age group, a significant increase in the volume of planned surgical care for the population, and the proportion of patients with immunodeficiency have led to a significant rise in inflammatory spinal disorders [1, 2, 3, 4]. In the general population, there has been an increase in the incidence of vertebral osteomyelitis (VO) from 2.2 per 100,000 population per year in 2008 to 11.3 in 2019. This rate reaches 21.6 per 100,000 population per year in the age group over 70 and 25.1 in the age group 80 and above [5, 6, 7].

The International Classification of Diseases, 10th Revision (ICD-10) is the primary classification used in most studies for documentation purposes and does not influence the choice of treatment [5, 7]. Guidelines and recommendations are used to determine treatment strategies [8, 9, 10, 11, 12], but a systematic evaluation of treatment outcomes based on the classification used is not provided. E. Pola et al. proposed a new classification for spondylodiscitis, the New Classification of Pyogenic Spondylodiscitis (NCPS), in 2017, with an inter-expert agreement among trained specialists of 67% [14]. The classification provides general data on treatment outcomes, including the proportion of recoveries, recurrences, fatal outcomes, and residual back pain based on the type of lesion, but an analysis of the effectiveness of treatment methods is not provided, and ventral interventions are absent from the treatment algorithm [13].

The aim of this study was to determine the relationship between long-term treatment outcomes of vertebral osteomyelitis and the type of lesion according to the modified Russian version of E. Pola's classification and the treatment methods used.

METHODS

Study design

A retrospective observational study was conducted.

The medical records of 266 patients with VO who underwent treatment from 2006 to 2019 at the State Budgetary Healthcare Institution Tyumen Regional Clinical Hospital No. 2, Tyumen, Russia, were analyzed.

Inclusion Criteria: all patients with nonspecific spinal osteomyelitis.

Exclusion Criteria:

– specific spondylitis (tuberculosis, brucellosis);

– postoperative spondylitis;

– lack of follow-up for one year or more since discharge;

– age under 18 years.

Patients

To determine the type of lesion, a modified Russian version of E. Pola's classification was used [15, 16]. The distribution of patients by types and subtypes is presented in Table 1.

Neurological disorders developed in 53 observations in patients with type C lesions. Acute and subacute forms of the disease were present in 160 (60.2%) patients, while chronic forms were present in 106 (39.8%) patients. The level of involvement was localized in the cervical spine in 20 (7.5%) observations, thoracic spine in 90 (33.8%), lumbar spine in 144 (54.1%), and multi-level processes were identified in 12 (4.5%) patients.

Table 1

Distribution of patients by types and subtypes of lesions, n (%)

Lesion type	Lesion subtype				Total
A	A.1 0 (0.0)	A.2 44 (68.8)	A.3 16 (25.0)	A.4 4 (6.2)	64 (100.0)
B	B.1 65 (52.0)	B.2 42 (33.6)	B.3.1 17 (13.6)	B.3.2 1 (0.8)	125 (100.0)
C	C.1 8 (11.4)	C.2 15 (21.4)	C.3 21 (30.0)	C.4 26 (37.2)	70 (100.0)
Lesions not classified according to NCPS*	7 (100.0)				7 (100.0)

* Lesions of posterior structures without involvement of the spinal-motor segment (n=6) and CI-CII articulation (n=1).

Conservative therapy was performed in 88 (33.1%) patients, while 178 (66.9%) patients underwent surgery. Debridement, stabilization, and reconstructive surgeries were applied (Table 2).

Ventral interventions were performed in 108 patients, with transpedicular fixation added in 75 (69.4%) cases. Anterior 360° spondylodesis, including reconstruction, was performed in 29 (26.8%) patients. The duration of hospital stay was 30.01±16.42 days.

Outcome assessment

Outcome assessment was conducted one year after discharge from the hospital. In the long-term period, the following were evaluated: pain severity using the Visual Analog Scale (VAS), functional status of the cervical spine using the Neck Disability Index (NDI), and the lumbar spine using the Oswestry Disability Index (ODI), severity of neurological di-sorders using the Frankel scale, and data from the SF-36 questionnaire.

Table 2

Distribution of patients by treatment methods and lesion type, n (%)

Treatment method	Lesion type			Lesions not classified according to NCPS * 7 (2.6)	Total 266 (100.0)
	A 64 (24.1)	B 125 (47.0)	C 70 (26.3)		
Conservative	38 (59.4)	42 (33.6)	7 (10.0)	2 (28.6)	89 (33.4)
Debridement	12 (18.7)	19 (15.2)	24 (34.3)	5 (71.4)	60 (22.6)
Stabilization	11 (17.2)	33 (26.4)	6 (8.6)	0 (0.0)	50 (18.8)
Reconstruction	3 (4.7)	31 (24.8)	33 (47.1)	0 (0.0)	67 (25.2)

* Lesions of the posterior structures without involvement of the spinal motion segment (n = 6) and the CI–CII articulation (n = 1).

