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THE INFLUENCE OF THE RIB CAGE ON THE SEVERITY OF THORACIC SPINE BURST FRACTURES

INFLUÊNCIA DA CAIXA TORÁCICA NA GRAVIDADE DA FRATURA DA COLUNA TORÁCICA TIPO EXPLOSÃO

LA INFLUENCIA DE LA CAJA TORÁCICA EN LA GRAVEDAD DE LA FRACTURA POR ESTALLIDO EN LA COLUMNA TORÁCICA

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ABSTRACT

Objective: To analyze the anatomic influence of the ribs related to the severity of thoracic spine burst fractures. Methods: A retrospective review of 28 patients with thoracic spine burst fractures hospitalized by the Spine Group of the Hospital Ortopédico de Passo Fundo between January 2002 and December 2016 was conducted. The kyphosis, vertebral collapse, and narrowing of the vertebral canal measurements were compared between patients who had fractures at the true and false rib levels (T1 to T10) and those with fractures at the floating rib levels (T11 to T12). Results: The kyphosis, vertebral collapse, and narrowing of the vertebral canal values, measured only for vertebrae pertaining to the rib cage, were low. In addition, there were no statistically significant differences between the measurements of the group of patients with fractures at the level of the true and false ribs (T1 to T10) and the group of patients whose fractures were at the level of the floating ribs (T11 and T12). Conclusion: The differences between the traumatic structural changes in the vertebrae with true and false ribs (T1 to T10) and the vertebrae with floating ribs (T11 and T12) were not significant in the present study. ***Level of Evidence II; Retrospective study.***

Keywords: *Spinal Fractures; Thoracic Vertebrae; Spinal Canal.*

RESUMO

Objetivo: Analisar a influência anatômica das costelas sobre a gravidade das fraturas da coluna torácica tipo explosão. Métodos: Foi realizada uma revisão retrospectiva de 28 pacientes com fratura tipo explosão na coluna torácica, internados no período compreendido entre janeiro de 2002 a dezembro de 2016 pelo Grupo de Coluna do Hospital Ortopédico de Passo Fundo . As mensurações de cifose, colapso vertebral e estreitamento do canal vertebral foram comparadas entre os pacientes que apresentavam fraturas no nível das costelas verdadeiras ou falsas (T1 a T10) e aqueles com fraturas no nível das costelas flutuantes (T11 a T12). Resultados: Os valores da cifose, colapso vertebral e estreitamento do canal vertebral, mensurados apenas nas vértebras pertencentes à caixa torácica, mostraram-se baixos. Além disso, as mensurações não apresentaram diferenças estatísticas significativas quando foram comparados os grupos de pacientes que apresentavam fraturas no nível das costelas verdadeiras ou falsas (T1 a T10) com aqueles cujas fraturas eram no nível das costelas flutuantes (T11 e T12). Conclusões: As diferenças entre as alterações estruturais traumáticas nas vértebras com costelas verdadeiras e falsas (T1 a T10) e as vértebras com costelas flutuantes (T11 e T12) não foram significativas no presente estudo. ***Nível de Evidência II; Estudo retrospectivo.***

Descritores: *Fraturas da Coluna Vertebral; Vértebras Torácicas; Canal Vertebral.*

RESUMEN

Objetivo: Analizar la influencia anatómica de las costillas con respecto a la gravedad de las fracturas de la columna torácica por estallido. Métodos: Se realizó una revisión retrospectiva de 28 pacientes con fractura de columna torácica por estallido, ingresados en el período comprendido entre enero de 2002 y diciembre de 2016 por el Grupo de Columna del Hospital Ortopédico de Passo Fundo. Se compararon las medidas de cifosis, colapso vertebral y estrechamiento del conducto vertebral entre los pacientes que presentaban fracturas a nivel de las costillas verdaderas o falsas (T1 a T10) y aquellos con fracturas a nivel de las costillas flotantes (T11 a T12). Resultados: Los valores de cifosis, colapso vertebral y estrechamiento del conducto vertebral, medidos solamente en las vértebras pertenecientes a la caja torácica, se mostraron bajos. Además, las mediciones no presentaron diferencias estadísticamente significativas al comparar los grupos de pacientes que presentaban fracturas a nivel de las costillas verdaderas o falsas (T1 a T10) con aquellos cuyas fracturas estaban a nivel de las costillas flotantes (T11 a T12). Conclusiones: Las diferencias entre los cambios estructurales traumáticos en las vértebras con costillas verdaderas y falsas (T1 a T10) y las vértebras con costillas flotantes (T11 y T12) no fueron significativas en el presente estudio. ***Nivel de Evidencia II; Estudio retrospectivo.***

