# SPINAL RECONSTRUCTION WITH TITANIUM MESHES IN PEDIATRIC PATIENTS

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**Objective.** To analyze the results of using titanium meshes for anterior fusion in spinal reconstruction in pediatric patients.
**Material and Methods.** Design: A retrospective cohort study from 2011 to 2014. Spinal reconstruction in 108 patients aged 8 months to 17 years was performed with titanium meshes filled with bone autografts. The indications for surgery were Pott's disease (n = 41), non-specific chronic spondylitis and its sequences (n = 42), spinal tumors (n = 11) and congenital spinal deformities (n = 6). Additional posterior instrumentation was carried out in case of multilevel spinal reconstruction or for spinal deformity. Clinical and radiological FU results were evaluated at the 6, 12, 18 months after surgery with the analysis of infection reactivation risk, changes in the apical Cobb angle and dynamics of block formation in anterior fusion zone.
**Results.** No cases of infection reactivation or process aggravation were detected during 6 months after surgery. Two patients (with TB spondylitis and giant cell tumor) had deterioration of vertebral destruction with mesh instability in the period from 6 to 12 months after surgery. No one case of mesh stability preservation was associated with deformity progression. Solid bone block was formed in 97 % of operated patients at 12 months after surgery.
**Conclusion.** Using of meshes in reconstructive surgery on the spine in children does not increase the rate of postoperative complications even in infectious spondylitis, due to biological inertia of the non-resorbable material.
**Key Words:** titanium meshes, spine, spinal fusion, spinal tuberculosis, spondylitis, congenital spinal deformity, spinal tumors, children.

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Bone autografts and allografts: ribs, iliac crest, and cortical blocks were previously considered the main material for replacing post-resected interbody spinal defect [3, 5, 6]. However, these reconstructions were accompanied by a high risk of fractures, resorption, absence of transplant fusion, purulence in the area of plastic reconstruction, that is, the situations associated with biological activity of the bone tissue [7, 12]. Titanium mesh cages proposed by Harms in 1986 represent a round or oval hollow tube with a mesh wall with different mesh sizes. These titanium mesh cages have been widely used for spinal reconstruction in the last decade [10, 19] reducing the risk of the indicated complications due to biological inertness, relative ease of modeling, and stability of the anterior spinal column immediately at the time of implantation. The properties of the implant are particularly important in the presence of infectious process at baseline that forces to implement radical debridement and reconstruction and stabiliziation stages of surgery [16, 20, 23]. The meshes containing osteoinductive materials – bone autograft or biocomposites (bi- and tricalcium phosphate complexes) significantly expanded the possibilities for reconstructive spinal surgery and reduced the risk of unsatisfactory long-term surgical outcomes [4, 13, 18, 21, 24]. However, despite the sufficient number of publications reflecting the using of titanium meshes in adults, there are no data on their application in reconstructive spinal surgery in children and adolescents.

This paper presents the first Russian and international 4-year experience of using titanium mesh cages in reconstructive spinal surgery in pediatric patients.

The purpose of the study was to evaluate the outcomes of using the titanium meshes for anterior interbody fusion in pediatric spine reconstruction in children with different diseases.

Study design: a retrospective cohort formed using the inclusion criteria (this paper was not aimed to compare the effect of titanium meshes with other methods of anterior fusion).

## Material and Methods

A total of 319 spinal operations were performed at the Pediatric Surgery Department, Saint-Petersburg Research

Institute of Phthisiopulmonology, during 2011–2014. The patients were selected for inclusion in the study, based on the following criteria:

– age under 18 years at the time of surgery;

– implementinganterior spinal column reconstruction;

– using titanium mesh for anterior fusion;

– catamnesis duration at least 18 months prior to surgery ;

– presence of a complete radiation archive (radiologic or CT scans).

Based on the given criteria, 108 patients were selected for the study; however, eight of them discontinued from the study due to the lack of a complete radiation archive. Thus, the final analysis included data on 100 patients. The average age of children at the time of surgery was 13.6 ± 6.7 years (min – 8 month, max – 17 years). Titanium meshes were filled with bone autograft fragments in all cases of anterior fusion.