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics 21 software package.

The distribution of quantitative variables was assessed using the Kolmogorov-Smirnov test. For normally distributed variables, the results are presented as the mean (M) and standard deviation (SD), while for non-normally distributed variables, the results are presented as the median (Me) and interquartile range (25^{th} and 75^{th} percentiles). Student's t-test was used for comparing variables between two groups with normal distribution, and the Mann-Whitney U test was used for non-normally distributed variables. One-way analysis of variance (ANOVA) or the Kruskal-Wallis test with Bonferroni correction was used for comparing variables among more than two groups. The Wilcoxon signed-rank test was used for comparing variables over time. Categorical variables in independent groups were compared using the chi-square test or Fisher's exact test, and in paired groups using McNemar's test. When comparing more than two groups, the significance level was adjusted using the Bonferroni correction by multiplying the original p-values by the number of performed comparisons. Survival analysis was performed using the Kaplan-Meier method with survival curves and the log-rank test for comparing survival between groups. Differences were considered significant at $p<0.05$.

RESULTS

All patients received inpatient treatment at the Traumatology and Orthopedics or Neurosurgery department of Hospital No. 2 in Tyumen. In most cases, the length of hospital stay was determined by the duration of the course of antibiotic therapy (ABT) for conservative treatment and the postoperative period. The average duration of ABT was 1.8-3.8 weeks during hospitalization and 4.0-7.2 weeks on an outpatient basis. An increase in the duration of antibiotic treatment was observed from mono-segmental lesions to poly-segmental and multi-level lesions, which amounted to 1.8-3.8 and 1.6-4.2 weeks during the hospital stage, and 3.9-7.2 and 4.2-7.2 weeks during the outpatient stage.

Surgical treatment methods were divided into three main types: debridement, stabilization, and reconstructive. The effectiveness of these me-thods was assessed based on the main types of lesions according to E. Pola's classification with co-authors. A statistically significant increase in the number of stabilization procedures was noted for type A lesions compared to more severe forms of the disease (p<0.001). In these cases, transpedicular fixation was performed in a minimally invasive manner without intervention at the infectious-inflammatory focus, which eliminated the need for prolonged wearing of a rigid brace and improved the quality of life. The proportion of reconstructive interventions increased for type B (p = 0.036) and type C (p<0.001) lesions compared to lesions without bone destruction, neurological disorders, and epidural abscess (type A).

The distribution of outcomes based on the type of lesion and treatment method is presented in Table 3. When analyzing the data presented in Table 3, some statistically significant differences were found for different types of lesions.

For type A lesions: the highest number of recovered patients was observed with conservative treatment (97.4%) and stabilization surgeries (90.9%), while the lowest was observed with reconstructive interventions at 33.3% (p = 0.002). Performing reconstructive interventions for these lesions resulted in a 66.7% mortality rate, whereas the mortality rate for conservative therapy was 2.6% (p = 0.001).

For type B lesions: conservative treatment remains highly effective for subtypes B.1 (82.8%) and B.2 (85.7%), which decreases with increasing severity of bone destruction. After extrafocal instrumental fixation for mild-destructive lesions, the recovery rates were 82.4% for B.1 and 100% for B.2. Bone-destructive processes with objective signs of segmental instability were an indication for reconstructive surgeries, including the use of ventral approaches. Overall, in-hospital mortality for type B lesions was 4.0%, and an increase in mortality was observed after debridement interventions to 15.8% (p = 0.022), with the indication for surgery being the patient's overall severe condition.

