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Sternal fractures in children

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BACKGROUND: Sternal fractures are a rare nosological form of injuries in children. The injuries of the sternum often are accompanied by fractures of the long bones of the skeleton or thoracic vertebrae. Isolated fractures of the sternum in children are rarely diagnosed. The medical information on pediatric sternum injuries is limited by a small number of scientific publications.

AIM: Our aim is to study the peculiarities of traumagenesis, clinic, diagnostics, treatment of sternal fractures in children.

MATERIALS AND METHODS: Clinical material for the served as experience in providing traumatology assistance to 8 children who received sternal fractures. The average age of the injured children was 11.5 years. 87.5% of the victims were boys. In all patients, sternal fractures had been diagnosed along with other damage to the musculoskeletal system. During the survey, traditional diagnostic methods for emergency traumatology were used.

RESULTS: The leading mechanism of injury, i.e., falling from a height of 2 meters and more were found in 62.5% of victims. In all clinical observations, fractures were localized at the level of the body of the sternum. All the children, besides sternal fractures, had uncomplicated fractures of the vertebral bodies. A total of 30 bodies of the vertebrae were compressed. Most often (in 16.75% of cases), the Th_v vertebra was compressed. The reliable symptoms of sternal fractures in patients were difficult and painful breathing, local swelling of soft tissues, soreness of the sternum during palpation, and amplification of the pain in the fracture area during pressure applied on half of the chest. Compliance with the strict bed mode on the roller-reclinator under the area of the compressed vertebrae and the exclusion of the axial load on the spine was a favorable fact sufficient and led to pain disappearance in 3–7 days. In all cases, the sternum fractures did not require any surgery. Fractures of the bodies of the vertebrae in 7 children were also treated conservatively. The Corsets “Orlett” was used for immobilization, ensuring a reliable degree of fixation. The average hospital stay amounted to 16. The duration of the hospital stay was influenced by the accompanying bone-articular damage to the skeleton. The evaluation of the long-term results was performed in 4 children. The results were interpreted as good.

CONCLUSIONS: When applying for emergency traumatology assistance to children with chest injury and spine, it is necessary to purposefully explore the state of the sternum.

Keywords: children; sternal fractures; features of traumagenesis, clinic, diagnosis, treatment.

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Переломы грудины у детей

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Обоснование. Переломы грудины являются редкой нозологической формой детского травматизма. Дети получают их, как правило, наряду с переломами трубчатых костей скелета или грудных позвонков. Изолированные переломы грудины у детей диагностируют редко. Медицинская информация, посвященная педиатрическим травмам грудины, представлена малым количеством научных публикаций.

Цель — изучить особенности травмагенеза, клинической картины, диагностики, лечения переломов грудины у детей.

Материалы и методы. Представлен опыт оказания медицинской помощи 8 детям в возрасте от 5 до 17 лет, у которых были диагностированы переломы грудины. Средний возраст травмированных составил 11,5 года. Среди пострадавших преобладали мальчики — 87,5 %. У всех пациентов переломы грудины были диагностированы наряду с другими повреждениями костно-мышечной системы. В ходе обследования использовали традиционные для экстренной травматологии методы диагностики.

Результаты. Ведущим механизмом травмы было падение с высоты 2 м и более — 62,5 % пострадавших. Во всех клинических наблюдениях переломы локализовались на уровне тела грудины. Все дети кроме стернальных переломов получили неосложненные переломы тел позвонков. В общей сложности было компримировано 30 тел позвонков. Чаще других зарегистрирована компрессия тела позвонка Th_v — 16,75 % случаев. Достоверными симптомами стернальных переломов у пациентов были затрудненное и болезненное дыхание, локальный отек мягких тканей, болезненность грудины при пальпации и усиление болей в области перелома при пальпации половин грудной клетки. Соблюдение строгого постельного режима на валике-реклинаторе под область компримированных позвонков и исключение осевой нагрузки на позвоночник являлось благоприятным фактом, в результате чего боли в проекции сломанной грудины у всех пациентов были купированы в течение 3–7 дней стационарного лечения. Во всех случаях характер переломов грудины не потребовал проведения операции. Переломы тел позвонков у 7 детей также были пролечены консервативно. С целью иммобилизации использовали корсеты Orlett, обеспечивающие надежную степень фиксации. Средний койко-день составил 16. На продолжительность койко-дня оказали влияние сопутствующие костно-суставные повреждения скелета. Оценка отдаленных результатов лечения переломов грудины была выполнена у 4 детей. Результаты были расценены как хорошие.