The indications for surgery included infectious or neoplastic destruction of the vertebrae, deterioration of spinal deformity (kyphotic or scoliotic), neurological disorders, and absence of response to antibacterial therapy over at least 2 months preoperatively in the cases of infectious spondylitis (tuberculous (TB) and non-specific spondylitis). The length of the disease was at least 4 months in all patients with destructive lesions of the spine at the time of surgery according to medical records.

Age ranking of the patients was conducted according to the approved periodization [2] and separation of early childhood (under 4 years), preschool (4–6 years), middle childhood (7–11 years) and secondary school (12–17) ages as graphically represented in Fig. 1. A general scheme of the study is shown in Fig. 2.

In cases when spinal reconstruction involved more than one spinal motion segment (3 or more vertebrae) or in spinal deformity, additional posterior instrumented fixation (PIF, n = 59) was performed with using transpedicular, laminar or hybrid constructs adapted for a particular age and weight group (the rod diameter was 3.5 to 5.5 mm).

The outcomes were studied in all operated children immediately and at 6, 12 and 18 months after surgery, and then once a year using radiography or, if possible, CT data. When evaluating conditionally long-term outcomes (a period of 18 months after surgery is not true long-term period for actively growing children), the study was conducted according to the regression graph of the total number of the examined children (Fig. 3).

Based on the etiological verification, patients were divided into 4 groups:

– Group 1 ($n_1$ = 42): TB spondylitis, including 33 patients with active TB spondylitis and 9 with its sequelae; postoperatively all the patients underwent a complex anti-TB chemotherapy according to the standard regimes lasting for at least 12 months;

– Group 2 ($n_2$ = 41): chronic nonspecific spondylitis and its sequelae, including 16 patients with monosegmental spondylodiscitis; at least two courses of antibacterial therapy were performed postoperatively based on the isolated microbiota;

– Group 3 ($n_3$ = 11): primary spinal tumors; patients with malignant lesions (n = 4) continued treatment at federal and regional medical oncological clinics after the operation; and

– Group 4 ($n_4$ = 6): congenital spinal deformities.

In all cases of destructive processes in the spine, etiological verification was conducted with a complex of morphological, biological and molecular genetic studies of the surgical specimens. In cases of vertebral anomalies, the diagnosis was established using radiologic data, which included radiologic spondilography in two projections, CT and MRI.

The patients were distributed as follows according to the spinal reconstruction level:

C : T : TL : L : LS = 9 : 31 : 12 : 43 : 5.

The study examined the following indicators:

1) infectious spondylitis flare frequency;

2) stability of deformity correction according the postoperative dynamic of the Cobb's angle (in degrees);

3) time course of anterior fusion (bone block formation) according to 5-point quantitative scale [1] with separate analysis of parameters for the upper and lower segments of the fusion zone (the parameter was studied in multilevel spinal reconstruction involving two or more spinal motion segments);

4) operative blood loss;

5) dynamics of neurological disorders before and after surgery according to the Frankel's scale [11];

6) pairwise correlations: a) age/number of the involved spinal motion segments; b) age/deformity magnitude; c) extent of reconstruction/operative blood loss; d) length of the bone block/grade of spinal fusion ≥4 scores; and e) use of PIF/grade of fusion ≥4 scores.

Statistical processing was performed with the Statistical Package for the Social Sciences software (SPSS), version 22.0 (SPSS Inc., Chicago, IL, USA). The sampling was checked for normality of distribution using the Pearson's goodness of fit test (Chi-square). Assessment of differences of average values with normal distribution using t-Student test = 1.984 (the confidence probability p = 0.05 when the number of degrees of freedom was 98); pair-wise correlation analysis with ranking the Pearson's correlation coefficient values ($p \leq 0.5$ is weak strength of the relationship; $0.5 < p \leq 0.7$ is moderate strength of the relationship, $p > 0.7$ is strong relationship), and evaluation of the bilateral significance of correlation with <0.05 were performed.