For type C lesions: conservative treatment was only used in the absence of neurological disorders and/or in the presence of absolute contraindications for surgery. Extrafocal stabilization was performed exclusively for subtypes C.1 and C.2 in neurologically intact patients. Focal lesion drainage and decompression via ventral or dorsal access were the preferred methods in cases of acute neurological deficit or sepsis when reconstruction was not possible due to the severity of the patient's condition. Stable hemodynamics and compensation of

Table 3

Disease outcomes according to lesion type and treatment method, n (%)

Lesion type	Treatment outcome*	Treatment method				p
		Conservative	Surgical			
			Debridement	Stabilization	Reconstruction	
A	Recovery	37 (97.4)	10 (83.3)	10 (90.9)	1 (33.3)	0.002
	Recurrence	0 (0.0)	2 (16.7)	1 (9.1)	0 (0.0)	0.089
	Fatal	1 (2.6)	0 (0.0)	0 (0.0)	2 (66.7)	0.001
	Total	38 (100.0)	12 (100.0)	11 (100.0)	3 (100.0)	
B	Recovery	35 (83.3)	12 (63.2)	30 (90.9)	26 (83.9)	0.087
	Recurrence	3 (7.1)	3 (15.8)	3 (9.1)	4 (12.9)	0.720
	Fatal	2 (4.8)	3 (15.8)	0 (0.0)	0 (0.0)	0.022
	Progression	2 (4.8)	1 (5.3)	0 (0.0)	1 (3.2)	0.641
	Total	42 (100.0)	19 (100.0)	33 (100.0)	31 (100.0)	
C	Recovery	5 (83.3)	17 (68.0)	5 (83.3)	23 (69.7)	0.795
	Recurrence	1 (16.7)	5 (20.0)	0 (0.0)	1 (3.0)	0.137
	Fatal	0 (0.0)	2 (8.0)	0 (0.0)	5 (15.2)	0.490
	Progression	0 (0.0)	1 (4.0)	1 (16.7)	4 (12.1)	0.520
	Total	6 (100.0)	25 (100.0)	6 (100.0)	33 (100.0)	

* One patient with a fatal outcome in monovertebral lesion (not classified according to NCPS) is not included in the table.

vital functions were the basis for reconstructive interventions for subtypes C.2-C.4. We did not find statistically significant differences in the number of cases of recovery, recurrence, and in-hospital mortality depending on the treatment method, which suggests a correct tactical approach in the treatment of type C lesions. The treatment outcomes of HOP based on the type of lesion, regardless of the treatment method, are presented in Table 4.

When analyzing the data presented in Table 4, a statistically significant decrease in the number of recovered patients was observed with increasing severity of spinal cord lesions (p = 0.016). The severity of neurological disorders was higher in patients after debridement (p = 0.002) and reconstructive interventions (p<0.001) both before and after treatment (p = 0.001, p<0.001, respectively). A statistically significant decrease in the severity of neurological deficit in the postoperative period was observed after debridement and reconstructive interventions (p = 0.004), while no such relationship was found after stabilization surgeries (p = 0.180). The dynamics of neurological deficit before and after treatment depending on the method are presented in Table 5.

In the conservative and surgical treatment groups, the severity of neurological disorders was significantly lower in the long-term period (p<0.001).

Significant differences in treatment outcomes were observed in patients with sepsis, which occurred in 26.1% (n = 6) of type A lesions, 34.8% (n = 8) of type B lesions, and 39.1% (n = 9) of type C lesions. The treatment outcomes depending on the presence of sepsis are presented in Table 6.

The analysis revealed a statistically significant increase in the proportion of in-hospital mortality by 12.5% (p = 0.039), recurrence by 13.9% (p = 0.043), and a decrease in the number of recovered patients by 27% (p = 0.004) in the presence of sepsis compared to the group of patients without this complication.

The long-term results were evaluated no earlier than one year after discharge from the hospital. The main criteria were the severity of pain syndrome assessed by VAS, the functional status of the spine assessed by ODI and NDI, and the overall health status of the patient assessed by SF-36. A statistically significant decrease in the severity of pain syndrome was observed after one year or more after discharge (p<0.001). The treatment results depending on the method are presented in Table 7.

No statistically significant differences were found when comparing the results between the comparison groups. The indicators reflecting the long-term treatment outcomes depending on the type of lesion are presented in Table 8.

When analyzing the intensity of pain depending on the main types of lesions according to E. Pola, a decrease in pain intensity was also observed in the long-term period (p < 0.001) in all comparison groups. No differences in the severity of pain syndrome were found depending on the type of lesion (p>0.05).

Survival analysis was conducted based on data from 198 patients, which accounted for 74.4% of the total cohort. The follow-up period for the patients was 47.50 [25.00; 82.00] months.