Заключение. При оказании экстренной травматологической помощи детям с травмами грудной клетки и позвоночника необходимо целенаправленно исследовать состояние грудины.

Ключевые слова: дети; переломы грудины; особенности травмагенеза, клинической картины, диагностики, лечения.

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BACKGROUND

Sternal fractures are rare nosological forms of childhood trauma [1]. Most often, sternal fractures in pediatric patients are established during clinical and radiation examinations for multiple or associated injuries [2]. Isolated sternal fractures are diagnosed much less frequently [3].

The domestic medical literature provided little data to various aspects of sternal fractures in children [4]. The foreign literature revealed diverse and more extensive scientific information about this type of pediatric fractures, despite the low frequency of referral of young patients for such injuries [5, 6]. According to Ramgopal et al., sternal fractures account for 0.07% of clinical observations in childhood injuries [7].

This study aimed to examine the features of trauma, clinical picture, diagnosis, and treatment of sternal fractures in children.

MATERIALS AND METHODS

The study type and design were based on the recommendations published in the journal *Traumatology and Orthopedics of Russia* [8]. This study employed an “observational, STROBE” design aimed at gaining knowledge for solving a specific practical problem, namely, studying the features of trauma, clinical picture, diagnosis, and treatment of sternal fractures in children and adolescents. The study also used an open cohort design.

We have provided medical care to eight children aged 5–17 years, who were found to have sternal fractures during a comprehensive examination. The average age of these patients was 11.5 ± 1.5 years. Among the patients, 7 (87.5%) were boys. In all patients, sternal fractures were diagnosed along with other injuries of the musculoskeletal system. Isolated sternal fractures were not identified in any of the clinical observations between January 1, 2010, and December 31, 2020, during which this study was conducted.

To detect sternal fractures, traditional research methods for emergency traumatology were used: collection of complaints and anamnesis, clinical and paraclinical studies, and radiation diagnostics. The radiation study consisted of a survey chest X-ray in two planes ($n = 8$) and computed tomography (CT) ($n = 8$). According to clinical indications, related specialists (a surgeon and a neurosurgeon) were involved in the examination of the patients.

The type and subtype of sternal fractures in the study group were determined using the AO/OTA classification. According to this classification, all sternal fractures are divided into three types: fractures of the arm, body, and xiphoid process. Each of these injuries includes three subtypes, depending on the fracture line of the sternum: transverse, oblique, and comminuted [9].

The cumulative severity of injuries was calculated according to the criteria of the Injury Severity Score (ISS) scale [10].

Data were statistically processed using Microsoft Excel (Microsoft Inc., USA) and Statistica 6.0 (Dell, USA) software packages. The specific weight of each of the variants of the studied indicators is presented as $p \pm m$, where p is the relative value of the indicator variants (%) and m is the error in the representativeness of the relative value.

RESULTS

In this study, data obtained are fully consistent with the literature that children sustained sternal fractures most often along with other injuries [7, 11]. Of the eight children diagnosed with sternal fractures, 6 (75.0%) had multiple injuries and 2 (25.0%) patients had combined injuries.

In the study group, the leading mechanism of injury was a fall from a height of >2 m in 5 (62.5%) children (three patients fell out of the windows, all from the 6th floor; two (25.0%) children fell on their buttocks on a bent position while standing). In 1 (12.5%) patient, the cause of a sternal fracture was head trauma by hitting the bottom of the reservoir while swimming in shallow water.

In all eight clinical observations, fractures were localized at the level of the body of the sternum, which, according to the AO/ATO classification, corresponded to type 16.3.2. Detailed examination of the fractures of the sternal body revealed subtype A in 4 (50.0%) patients, subtype B in 3 (37.5%), and subtype C in 1 (12.5%) [9].

As a result of the above injuries, all children, except those with sternal fractures, sustained uncomplicated vertebral fractures. Apart from sternal and vertebral fractures, 2 (25.0%) patients had forearm fractures. Two (25.0%) children sustained a closed head injury. One case each of traumatic dislocation of one of the hips (12.5%), multiple fractures of the ribs (12.5%), unilateral pneumothorax (12.5%), and unilateral hydrothorax (12.5%) was recorded. Grade 1 traumatic shock was detected in 1 (12.5%) patient.