Descriptores: *Fracturas de la Columna Vertebral; Vértebras Torácicas; Conducto Vertebral.*

Study conducted at the Hospital Ortopédico de Passo Fundo, the Hospital de Clínicas de Passo Fundo, and the Faculdade de Medicina da Universidade de Passo Fundo, RS, Brazil.
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INTRODUCTION

Burst-type spinal fractures occur due to failure of the vertebral body when submitted to pressure on the axial axis.[1] They are usually caused by high-energy trauma, including automobile accidents and falls from considerable heights. They account for almost 20% of all thoracolumbar fractures.[2] They are usually associated with bone fragments in the vertebral canal and can lead to irreversible neurological damage.[3] They are characterized by the displacement of the pedicles in the anteroposterior radiograph, decreased vertebral height in the lateral radiograph, and fragmentation of the vertebral body into the vertebral canal, which is more adequately visualized via computed tomography.[1,4] However, the thoracic burst-type fracture is directly influenced by the anatomical and biomechanical particularities that surround it.[5]

While the type of fracture is important to determine therapeutic conduct, it is essential to identify the spinal segment where the fracture occurred.[6,7] The thoracic segment is in kyphosis and is protected by the rib cage. The vertebrae of the thoracic spine have a particular anatomy that differentiates them from the vertebrae of the other spinal segments. They have costal facets that articulate with the ribs. These, in turn, are divided into three anatomical types. The first seven ribs are called true ribs because they are attached directly to the sternum by their own costal cartilages. The 8th, 9th, and 10th ribs are known as false ribs, as they have no direct connection to the sternum. Their cartilages are joined to the cartilage of the rib adjacent to and above them. The 11th and 12th ribs are defined as floating. Unlike the others, their rudimentary cartilage does not connect to the sternum. They extend only to the posterior abdominal musculature (Figure 1).[8]

Although Morgenstern et al.,[9] have shown that the concomitant presence of a sternum fracture is an indicator of instability for A3/A4, B, and C type fractures and, consequently, result in greater neurological impairment and the need for surgical treatment, no studies were found in the literature that addressed the anatomical importance of the rib cage, with its ribs, with regard to the incidence and severity of burst-type thoracic spine fractures.

The small number of publications with emphasis on burst-type fractures of the thoracic spine encouraged an evaluation of the severity of the associated traumatic structural changes in the present study. In addition, the study objective was to investigate possible structural differences among burst-type fractures that occurred in thoracic vertebrae with true and false ribs (T1 to T10) and fractures that occurred in vertebrae with floating ribs (T11 and T12).

METHODS

During the period between 2002 and 2016, 97 patients with burst-type vertebral fractures were hospitalized by the Spine Group of the Hospital Ortopédico de Passo Fundo. In 28 patients, these fractures occurred in the thoracic spine. Thus, a retrospective study of burst-type fractures of the thoracic spine was conducted through analysis of the medical records of the Medical Archive and Statistics Service of the aforementioned institution.

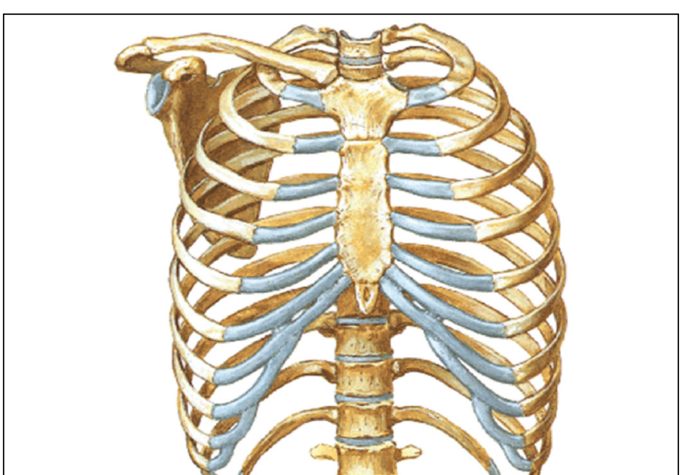

Figure 1. Sagittal and axial MRI cuts ULDH.