The overall survival rate for all types of lesions over the entire follow-up period was 84.4%. No statistically significant differences were found between the types of lesions, but in absolute numbers, this indicator decreased with increasing severity of the disease: 92.1% for type A, 86.8% for type B, and 76.0% for type C. There was a tendency towards higher survival rates in type A compared to type C (p = 0.080). Analysis of the proportion of surviving patients in conservative treatment and the

Table 4

Distribution of patients according to treatment outcomes based on lesion type regardless of treatment method, n (%)

Criterion	Lesion type			*p*
	A	B	C	
Recovery	57 (89.0)	103 (82.4)	50 (71.4)	0.016
Recurrence / Progression	4 (6.3)	17 (13.6)	13 (18.6)	0.106
Hospital mortality	3 (4.7)	5 (4.0)	7 (10.0)	0.207
Total	64 (100.0)	125 (100.0)	70 (100.0)	—

Table 5

Neurological deficit before and after treatment based on treatment method, n (%)

Neurological deficit by Frankel grade	Treatment method			
	Conservative		Surgical	
	Before treatment	After treatment	Before treatment	After treatment
A	0 (0.0)	0 (0.0)	12 (6.7)	7 (3.9)
B	0 (0.0)	0 (0.0)	9 (5.1)	2 (1.1)
C	1 (1.1)	0 (0.0)	20 (11.2)	16 (9.0)
D	1 (1.1)	0 (0.0)	10 (5.6)	19 (10.7)
E	86 (97.8)	88 (100.0)	124 (69.7)	134 (75.3)
R*	0 (0.0)	0 (0.0)	3 (1.7)	0 (0.0)

* R - Radicular syndrome; *p*<0.001.

Table 6

Treatment outcomes based on the presence of sepsis, n (%)

Criterion	Sepsis		*p*
	Absent	Present	
Recovery	203 (83.5)	13 (56.5)	0.004
Recurrence	19 (7.8)	5 (21.7)	0.043
Progression*	9 (3.8)	1 (4.3)	0.602
Hospital mortality	12 (4.9)	4 (17.4)	0.039
Total	243 (100.0)	23 (100.0)	—

* Progression against the background of complex treatment.

Table 7

Long-term treatment outcomes based on treatment method

Criterion	Treatment method		*p*
	Conservative	Surgical	
VAS before treatment. Me [25%; 75%]	9.0 [8.00; 10.00]	9.0 [8.00; 10.00]	0.790
VAS after treatment, Me [25%; 75%]	2.0 [0.00; 4.00]	2.0 [0.00; 3.00]	0.425
NDI, Me [25%; 75%]	–	12.17 [9.00; 17.00]	–
ODI, Me [25%; 75%]	16.0 [4.00; 26.00]	12.67 [2.00; 31.10]	0.626
PH (SF-36), M±SD	40.33±10.04	41.00±10.57	0.824
MH (SF-36), M±SD	47.00±11.62	47.28±10.71	0.776

When comparing the intensity of pain syndrome before treatment and in the long-term period, a statistically significant reduction was observed within the comparison groups (p<0.001).

Table 8

Long-term treatment outcomes based on lesion type

Criterion	Lesion type			p
	A	B	C	
	Me [25; 75%]	Me [25; 75%]	Me [25; 75%]	
VAS before treatment, Me [25%; 75%]	9.0 [8.00; 10.00]	9.0 [8.00; 10.00]	10.0 [8.00; 10.00]	0.640
VAS after treatment, Me [25%; 75%]	2.0 [0.00; 4.00]	2.0 [0.00; 2.00]	2.0 [0.00; 4.00]	0.260
NDI, Me [25%; 75%]	–	–	12.17 [9.00; 17.00]	–
ODI, Me [25%; 75%]	16.0 [0.00; 20.00]	13.33 [4.00; 28.00]	29.40 [4.00; 36.00]	0.223
PH (SF-36), M±SD	39.26±9.10	41.59±10.23	39.69±11.29	0.578
MH (SF-36), M±SD	47.55±8.14	46.98±11.28	47.37±12.37	0.973

When comparing the intensity of pain syndrome before treatment and in the long-term period, a statistically significant reduction was observed within the comparison groups ($p<0.001$).

main types of surgical interventions revealed the following differences: survival rate in conservative treatment reached 92.1%, in stabilization surgeries — 88.9%, in debridement — 84.2%, and in reconstructive interventions — 74.3%.

Statistically significant differences were found between conservative treatment and 360° spinal fusion (log rank = 4.028; p = 0.045). The highest survival rate was observed in the absence of surgical intervention and decreased with increasing volume and invasiveness.

Long-term survival (after discharge from the hospital) was 90.4%, and no statistically significant differences were found between the conservative and surgical treatment groups — 95.5% and 88.4% respectively (log rank = 1.286; p = 0.257) (Fig. 1).