## Results and Discussion

The results were assessed based on the analyzed criteria.

1. The risk of infectious complications after surgery and deterioration/relapse of destructive process. In the short term after operation (follow up untill 6 months) no reactivation or aggravation of infection have been detected. From 6 till 12 months after surgery, the mesh instability due to disease progression was observed only in two cases (TB spon-

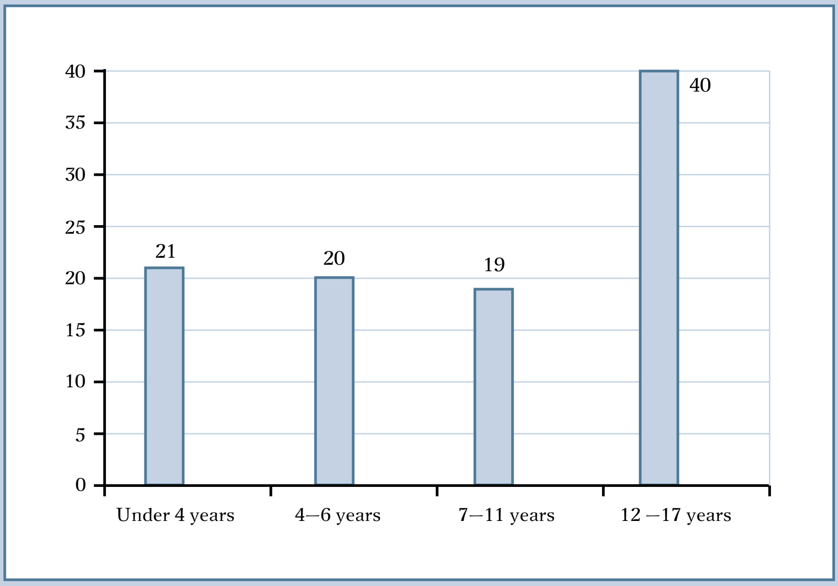


**Fig. 1**
Age distribution of children included in the study

dylitis and giant cell tumors). In other diseases, no loss of the implant stability were revealed.

2. Changes in correction of the kyphotic Cobb's angle (Table 1). The loss of surgical correction estimated according to the dynamics of postoperative changes in sagittal Cobb's angle did not exceed 5° at 18 months after surgery (min = 1.2°, max = 5°, M ± m = 3.2 ± 0.9°), which corresponds to the error in measuring the Cobb's angle.

3. Grade of the bone block formation in anterior fusion zone. At 6 months after the operation, vertebral bone block formation was estimated as 3 out of 5 scores in 95 % of cases. At 12 months after the operation, the signs of solid bone block in anterior fusion zone were graded as 4 and 5 scores in 97% of cases. Bone block grading by at 6 and 12 months after surgery is presented in Table 2.

