COMPRESSION FRACTURES OF THE SPINE IN CHILDREN: ISN'T IT TIME TO CHANGE SOMETHING?

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Objective. To analyze the efficacy of various methods for treatment of children with compression fractures of the thoracic and lumbar spine on the basis of literature data.
Material and Methods. A systematic review of the literature on methods for the diagnosis and treatment of compression fractures of the spine in children was carried out. PubMed, Science Direct, and Google Scholar databases were searched for literature sources for analysis.
Results. A significant number of discrepancies between the approaches used in the treatment of compression fractures in children and the available literature data were noted. In particular, not any diagnostic protocol includes MRI as a tool to confirm the presence of a fracture, due to the high cost of the method and its low influence on the treatment tactic choice. The data of biomechanical studies cast doubt on the feasibility of long-term bed rest compliance and restrictions on sitting. As for bracing of patients with compression fractures, it has been demonstrated that wearing of rigid brace does not allow achieving better results in comparison with its absence. The child's ability to remodel residual deformations of vertebral bodies ensures the restoration of their height and shape in the vast majority of cases. Currently, there is no data confirming the fact of earlier development of degenerative diseases and back pain in children who sustained compression vertebral fractures.
Conclusion. The review results allow to analyze the efficacy of various treatment methods and can be the basis for reviewing the existing treatment tactics for children with compression fractures of the vertebral bodies.
Key Words: compression fractures, spine, children, treatment, brace, regimen.
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The significance of the problem of treating children with compression fractures of the thoracic and lumbar spine is determined by the high incidence of these injuries and the importance of social and economic problems that arise during treatment in the acute phase and in rehabilitation. Despite the fact that, in general, spine injuries are relatively rare among all injuries in children and account for, on average, 1–3 % of all injuries of the musculoskeletal system, thoracic spine fractures are observed in 20–30 % of patients, and lumbar spine injuries are found in 30–50 % of cases [1–3]. Up to 80 % of injuries are type A1 compression fractures according to the AOSpine Thoracolumbar Classification System [4, 5]. Thus, among all spine injuries, this type of trauma occurs most often, which again emphasizes the importance and significance of the problem under consideration.

Since these fractures belong to the category of uncomplicated mechanically and neurologically stable injuries, they do not pose a serious threat to the child's life and health. However, it should be noted that all patients with compression fractures of the spine are hospitalized for additional examination, including MRI and treatment, with the treatment often lasting for years [6]. It is no wonder that the economic costs of treating such patients should be quite high. This systematic review presents an attempt to understand how feasible this approach is, whether there is an alternative strategy and whether the methods used for the treatment of such patients are effective.

The aim of the current study is to analyze the efficacy of various methods for treatment of children with compression fractures of the thoracic and lumbar spine using various approaches based on the literature data.

Material and Methods

The current study presents a systematic review on a specific topic. The pool of literature sources for subsequent analysis was formed using PubMed, Science Direct, and Google Scholar databases. Papers on the diagnosis, treatment and outcome of pediatric patients with compression fractures of the thoracic and lumbar spine were included in the review. In addition, we searched for literature covering biomechanical features of the spine in order to confirm the existing recommendations for limiting physical activity in such patients, in particular, the need to limit sitting time and exclude sports for a long time after injury. For example, the search in PubMed was performed with a query of keywords or phrases "wedge fractures, compression, spine, vertebrae, pediatric, treatment, bracing, outcome, diagnostics, MRI, children, posture, axial load" and

using their combination depending on the search topic. The inclusion criteria were full-text paper availability, pediatric patients, compression fractures of the vertebral bodies as the condition. Exclusion criteria were articles on pathological vertebral fractures in children as well as papers describing the results of *ex vivo* experiments and computer simulations. A separate search was conducted on the issue of spine biomechanics at different trunk positions; the patent's age was not taken into account in this case. The status of the paper (published/submitted/under review) was not also considered. After collecting data from all of the selected sources, the papers were checked, and duplicates were excluded. The resulting review included in total 30 papers and one study guide. The level of evidence and design of the papers were not taken into account. We decided not to limit the search to any specific time period because at the initial search it became clear that there are very few publications on the topic under discussion, while only single papers are found on some of the addressed issues. To extract the necessary information, one of the authors read the full text of an article and highlighted the key findings. Next, the data were systematized according to the main issues considered (diagnosis, treatment and outcome of the disease), after which their analysis was performed, and conclusions were drawn.