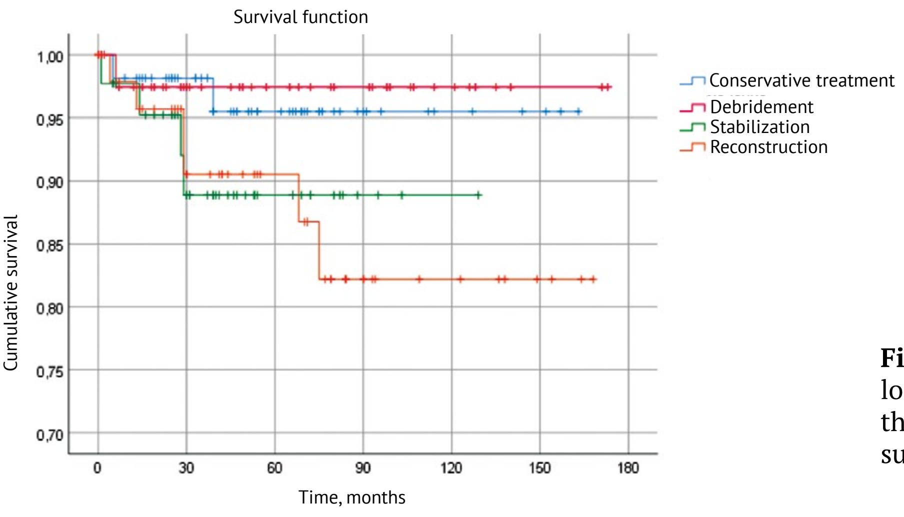

Fig. 1. Patient survival in the long-term period depending on the treatment method and type of surgery

DISCUSSION

Evaluation of the treatment outcomes of pyogenic spondylodiscitis (PSD) in most publications is traditionally conducted through comparisons of the localization of the pathological process, presence of complications, effectiveness of treatment methods, and types of surgeries [17, 18, 19, 20, 21, 22, 23], or it is justified by the necessity of surgical treatment in the absence of adequate progress with conservative therapy [24]. The need for a multidisciplinary approach to PSD treatment is acknowledged by many researchers [25, 26]. The initial experience of applying tactical classifications and algorithms aims to prove the validity of this approach, and authors present general treatment outcomes based on the different variants of the pathological process without providing evidence of the effectiveness of the proposed treatment options [10, 11, 13].

While the development of a tactical classification is considered the first step in the treatment of multidisciplinary conditions [10, 27], and the validation of its accuracy is the second step [14, 16], the third step undoubtedly should be the evaluation of the effectiveness of the proposed algorithm, which involves matching the type/subtype of the lesion to the chosen treatment method. The use of the aforementioned classifications in clinical practice allows for better consideration of the various disease progressions, as demonstrated in the New Classification for the Treatment of Pyogenic Spondylodiscitis by E. Pola et al. [13], without increasing the complexity of its application. Although the use of this classification in Russia is currently recommended, it is actively applied in specialized institutions where patients with spinal osteomyelitis are treated [16].

The original paper by E. Pola et al. presented three main types of lesions: Type A, without bone destruction; Type B, with bone destruction; and Type C, with epidural abscess and/or neurological deficit. The criteria, such as the degree of involvement of paravertebral tissues, instability of the affected spinal segment, and presence of neurological deficit, allow for the selection of the optimal treatment approach for patients [13]. However, there are some limitations to the use of this classification, including specific etiology of the disease, postoperative spondylodiscitis, and localization in the cervical spine [16]. Additional considerations, such as accounting for the presence of systemic inflammatory response syndrome and sepsis, as well as treatment options for cervical spine involvement, are necessary for the development of an algorithm that takes into account lesions in all segments of the spine and the most significant complications [28].

The results presented in our study are based on three main types of lesions. Conservative treatment is the primary method for Type A lesions, compared to Types B and C, where the proportion of surgical interventions significantly increases ($p<0.01$). Laminectomy was performed more frequently for Type C lesions than for Type B ($p<0.001$). The use of posterior approaches with bone resection elements for Types B and C can only be justified for lesions involving the vertebral arches or processes or for reconstruction using a posterior approach. The frequency of anterior debridement and/or reconstruction increases for Type C lesions compared to Types A ($p = 0.012$) and B ($p<0.001$). Thus, the extent of surgical intervention correlates strictly with the type/subtype of the lesion (severity of the disease), while maintaining the high effectiveness of conservative treatment in uncomplicated cases.

Considering the lack of data on the effectiveness of treatment methods in the work by E. Pola et al., we conducted a comparative analysis of the main outcomes, taking into account a comparable number of patients in both studies — 250 and 259 observations, respectively — classified according to the New Classification for the Treatment of Pyogenic Spondylodiscitis (NCPS). The comparative analysis of our own treatment outcomes for PSD with the data from E. Pola et al. is presented in Table 9.