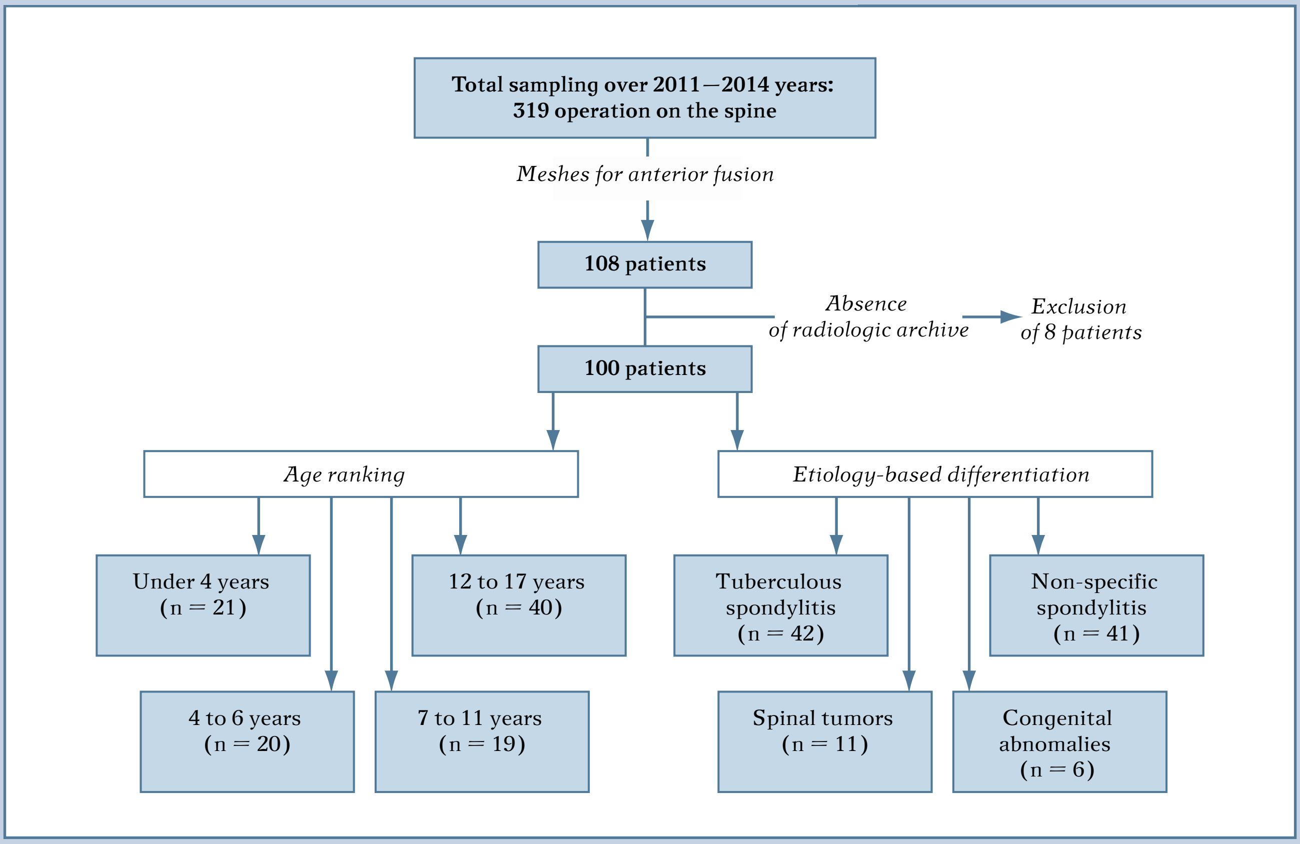


**Fig. 2**
A general scheme of the study with age distribution and etiology-based differentiation of a diagnosis

4. Operative blood loss was 207.9 ± 139.1 ml on average (min – 50.0, max – 500.0).

5. Preoperative neurological impairment was detected in 13 children (Table 3).

No cases of postoperative motor disorder aggravation were observed, in 8 cases the improvement was complete, including 7 patients with moderate features of myelopathy at baseline (type D according to the Frankel's scale) and in one patient with tetraplegia. Progression of neurological disorders in the long-term period after surgery was noted in one case (Patient 13, Table 3), it was caused by malignant tumor progression and led to death.

6. Correlation analysis. Pair-wise correlation analysis established relationships presented in Table 4.

Clinical examples of using titanium meshes for spinal reconstruction in children are shown in Figs. 4–6.