Results

We decided to start the review with discussion of one of the most important (in our opinion) issues: the diagnostics of compression fractures of the spine in children, namely, the need for MRI. Traditionally, in addition to clinical examination, such patients undergo not only radiography of the injured area of the spine but also MRI to confirm the presence of a fracture and the exact number of injured vertebrae. Indeed, interpretation of the X-ray data in a young child may be difficult due to the radiological features of the pediatric skeleton: physiological wedging of the vertebral bodies at the apex of the thoracic kyphosis in school-aged children and the presence of apophyses [7, 8]. In case of doubt, additional methods for diagnostics of spine injury are used, among which CT is the most accurate for determining the nature and extent of the injury [9]. MRI is absolutely indicated in case of neurologically complicated spinal injury as well as for assessing the condition of the posterior supporting structure (in some cases of burst fractures its preservation favors the conservative treatment) [10]. However, performing such study in patients with compression fractures of the vertebrae may often lead to overdiagnosis: hyperintensity on T2 and STIR sequences and hypointensity on T1-weighted images along the 5–8 vertebrae are interpreted as a fracture, and the relevant treatment is prescribed. Meanwhile, the presence of these signals in the absence of plastic deformation of the vertebral endplates is described in the literature as vertebral bone bruise. In 1989, Mink and Deutsch [11] were the first to describe this condition using injury to the knee joint articular surface as an example. This case once again emphasizes the need for the combined analysis of the X-ray and MRI data. Only wedge-shaped deformity of the vertebral body or endplate deformation resulting from injury in combination with changes in MRI signals confirms a compression fracture of the vertebra. Currently, slightly more than 50 cases with a vertebral bone bruise are described in the literature, 26 of them are children. Scheunemann et al. [12] and Yokoyama et al. [13] in 2005 and 2017, respectively, evaluated the results of treating such patients: in all cases, a complete recovery was observed within 1 month upon immobilization with a soft brace or a short-term bed rest with subsequent early verticalization. For evaluation of the treatment results, the authors used clinical examination and control MRI data: there were no complains on spine function among patients or any case of post-traumatic deformity. Teli et al. [14] also did not reveal any significant post-traumatic deformity in 30 adult patients with a vertebral bone bruise. These results allow us to suggest that such injuries are harmless in relation to prognosis and do not require a comprehensive treatment.

When it comes to choosing the strategy for the treatment of patients with confirmed diagnosis of compression fractures of the spine, one should first consider the need for a child's hospitalization. This approach is absolutely reasonable in multiple and combined injuries, in conditions requiring follow-up control and therapy correction. However, in such case, the patient is usually in a compensated and stable condition with isolated, uncomplicated, and mechanically and neurologically stable spine injury and admitted only for providing bed rest in a hospital and traction in combination with physiotherapy. How reasonable is this approach? Horal et al. [15], Hubbard [16] and McPhee [17] managed to demonstrate the advantages of early verticalization with a brace in comparison with long-term bed rest in the 70–80s of the 20th century. However this rough and unreasonable approach is still used in combination with chin or axillary traction. Meanwhile, the effectiveness of traction in compression fractures does not even have a theoretical justification. In contrast to comminuted fractures, in which fragments can be enclosed by ligamentotaxis, the height of the compressed cancellous bone in the case of compression can be restored only from the inside of the injured body which might be achieved by balloon kyphoplasty in adults [18]. We have not found any data proving the effectiveness of traction in patients with compression fractures of the spine. Evaluation of the effectiveness of physiotherapeutic methods in the treatment of patients of this group cannot be conducted due to a large number of papers with a low class of evidence, which cannot be analyzed from the standpoint of modern approaches and the principles of evidence-based medicine.