The studies presented here show differences in the disease structure, diagnostic timelines, and consequently, treatment outcomes, due to the predominance of Type C lesions in the work by E. Pola et al. and Type B lesions in our study. It is important to note that comparing the total number of patients without analyzing the subtypes, considering the severity of neurological deficit, extent of paravertebral abscesses, and instability of the affected spinal segment, does not allow for a direct comparison of the results obtained. These differences may be attributed to differences in the timing of diagnosis, age composition of the studied cohorts, comorbidities, and organization of patient care. It is crucial to emphasize that adherence to tactical classifications and treatment algorithms must be consistent with the basic principles of PSD treatment, including appropriate composition and duration of antibiotic therapy and immobilization of the affected spinal segment [9, 24, 29, 30].

Further investigation into the effectiveness of treatment methods for spinal osteomyelitis, specifically in relation to lesion types and the justification of tactical algorithms, should be conducted in a multicenter prospective study. This would help address various organizational and practical challenges in the treatment of this multidisciplinary condition.

CONCLUSION

A systemic approach to treatment using a tactical classification and treatment algorithm allows for the assessment of the effectiveness of the utilized methods for different types of spinal osteomyelitis. For minimally destructive and non-septic Type A and Type B lesions, conservative treatment and focal stabilization achieve 97.4% and 90.9% of recoveries, respectively ($p = 0.002$). The use of reconstructive interventions leads to an increase in recurrence rate and mortality ($p = 0.001$). The mortality rate for Type B lesions after debridement procedures reaches 15.8%

Table 9

Distribution of treatment outcomes for hematogenous spondylodiscitis based on lesion type compared to the data from E. Pola et al. [13], n (%)

Treatment outcome	Lesion type					
	A		B		C	
	E. Pola et al.	Own research	E. Pola et al.	Own research	E. Pola et al.	Own research
Recovery	81 (96.43)	57 (89.06)	43 (93.48)	103 (82.40)	108 (90.00)	50 (71.43)
Recurrence	8 (9.52)	4 (6.25)	2 (4.35)	17 (13.60)	4 (3.33)	13 (18.57)
Mortality	3 (3.57)	3 (4.69)	3 (6.52)	5 (4.00)	6 (5.00)	7 (10.00)
Total	84 (33.60)	64 (24.10)	46 (18.40)	125 (47.00)	120 (48.00)	70 (26.30)

(p=0.022), which is attributed to the presence of sepsis in operated patients. No statistically significant differences were found in the results of the presented treatment methods for Type C lesions. A significant reduction in pain syndrome in the long-term period was observed in all patient groups (p<0.001), as well as a decrease in the severity of neurological deficits in the postoperative period (p<0.001). No differences in treatment outcomes were found in the long-term period based on ODI, NDI, and SF-36 scales. The overall survival rate was 84.4%, and the long-term survival rate was 90.4%, with a significant increase in survival observed with conservative treatment compared to reconstructive interventions.

DISCLAIMERS

Author contribution

Bazarov A.Yu. — the conception and design of the study, the analysis and interpretation of data, the writing of the article.

Sergeev K.S. — the analysis and interpretation of data, the drafting of the article.

Tsvetkova A.K. — data collection and processing.

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.

Funding source. This study was not supported by any external sources of funding.

Disclosure competing interests. The authors declare that they have no competing interests.

Ethics approval. Not applicable.

Consent for publication. Not required.