Spinal surgery is on the rise and it is undergoing a period of wide implementation of non-biological implants for anterior spinal support, specifically in infectious processes. This is associated with the high (from 6.5 to 40 %) incidence of long-term complications after anterior fusion with bone tissue leading to the loss of deformity correction [2, 14, 23]. Modern technologies of posterior instrumentation improve the quality of patient treatment, shorten the hospital stay, and prevent the development of complications [3, 22]. Harms titanium mesh cages are versatile interbody implants, which has been relatively long and successfully used in various spinal diseases in adults, including inflammation [3, 8, 13, 15, 16, 21, 24]. Eysel et al. [9] presented the first experience of their successful application in the treatment of 23 patients with spondylodiscitis as early as in 1997, with no detected cases of complications and loss of the Cobb's sagittal angle correction of no more than 2.7° in the long-term post-op period. However, during the study of the largest medical databases (Scopus, PubMed, ClinicalKey, eLIBRARY), we have found no papers describing the experience of application of titanium meshes in children, and thus, we have presented our own material.

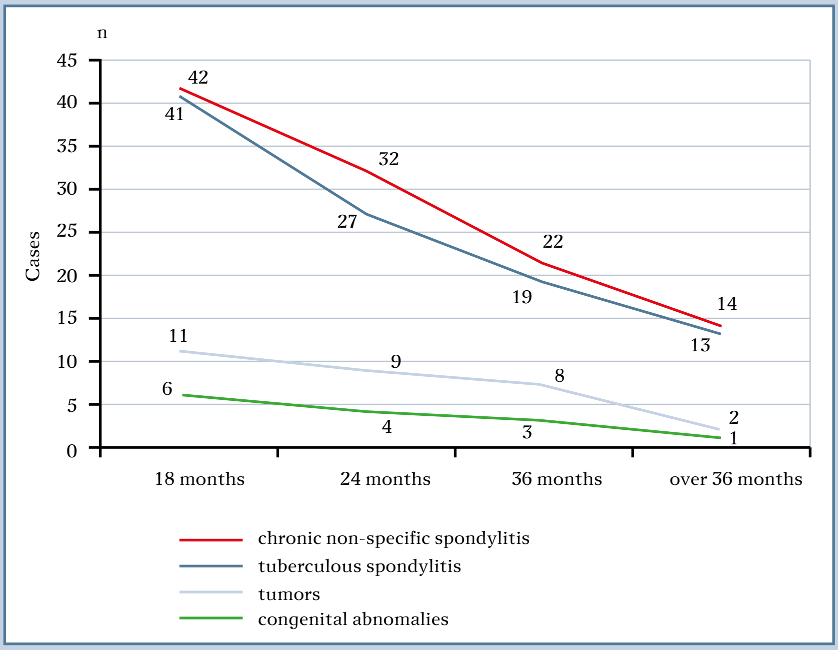


**Fig. 3**
Dynamics of the number of patients with follow-up data at periods over 18 months

**Table 1**
Kyphotic deformity before and after surgery, degrees

| Magnitude of kyphosis | Min | Max | M ± m |
|---|---|---|---|
| Before surgery | 15,00 | 92,00 | 58,66 ± 33,16 |
| After surgery | 2,00 | 47,00 | 29,00 ± 17,71 |

## Conclusions

The study illustrates not only the possibility and effectiveness of titanium meshes for anterior fusion in complex surgical treatment of different spinal diseases in children and adolescents. It focuses on the certain features so that to attract attention of practicing physicians:

1) the use of meshes in reconstructive spine surgery in children due to biological inertia of non-resorbable material does not increase the number of postoperative complications even in infectious (TB and nonspecific) spondylitis;

2) reliable support and stability of an interbody mesh retaining in the short-term and long-term postoperative periods create favorable conditions for durable bone grafts fusion with the recipient vertebrae in the first year after surgery; this allows earlier than in conventional bone grafting to raise the question about removing posterior metal constructs, which can reduce the risk of secondary disc degeneration inside extended posterior fixation zone [17];

3) the fundamental issue remains unresolved: how a new vertebra will grow during a growth spurt? The answer could be found when analyzing the long-term outcomes. The maximum available period of observation in this study is limited to four years, which is insufficient to draw unambiguous conclusions.