After discharge from the hospital a period of dealing with a large number of limitations begins, one of which is a long-term (3 to 6 months) restriction on sitting and limitation of movements that cause excessive body bending. The patient and his family have to substantially reconsider

their lifestyle for the next six months from the moment of injury: exclusion of learning at school, lack of the possibility of free movement in the transport. Even the simple implementation of daily hygiene measures can become a real challenge because of fear of violating any of these recommendations. The reason for such severe restrictions is in the traditional belief that there is an increase in the spinal load in a sitting position. To investigate whether this assumption is true or not, Nachemson [19, 20] was the first to measure the pressure in the intervertebral disc at various body positions in 1963–1965. His findings indicated that pressure increased in the sitting position and during forward bending of the trunk: on average, the spinal load was increased by 40% in the sitting position, while every 20° of the forward bending increased it by another 30 %. The author used the equipment that was not very accurate in comparison with the modern analogues. Later, other researchers repeatedly returned to this issue and received different results. For instance, according to Wilke et al. [21], the load on the intervertebral disc at L4–L5 is the same in the sitting and standing positions of a patient. It should be noted that all of the performed studies the results of which are presented in the literature were limited to measuring the pressure at the L3–L4 and L4–L5 levels. For this reason, they cannot be fully applied to the thoracic region. The thoracic spine is also known to have a more pronounced stability provided by the rib cage [22]; therefore, the possible harm due to the increased loading in the sitting position in compression fractures of the thoracic spine can be rightly called into question.

These aspects are important for understanding, since this restriction leads to the greatest inconvenience for the patient and his family. From this perspective, the existing postulates require additional analysis and studies for re-evaluation and reinterpretation of the current recommendations for patients with compression fractures.

When considering the need to supply patients with a rigid brace, attention should be paid to the study by Singer et al. [23], which presents a prospective evaluation of the results of treatment of 34 children injured at the age of 1 to 17 years (mean age 11.6 years); with a mean follow-up period of 7.9 years (2.4 to 13.1 years). The choice of treatment method depended on the preference of the attending physician: provision with a rigid thoracolumbar brace for a period of up to 6 weeks after injury (group 1, n = 17) or immediate verticalization without a brace with restriction of physical activity for the same period of up to 6 weeks after injury (group 2, n = 17). By measuring the wedge angle, the authors evaluated the degree of restoration of the damaged vertebra depending on the child's age (older or younger than 12 years) and whether a brace was used for correction or not. A slightly better degree of restoration of the damaged vertebral body's height was observed in patients under 12 years of age. At the same time, the brace did not significantly facilitate height restoration. Another peculiar work is a multicenter study by a group of American authors [24] devoted to the validity of the TLICS scale in pediatric patients, which presents the following data: of the 102 patients who underwent conservative treatment, 36 (35%) patients received it without using a brace, 64 (63 %) individuals wore a brace for a period of 12 weeks. For two patients, the status was unknown. Furthermore, 86 (84 %) patients had compression fractures of the spine, there were 12 (12 %) cases with burst fractures and 4 (4 %) cases with chance injuries. Of 102 patients, 79 (77 %) were available for the follow-up examination on average after 4 months (0.6–95.0 months). As a result, no neurological disorders or deteriorations requiring surgical treatment were noted in any patient. Two points are noteworthy in this study: the fact that brace was not used in one third of the patients, the vast majority of whom had compression fractures of the spine, as well as the period of brace wearing (12 weeks is the longest period of correction with a brace that we found in foreign literature). In this regard, correction with a semi-rigid brace for a period of 6 months to 2 years after injury causes a number of questions and casts doubt on its need for such a long period.

Finally, when assessing the long-term results of treating children with compression fractures of the spine, the exceptional ability of the child's body to remodel residual deformities of not only long tubular bones but spine as well should be kept in mind [25]. Starting from the 70s to the beginning of the 2000s, there were numerous publications on restoration of the damaged vertebral body's height in children [5, 15, 17, 26–28]. A retrospective evaluation allowed authors to identify the prognostic factors affecting the possibility of such remodeling. Among them are the child's age and the degree of skeletal maturity determined by the Risser test, as well as the plane in which the traumatic deformity is formed. It was found that in case of the Risser test $\leqslant 2$, good outcome is observed both when using conservative treatment as well as in its absence. In Risser >3 patients, even in case of prolonged conservative treatment, complete restoration of the damaged vertebral body's height was not observed [25, 27, 29]. The same is noted in deformities in the two (sagittal and frontal) planes: in such patients, regardless of age, there is a residual deformity and the risk of post-traumatic scoliosis in most cases [30].