REFERENCES

1. Sobottke R., Zarghooni K., Krengel M., Delank S., Seifert H., Fätkenheuer G. et al. Treatment of spondylodiscitis in human immunodeficiency virus-infected patients: a comparison of conservative and operative therapy. *Spine (Phila Pa 1976)*. 2009;34(13):E452-458. doi: 10.1097/BRS.0b013e3181a0aa5b.
2. Vichnevsky A.A. The nonspecific osteomyelitis of the spine as a problem of nosocomial infection. *Voprosy travmatologii i ortopedii*. 2013;1(6):14-19. (In Russian).
3. Shuvalova E.V., Vishnevskiy A.A. Comorbidity in patients with HIV infection and tuberculous spondylitis as a risk factor for infectious complications. *Spine Surgery.* 2020;17(1):96-101. (In Russian). doi: 10.14531/ss2020.1.96-101.
4. Maamari J., Tande A.J., Diehn F., Tai D.B.G., Berbari E.F. Diagnosis of vertebral osteomyelitis. *J Bone Joint Infect*. 2022;7(1):23-32. doi: 10.5194/jbji-7-23-2022.
5. Grammatico L., Baron S., Rusch E., Lepage B., Surer N., Desenclos J.C., Besnier J.M. Epidemiology of vertebral osteomyelitis (VO) in France: analysis of hospital-discharge data 2002-2003. *Epidemiol Infect.* 2008;136(5):653-660. doi: 10.1017/S0950268807008850.
6. Akiyama T., Chikuda H., Yasunaga H., Horiguchi H., Fushimi K., Saita K. Incidence and risk factors for mortality of vertebral osteomyelitis: a retrospective analysis using the Japanese diagnosis procedure combination database. *BMJ Open.* 2013;3(3):e002412. doi: 10.1136/bmjopen-2012-002412.
7. Conan Y., Laurent E., Belin Y., Lacasse M., Amelot A., Mulleman D. et al. Large increase of vertebral osteomyelitis in France: a 2010-2019 cross-sectional study. *Epidemiol Infect.* 2021;149:e227. doi: 10.1017/S0950268821002181.
8. Primary infectious spondylitis, and following intradiscal procedure, without prothesis. Short text. *Med Mal Infect.* 2007;37(9):554-572. (In French). doi: 10.1016/j.medmal.2007.03.008.
9. Berbari E.F., Kanj S.S., Kowalski T.J., Darouiche R.O., Widmer A.F., Schmitt S.K. et al. Infectious Diseases Society of America. 2015 Infectious Diseases Society of America (IDSA) Clinical Practice Guidelines for the Diagnosis and Treatment of Native Vertebral Osteomyelitis in Adults. *Clin Infect Dis.* 2015;61(6):e26-46. doi: 10.1093/cid/civ482.
10. Homagk L., Homagk N., Klauss J.R., Roehl K., Hofmann G.O., Marmelstein D. Spondylodiscitis severity code: scoring system for the classification and treatment of non-specific spondylodiscitis. *Eur Spine J.* 2016;25(4):1012-1020. doi: 10.1007/s00586-015-3936-8.