**Table 2**

Dynamics of bone block formation in the upper and lower segments of anterior spinal fusion

| The evaluated segment | Periods of observation, months | Scores | | | | |
|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 |
| Cranial segment | 6 | 0 | 0 | 95 | 3 | 0 |
| | 12 | 0 | 0 | 0 | 69 | 28 |
| Caudal segment | 6 | 0 | 11 | 86 | 1 | 0 |
| | 12 | 2 | 1 | 12 | 59 | 23 |

The total number of evaluated segments is lower than the total number of case observations due to evaluation of the bone block formation only based on data of CT which not all the patients had.

**Table 3**

Features of neurological status in patients with neurological disorders

| Patients | Gender | Age, years | Level of pathology | Frankel type | | Diagnosis |
|---|---|---|---|---|---|---|
| | | | | before surgery | after surgery | |
| 1st | m | 5 | T8 | A | B | B-lymphoma |
| 2nd | m | 5 | L1 | C | D | Neuroblastoma |
| 3rd | m | 12 | T9–T10 | D | E | Extrarenal rhabdoid tumor |
| 4th | m | 9 | T4 | D | E | Langerhans-cell histiocytosis |
| 5th | m | 17 | T6–L4 | D | E | TB-spondylitis complicated by abscesses |
| 6th | m | 12 | T2–T3 | D | E | Congenital kyphosis type 1 |
| 7th | m | 13 | L2–L4 | D | E | Giant cell tumor |
| 8th | m | 4 years 6 months | T9–T12 | B | C | Consequences of TB spondylitis |
| 9th | m | 6 | L1–L5 | C | D | Congenital lumbosucral anomaly, spinal stenosis |
| 10th | f | 11 | T8–T10 | D | E | Chronic nonspecific spondylitis |
| 11th | m | 1 year 3 months | T3–T4 | B | E | Tuberculous spondylitis |
| 12th | f | 12 | T6–T9 | D | E | Consequences of TB spondylitis |
| 13th | f | 4 | T1–T2 | B | C–B | Sa Ewing |

**Table 4**

Pair-wise correlation analysis

| Matched pair | Pearson's coefficient | Two-sided significance | Evaluation |
|---|---|---|---|
| Age/number of involved spinal motion segments | 0,145 | 0,592 | An insignificant correlation of weak strength |
| Age/magnitude of deformity | 0,093 | 0,731 | An insignificant correlation of weak strength |
| Extent of reconstruction/operative blood loss | 0,635 | 0,001 | Significant correlation of medium strength: the larger the reconstruction the greater the operative blood loss |
| Length of block/grade of fusion ≥4 scores | 0,606 | 0,002 | Significant correlation of medium strength |
| Posterior instrumentation fixation/grade of fusion ≥4 scores at period of 6 to 12 months | 0,518 | 0,040 | Significant correlation of medium strength |