The patient's parents are concerned about possible adverse effects of the injury: early degenerative changes, post-traumatic disc herniation at the injured segment, development of back pain in the future. The fear of such complications makes them adhere to any recommendations in an attempt to prevent such significant problems. There are not so many works on the assessment of long-term results of treatment in such patients. The longest follow-up period (27–47 years) was reported in a study by Moller et al. [31]. Using an data of 23 patients who had spine injury at the age of 16–18 years, the authors demonstrated that, despite the fact that there were no cases with restoration of the vertebral body shape and height, 18 (78 %) of 23 patients had no complaints about spinal function, while the Oswestry scale value was 2.5 ± 6.3. It should be noted that the average incidence of back pain among the adult population reaches 20 % [32]. Thus, it has been demonstrated that the vertebral body shape and function

do not always correlate directly, and complete restoration of the vertebral height of the injured segment, apparently, should not be the ultimate goal of the treatment. Although Kerttula et al. [33] revealed a somewhat higher incidence of degenerative changes (which reached 57 % in the study group) after compression fracture, especially in the case of cranial endplate injury, it is worth noting that no connection was found between the injury, changes in the spine, and spinal function: none of the patients in the study group had complaints of back pain. In 2003, the above-mentioned Karlsson et al. [28] also presented the results of MRI of the spine in 20 adult patients who had had compression fractures in childhood, whose average age at the time of injury was 12 years (7–16 years). Eighteen of them were diagnosed with an injury to the spinal cord only, Denis type B fractures were observed in 2 patients. All patients were verticalized without a brace immediately after exclusion of more serious injuries. The authors demonstrated that degenerative changes at the injured segment were not observed more often in patients of this group than in conditionally healthy people in the general population. However, a slightly higher frequency of Schmorl's nodes in vertebral bodies adjacent to the damaged one was found [28]. In 2017, Angelliaume et al. [29] conducted a retrospective multicenter study devoted to the effect of the injury on changes in the sagittal profile among 48 patients (mean age at the time of injury was 12 years), the mean follow-up was 49 months. The study demonstrated the absence of local kyphotic deformity progression and a significant increase in lumbar lordosis, which prompted the authors to hypothesize the presence of compensatory mechanisms in children, in addition to the remodeling ability, which prevent post-traumatic disturbance of the sagittal balance. Thus, to date, there are a number of works demonstrating that such patients do not suffer from the adverse effects of the compression fracture in the future.

We have not found any studies on the need for long-term follow-up or rehabilitation for children with compression fractures of the spine, including sanatorium therapy and long-term restriction of physical activity.

We deliberately did not include the results of domestic studies in the final analysis. Despite the fact that the current study was not an attempt to perform a meta-analysis, it turned out that most of the papers present a survey or epidemiological study or has an extremely low level of evidence. Moreover, they share the same strategy for the assessment of the severity of these injuries and approaches for treating such patients, which is expressed in the current system of care for children with compression fractures of the spine.

Conclusion

To date, the issues of diagnosis and medical care for children with unstable and complicated spinal injuries are practically resolved in the Russian Federation. However, at the same time, the problem of patients with stable compression fractures of the thoracic and lumbar spine remains unresolved. The strategy for managing these patients is mainly based on the traditional concepts of the last century. We made an attempt to collect and summarize the data of recent years in order to revise the existing ideas used by orthopedic doctors when treating children with compression fractures of the spine. Among limitations of the current study is the fact that it presents a systematic review but not a meta-analysis and thus has a low level of evidence. In addition, a limited amount of data was found on some of the considered issues. In our opinion, a serious revision is required for the need for long-term hospitalization of stable-state patients with compression fractures of the thoracic and lumbar spine in the acute post-injury period. There is no reason to believe that prolonged bed rest in the early period after injury facilitates the recovery or improves the outcome, as well as that early verticalization is harmful to such patients. On the contrary, it is possible in the absence of complaints of pain and restricted ability to move independently. In the latter case, the patient's quality of life is less affected. There is also doubt about the need for bed rest after discharge from the hospital during the rehabilitation period.

The need to limit sitting is an extremely difficult and at the same time quite questionable measure, which should be considered unreasonable in compression injuries of the thoracic and thoracolumbar spine. Indeed, data of the biomechanical studies indicate an increase in the spinal load when sitting and leaning forward. But is this load essential for such severe long-term restrictions, especially several months after injury? As a rule, sitting in such patients is not accompanied by pain, which can directly or indirectly indicate that stability of the injured segment is preserved. In addition, in case of vertebral fractures of the thoracic region, the ribs and sternum serve as a strong stabilizing system. Apparently, this is the reason why some authors do not see the need to supply children with a rigid brace: the results of their studies demonstrate the same outcome in the groups of braced and non-braced patients.

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