Throughout the examination, 1 (12.5%) patient corresponded to the maximum criteria on the ISS scale, when the injuries were assessed at once in five anatomical regions. Seven (87.5%) patients had injuries to two or three analyzed areas of the trunk, limbs, and head. In the analysis of the severity of injuries, 7 (87.5%) patients scored 13–19 points and 1 (12.5%) patient scored 20–34 points [10].

In all eight patients, sternal fractures were combined with uncomplicated vertebral fractures. In total, 30 vertebrae were compressed in eight patients of the study cohort, which involved 23 thoracic and seven lumbar vertebrae. Moreover, 6 (75.0%) children had multiple vertebral fractures and

2 (25.0%) had a single fracture. Fractures of the cervical vertebrae and Th_I vertebra were not recorded. Compression of the Th_V vertebra was found more often than others in 5 (16.75%) patients. Less often, in 1 (3.33%) case, fractures of the Th_{II}, Th_X, Th_{XI}, Th_{XII}, L_{IV}, and L_V vertebrae were established.

Regarding the clinical picture, symptoms of sternal fractures in children were not as pronounced as those of concomitant injuries. Pain syndrome characteristic of vertebral fractures, pain and deformity of limb segments inherent in forearm fractures, and iliac dislocation of the femur prevailed over the algic syndrome in the area of the fractured sternum. Difficult and painful breathing, local soft tissue edema, tenderness of the sternum on palpation, and increased pain in the fractured area on palpation of the right and left sides of the chest were significant symptoms of sternal fractures. Well-known symptoms of bone fractures, such as deformity, pathological mobility, and crepitus, were uncommon for this type of injury.

CT reliably confirmed vertebral fractures and determine the nature of the sternal injuries in all cases (Figure).

Sternal fractures are an indication for emergency electrocardiography. In all eight cases, the age of the patients varied.

Injuries of the spine and other segments of the extremities accompanying sternal fractures were considered indications for emergency hospitalization of children in the trauma and orthopedic department. Previously, children with traumatic iliac dislocation of the femur (1 patient)

and forearm fractures (2 patients) received the necessary medical attention. Conservative therapy was selected in patients with concomitant rib fractures (1 patient) and pneumo- and hydrothorax (2 patients).

Compliance with strict bed rest on the reclinator roller under the area of the compressed vertebrae and elimination of the axial load on the spine were favorable; as a result, pain in the projection of a fractured sternum in all patients was alleviated within 3–7 days of inpatient treatment. In all cases, sternal fractures did not require surgery. Vertebral fractures in seven children were also treated conservatively. As the study cohort had sternal and vertebral fractures, Orlett corsets were used for immobilization; contact of the elements of these devices with the sternum was avoided to provide reliable fixation of the spine [12]. The time period for fixation with such corsets ranged from 16 to 20 weeks, during which the sternal fractures consolidated.

In one clinical case, a 16-year-old patient who had comminuted fractures of L_I, L_{II}, and L_V vertebrae following a fall from the 6th floor underwent posterior fusion at the level of Th_{XI}–S_I.

The average hospital stay was 16 + 1.7 days. The number of bed-days was influenced not by sternal fractures but by the concomitant more severe osteoarticular injuries of the skeleton. Thus, a 14-year-old patient, after closed reduction of a traumatic dislocation of the left femur, spent 27 days on skeletal traction along the axis of the femur to unload the hip joint.

The long-term results of conservative treatment of sternal fractures in 4 (50.0%) patients were evaluated 6–18 months after injury. None of the patients presented any complaints about the sternum and any pain. Visually, the anterior surface of the chest appeared normal in all patients, and the right and left halves were symmetrical. Palpation of the arm, body, and xiphoid process of the sternum and palpation on the half of the chest in the frontal and sagittal planes did not induce pain. All patients could take a full deep breath. The absence of any complaints and clinical symptoms after sternal trauma in children and adolescents was the reason an X-ray examination of the chest was not performed to reduce the radiation exposure. The result of the treatment was assessed as good. In the available literature, no sources provided criteria for assessing the treatment results of sternal fractures in children.