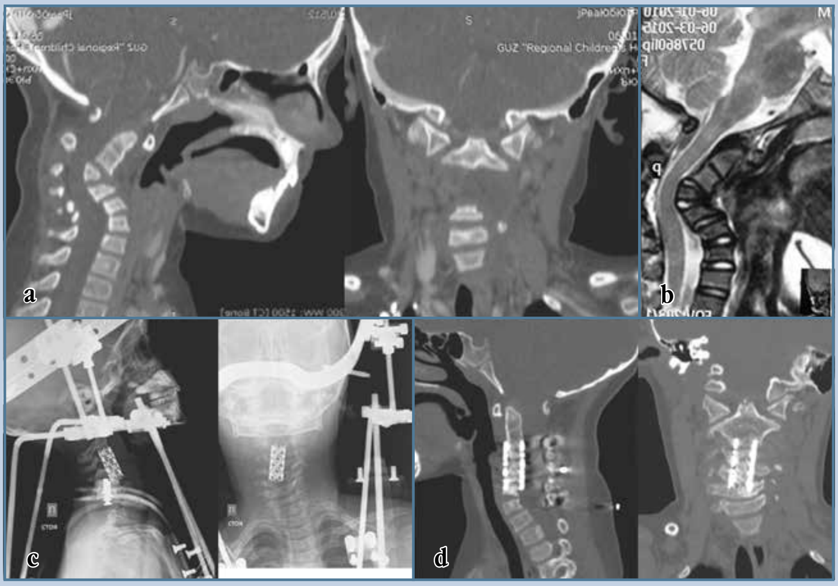


**Fig. 4**
Patient M., female, aged 5 years, with neurofibromatosis type I, Frankel type E: CT **(a)** and MRI **(b)** before surgery: 66° kyphosis of C2–C4 , deformity and bending of the spinal cord at C3; the mother says that the cervical deformity formed within 4 months; radiographs of the cervical spine **(c)** after anterior C2–C5 reconstruction was performed in halo-cast fixation; cervical spine CT **(d)** 6 months after posterior instrumentation at C2–C7 using a multi-anchored system with 8 hooks performed in 10 days after anterior reconstruction; complete preservation of kyphosis correction; bone block within mesh was graded as 4 scores (absence of resorption with reactive contact sclerosis)

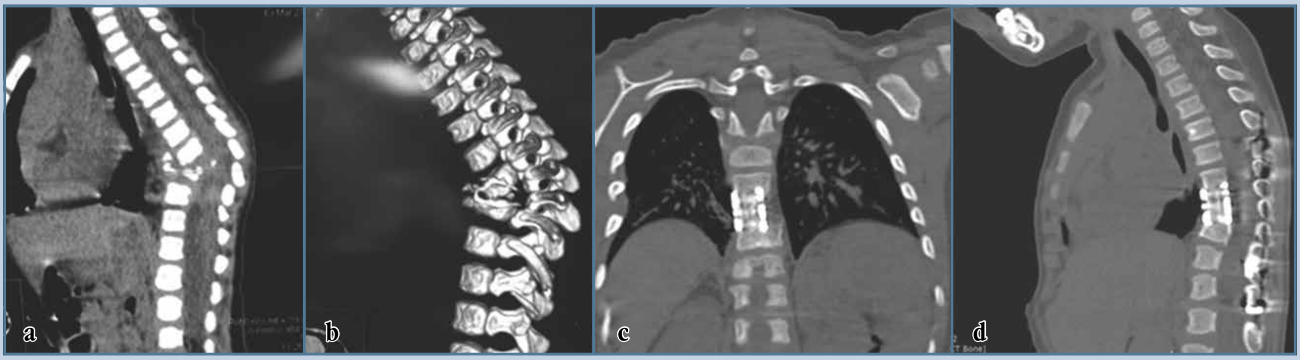


**Fig. 5**
Patient G., female, 8 months old with chronic osteomyelitis at T8–T10 after neonatal sepsis: sagittal CT scan **(a)** and 3D-CT **(b)**: 58° kyphosis, bone sequesters in the epidural space and prevertebrally; coronal **(c)** and sagittal **(d)** CT scans 12 months after reconstruction at T7–T11 using a titanium mesh with bone autograft, posterior T5–L1 instrumentation by multi-anchored system with 8 anchoring elements, 18° kyphosis; bone block in the upper segment graded as 4 scores and in the lower segment as 5 scores