11. Homagk L., Homagk N., Meise H.J., Hofmann G.O., Marmelstein D.A. Spondylodiscitis scoring system: SponDT – spondylodiscitis diagnosis and treatment. *JSM Spine*. 2016;1(1):1004. Available from: https://www. jscimedcentral.com/Spine/spine-1-1004.pdf.
12. Lazzeri E., Bozzao A., Cataldo M.A., Petrosillo N., Manfrè L., Trampuz A. et al. Joint EANM/ESNR and ESCMID-endorsed consensus document for the diagnosis of spine infection (spondylodiscitis) in adults. *Eur J Nucl Med Mol Imaging*. 2019;46(12):2464-2487. doi: 10.1007/s00259-019-04393-6.
13. Pola E., Autore G., Formica V.M., Pambianco V., Colangelo D., Cauda R. et al. New classification for the treatment of pyogenic spondylodiscitis: validation study on a population of 250 patients with a follow-up of 2 years. *Eur Spine J*. 2017;26(Suppl 4):479-488. doi: 10.1007/s00586-017-5043-5.
14. Willhuber G.C., Guiroy A., Zamorano J., Astur N., Valacco M. Independent Reliability Analysis of a New Classification for Pyogenic Spondylodiscitis. *Global Spine J*. 2021;11(5):669-673. doi: 10.1177/2192568220919091.
15. Bazarov A.Y. Classifications of Non-Specific Hematogenous Vertebral Osteomyelitis. Critical Review and Suggestions for Clinical Use. *Traumatology and Orthopedics of Russia*. 2019;25(1):146-155. doi: 10.21823/2311-2905-2019-25-1-146-155.
16. Bazarov A.Yu., Naumov D.G., Mushkin A.Yu., Sergeyev K.S., Ryabykh S.O., Vishnevsky A.A. et al. A new classification of spondylodiscitis: possibility of validation and multidisciplinary expert consensus. *Spine Surgery*. 2022;19(4):68-76. (In Russian). doi: 10.14531/ss2022.4.68-76.
17. Naumov D.G., Tkach S.G., Mushkin A.Yu., Makogonova M.E. Chronic infectious lesions of the cervical spine in adults: monocentric cohort analysis and literature review. *Spine Surgery*. 2021;18(3):68-76. (In Russian). doi: 10.14531/ss2021.3.68-76.
18. Yagdiran A., Otto-Lambertz C., Lingscheid K.M., Sircar K., Samel C., Scheyerer M.J. et al. Quality of life and mortality after surgical treatment for vertebral osteomyelitis (VO): a prospective study. *Eur Spine J*. 2021;30(6): 1721-1731. doi: 10.1007/s00586-020-06519-z.
19. Rutges J.P., Kempen D.H., van Dijk M., Oner F.C. Outcome of conservative and surgical treatment of pyogenicspondylodiscitis: a systematic literature review. *Eur Spine J*. 2016;25(4):983-999. doi: 10.1007/s00586-015-4318-y.
20. Herren C., Jung N., Pishnamaz M., Breuninger M., Siewe J., Sobottke R. Spondylodiscitis: Diagnosis and Treatment Options. *Dtsch Arztebl Int*. 2017;114(51-52):875-882. doi: 10.3238/arztebl.2017.0875.
21. Luo W., Ou Y.S., Du X., Wang B. Anterior oblique retroperitoneal approach vs posterior transpedicularapproach for the treatment of one- or two-level lumbar vertebral osteomyelitis: a retrospective cohort study. *Int Orthop*. 2020;44(11):2349-2356. doi: 10.1007/s00264-020-04650-6.
22. Lee J.H., Kim J., Kim T.H. Clinical Outcomes in Older Patients Aged over 75 Years Who Underwent Early Surgical Treatment for Pyogenic Vertebral Osteomyelitis. *J Clin Med*. 2021;10(22):5451. doi: 10.3390/jcm10225451.
23. Mehkri Y., Felisma P., Panther E., Lucke-Wold B. Osteomyelitis of the spine: treatments and future directions. *Infect Dis Res*. 2022;3(1):3. doi: 10.53388/idr20220117003.
24. Giampaolini N., Berdini M., Rotini M., Palmisani R., Specchia N., Martiniani M. Non-specific spondylodiscitis: a new perspective for surgical treatment. *Eur Spine J*. 2022;31(2): 461-472. doi: 10.1007/s00586-021-07072-z.
25. Ntalos D., Schoof B., Thiesen D.M., Viezens L., Kleinertz H., Rohde H. et al. Implementation of a multidisciplinary infections conference improves the treatment of spondylodiscitis. *Sci Rep*. 2021;11(1):9515. doi: 10.1038/s41598-021-89088-5.
26. Pola E., Taccari F., Autore G., Giovannenze F., Pambianco V., Cauda R. et al. Multidisciplinary management of pyogenic spondylodiscitis: epidemiological and clinical features, prognostic factors and long-term outcomes in 207 patients. *Eur Spine J*. 2018;27(Suppl 2): 229-236. doi: 10.1007/s00586-018-5598-9.
27. Almansour H., Pepke W., Akbar M. Pyogenic spondylodiscitis. The quest towards a clinical-radiological classification. *Orthopade*. 2020;49(6):482-493. doi: 10.1007/s00132-019-03836-0.
28. Bazarov A.Yu. Actual tactical classifications of the infectious inflammatory lesions of the cervical spine and their use on the example of a series of 24 cases. *Spine Surgery*. 2022;19(2):57-66. (In Russian). doi: 10.14531/ss2022.2.57-66.
29. Bernard L., Dinh A., Ghout I., Simo D., Zeller V., Issartel B. et al. Duration of Treatment for Spondylodiscitis (DTS) study group. Antibiotic treatment for 6 weeks versus 12 weeks in patients with pyogenic vertebral osteomyelitis: an open-label, non-inferiority, randomised, controlled trial. *Lancet*. 2015;385(9971): 875-882. doi: 10.1016/S0140-6736(14)61233-2.
30. Park K.H., Cho O.H., Lee J.H., Park J.S., Ryu K.N., Park S.Y. et al. Optimal Duration of Antibiotic Therapy in Patients With Hematogenous Vertebral Osteomyelitis at Low Risk and High Risk of Recurrence. *Clin Infect Dis*. 2016;62(10):1262-1269. doi: 10.1093/cid/ciw098.

Authors' information

✉ *Alexander Yu. Bazarov* — Cand. Sci. (Med.)
Address: 75, Mel'nikayte st., Tyumen, 625039, Russia
https://orcid.org/0000-0002-5309-4667
e-mail: tyumen_trauma@mail.ru

Konstantin S. Sergeev — Dr. Sci. (Med.), Professor
https://orcid.org/0000-0002-6621-9449
e-mail: sergeev.trauma@inbox.ru

Aleksandra K. Tsvetkova
https://orcid.org/0000-0002-6035-261X
e-mail: sashablackberry1@gmail.com