DISCUSSION

In line with the aim of this study, several statistical indicators characterizing sternal fractures in children are, in our opinion, of interest to interested specialists. The results of this study confirmed the rarity of isolated sternal fractures in pediatric patients [13]. Most children who experienced trauma had other more severe injuries to the skeleton and



Figure. Computed tomography of the thoracic spine and sternum of Patient V (16 years old). Compression fracture of the Th_{VII} vertebra. Comminuted fracture of the sternum (type 16.3.2.C according to the AO/ATO classification)

internal organs [7, 11]. In our study cohort, all eight patients had such concomitant injuries.

Our literature review of the problem has confirmed that sternal fractures are more common in boys and young men. According to Chaplin et al., 71% of men had sternal fractures, and their average age was 11 years [6]. According to Ramgopal et al., gender differences are even higher with 79%, and the average patient age was 14 years [7]. In addition, Schmidt et al. reported that the age peak of sternal fractures in pediatric German patients was 18 years [14]. In our study, 87.5% of the patients were male, and their average age was 11.5 years.

The literature provides different information regarding the mechanism of injury in children with sternal fractures. In Turkey, Ozsoy et al. tended to believe that such injuries are mainly caused by high-energy trauma, such as vehicular accidents and catatrauma (fall from height) [1]. Moreover, in Chile, Buhlmann et al. argued that in 92% of cases, pediatric fractures were caused by low-energy trauma, including falling onto the buttocks of their own height [15]. In the present study, both high-energy (3 children fell out of windows from the 6th floor; one case was a suicidal attempt [16]) and low-energy (2 children fell on their buttocks while standing) were the mechanisms leading to fractures in the studied cohort, which is confirmed by the information published by Turkish and Chilean authors.

The low frequency of occurrence and predominant localization of fractures in children in the body of the sternum are primarily due to the anatomical and physiological features of the ossification of this unpaired skeleton. These conclusions are reached by a group of American researchers led by Weaver, who studied not only the morphology of this bone in terms of the age but also CT data in 330 patients aged 0–100 years [17]. Wang et al. agreed with the expressed opinion and emphasized that the proportion of sternal fractures increased with age, which was associated, among other things, with the natural “loss” of the elasticity of this bone [18].

In the present study, all eight patients had sternal fractures along with vertebral fractures. In total, 30 vertebrae were fractured, including 23 thoracic and seven lumbar vertebrae. Literature data indicate that the frequency of diagnosis of vertebrogenic fractures in these patients can range from 31% [19] to 87% [20].

Paradoxically, none of the authors mentioned which vertebrae are more often compressed in patients with sternal fractures. However, only Huang et al. presented evidence that the thoracic vertebrae are the main sites of injuries [21]. Given this research gap, we ranked the compressed bodies of the 30 vertebrae in the study group according to the frequency of their lesions; as a result, Th₇ was subjected to compression more often than others in 5 (16.75%) clinical cases.

Of practical interest is the analysis of the severity of injuries to the skeletal system, including the sternum, in the study group. In 7 (87.5%) of 8 children, the average ISS polytrauma score ranged from 13 to 19 points, with an average of 16 points, which indicates an insignificant severity of injuries [10]. In 1 (12.5%) patient, the total polytrauma score was 28 points. American researchers led by Rosenfeld provided interesting information about the severity of injuries in their analysis of the National Trauma Data Bank (NTDB) for 2007–2014. According to publications, during this period, 3160 patients with sternal fractures aged <18 years received treatment in the United States. The average polytrauma score on the ISS scale in this category of patients was 17 points [5].

Based on our own experience and literature data, we can conclude that in most cases the clinical symptoms of sternal fractures and associated injuries in children are not severe and life threatening. In cases of trauma or catatrauma, mortality from injuries in the general population of children and adults can reach 8%, as reported by Ovetunji et al. based on their analysis of the same NTDB database, which during the study included a cohort of 23,985 patients with sternal fractures [22].

In clinical practice, there are cases of which sternal fractures are diagnosed not during presentation for treatment but several days later [23]. In the present study, in 2 (25.0%) patients, the diagnosis of sternal fractures was established one day after admission. Their reason for hospitalization was compression fractures of the vertebrae of the mid-thoracic level. The reason for the delayed diagnosis was vertebral pain syndrome caused by vertebral fractures, which prevailed in clinical symptoms, and pain in the fractured sternum was considered due to vertebral compression. Edema and/or bruising of soft tissues, local tenderness on palpation, painful axial load on the chest, and painful spontaneous deep breathing may not be pathognomonic symptoms of sternal fractures in children, but with a high degree of probability, these may indicate the presence of injury.