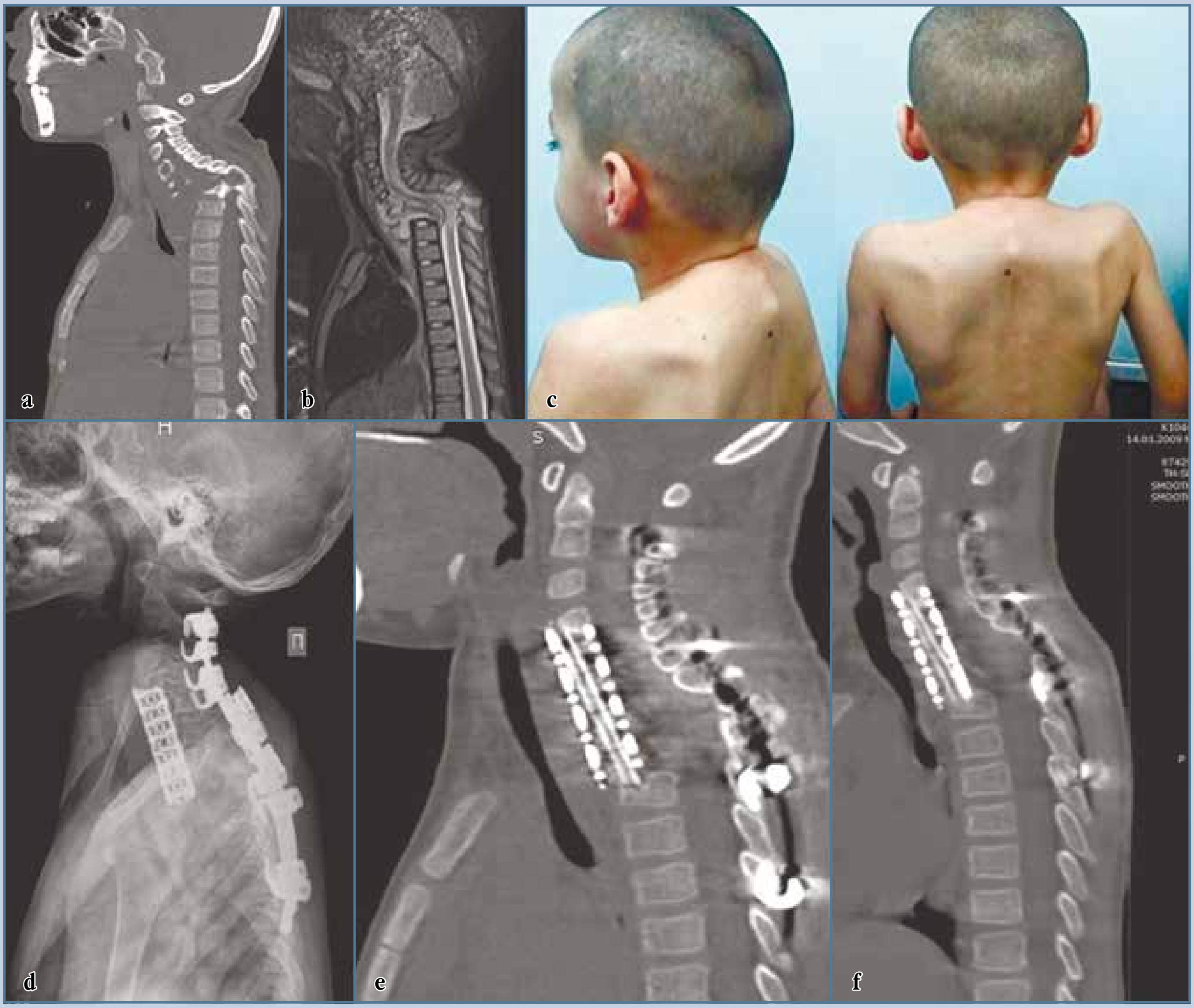

**Fig. 6**
Patient X., male, 5 years old, with primary generalized tuberculosis involving the lungs, spine, and foot bones: CT **(a)**, MRI **(b)** and the appearance **(c)** of the child before spinal surgery; the C5–T3 spondylitis complicated with bayonet deformity, perivertebral abscesses; Frankel type E ; C4–T3 spinal reconstruction was performed in three stages (halo-cast fixation with traction, posterior C2–T7 instrumentation with posterior debridement, combined anterior fusion with a titanium mesh and bone autograft); lateral X-ray **(d)** after reconstruction (complete correction of the deformity), sagittal CT scan **(e)** 6 months post-op: the bone block in the upper segment was graded as 4 scores, in the lower as 3 scores (a thin strip between bone autograft and vertebral body); and sagittal CT scan **(f)** 9 months post-op: the bone block in the upper and lower segment with preservation of correction corresponds to 5 scores

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