As with any injury, it is possible to establish a definite diagnosis of sternal fracture, to determine the nature and extent of damage, using radiation diagnostics [2]. In the present study, all sternal fractures were diagnosed by CT. CT, especially sagittal scans, can visualize all sternal fractures, surpassing the accuracy of diagnosis by plain radiography of this bone in the anteroposterior and lateral planes [24]. Ferguson et al. confirm these data by reporting that the radiological diagnosis was made only in 12 (36.36%) of 33 children with sternal fractures [25]. Studies have also reported the diagnostic value of ultrasonographic examination for the diagnosis of sternal fractures in children [26, 27].

The scope of treatment for fractures of any bone, including the sternum, is determined by the nature of

the damage. According to Ferguson et al., in more than half of the patients during their study, only a fracture of the anterior cortical bone plate was noted, without any displacement [25]. In these cases, in the absence of concomitant damage to other bones, patients can be treated on an outpatient basis, without immobilization [6, 25]. In inpatient treatment of sternal fractures, the average length of hospital stay for children is 4 bed-days [5]. In the present study, the average number of bed-days was 16 days. This duration of inpatient treatment was due to the need for therapy of concomitant injuries of the skeletal bones in children. Since all patients with sternal fractures had compression fractures of the vertebral bodies, Orlett braces were used for immobilization, which were intact in relation to the sternum. This finding was considered extremely important, since during immobilization with the help of reclining corsets and orthoses of the trunk, the latter support three anatomical regions: area behind the lumbar spine, in front on the public articulation, and the sternum [28]. In our clinical observations, contact of corsets with a broken sternum was unacceptable. Interestingly, Greek authors led by Korovessis described a patient who spontaneously sustained sternal fracture during the treatment of kyphoscoliosis using a Boston brace [29].

In the present study, clinical indications for surgical treatment of sternal fractures were not revealed in any of the observations. Our analysis of literature data revealed that such procedures can be performed on children, especially in cases of multiple damage to the rib cage and chest organs [4]. In isolated sternal fractures, the indications for surgical treatment are displaced fractures, accompanied by pain and respiratory disorders. In these cases, various types of plates are used for osteosynthesis [30].

CONCLUSION

The relevance of sternal fractures in pediatric traumatology is primarily attributed to the low number of visits by children with this type of injury. Thus, the clinical picture is dominated by injuries of other bones and/or internal organs, since isolated sternal fractures are rare.

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The results of this study showed that sternal fractures in our cohort of eight pediatric patients were diagnosed with other injuries: six cases were attributed to multiple trauma and two with combined injuries.

Sternal fractures were caused by both a high-energy mechanism (catatrauma) and a low-energy mechanism (falling onto the buttocks while standing). In all cases, the vertebrae were compressed, more often than others the Th_v vertebral body in 16.75% of the clinical cases. Compression of the middle thoracic vertebrae, including vertebrogenic pain syndrome and shortness of breath, is the most frequent reason for the delayed diagnosis of sternal fractures, as recorded in the two cases in our study. CT can reliably establish the diagnosis of sternal fractures, clarify the nature of the damage, and determine the treatment techniques. The use of conservative treatment, primarily orthopedic corsets in fixing the injured spine and eliminating pressure on the sternum, makes it possible to obtain good long-term results. In our study, there were no indications for surgical treatment of sternal fractures in any of the clinical observations.

When providing emergency trauma care to children and adolescents with chest and spinal injuries, a purposeful examination of the sternum is necessary.

ADDITIONAL INFORMATION

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Conflict of interest. The authors declare no evident or potential conflict of interest related to the current article.

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Author contributions. E.G. Skryabin — treatment of patients in the study group, development of the study design, analysis of literary sources, and writing the main text of the article. S.V. Naumov — treatment of patients of the studied group and revision of the text of the article. P.B. Zotov — analysis of literary sources and editing of the text of the article. M.A. Akselrov — treatment of the patients, analysis of literary sources, and copyright editing of the text of the article.

All authors made significant contributions to the research and preparation of the article, read and approved the final version before publication.

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