The authors of the present study signed the Informed Consent Form (ICF) for the use of data, committing to do so anonymously. It should also be noted that the research project was approved by the Institutional Review Board of the Universidade de Passo Fundo (IRB/UPF), after being forwarded via Plataforma Brasil as protocol number 348/2011.

All the cases were documented with anteroposterior and lateral radiographs of the thoracic spine and computed tomography with axial, sagittal, and coronal slices.

The fractures were classified as burst-type fractures, according to the characteristics described by Vaccaro et al.,[10] who consider these injuries to belong to subgroups A3 and A4. In these fractures, the vertebral body is partially or totally comminuted, there is centrifugal extrusion of bone fragments, fragments of the posterior wall are retropulsed, while the posterior ligament complex remains intact. According to the authors mentioned above, if the posterior arch is fractured the injury presents a vertical line in the frontal plane.[10]

Thoracic burst fractures were divided into two groups: Group 1 (T1 to T10), which have real and false ribs, and Group 2 (T11 and T12), which have floating ribs.

Three variables were used to grade the severity of the vertebral injury: the degree of kyphosis, the percentage of vertebral body collapse, and the percentage of vertebral canal stenosis. These variables represent the traumatic structural changes that were measured for each fractured vertebra. The mean measurements also allowed us to compare Groups 1 and 2.

The degree of kyphosis was measured in the lateral radiographs using the method described by Cobb.[11]

The method proposed by Willen et al.[12] was used to determine the percentage of vertebral body collapse in each of the fractured vertebrae. The formula estimates the vertebral body height before the occurrence of the fracture.

The technique for measuring the narrowing of the vertebral canal in the axial CT bone window from the bone fragment projected into it was performed with a transparent graduated millimetric ruler and based on the mean sagittal diameter. The diameter of the normal vertebral canal, before the trauma, was estimated as the mean of the values found in the axial slices of the corresponding anatomy of the vertebrae adjacent to the fracture location.[12-14]

In the statistical analysis between the measurements and the different vertebral groups, it was identified that non-parametric measurements had been used, as the Kolmogorov-Smirnov and Shapiro-Wilk tests indicated the non-normality of the variables. Therefore, the Mann-Whitney test was used. A significance level of 0.05 ($\alpha=5\%$) was adopted and descriptive levels (p) lower than this value were considered significant and represented by $p < 0.05$. All analysis was conducted using SPWA for Windows version 18 software.

RESULTS

Of the 28 patients evaluated, 21 (75%) were male and 7 (25%) were female. Their ages ranged between 17 and 82 years, with a mean age of 44.9 years.

The trauma mechanisms were fall from height in 16 patients (57%), car, or motorcycle accident in 10 patients (36%), and direct trauma to the spine in two patients (7%) (Figure 2).

The initial neurological function of all the patients analyzed was normal (Frankel E).

In addition, 22 (79%) of them were classified as A3 and six (21%) as |A4.

Six patients (21%) had spinal fractures in vertebrae not adjacent to those selected for the present study, while 22 patients (79%) had no other spinal injuries.

Associated fractures in limbs or injuries to other organs or systems were present in 8 patients (29%), while no associated injuries occurred in the other 20 cases (71%).

Laminar fractures were present in four patients (14%) and absent in 24 (86%) of the cases evaluated.

Regarding the anatomical distribution of the fractures, there were 6 cases (21%) in Group 1 (T1 to T10, which have true or false ribs) and 22 cases (79%) in Group 2 (T11 and T12, which have floating ribs).

Twenty patients (71%) were treated conservatively, and eight (29%) underwent surgical treatment.

Vertebral body collapse (%)

The percentage of vertebral body collapse measured for thoracic vertebrae ranged from 18 to 66.7%, with a mean value of 37.3%. In Group 1 (T1-T10) the minimum collapse was 18.5% and the maximum was 66.7%, with a mean of 38.3%. In Group 2 (T11 and T12), the mean was 37% with individual patient measurements ranging from 18 to 64.7% (Table 1).

Local kyphosis (°)

The Cobb angle, calculated on the thoracic vertebrae adjacent to the fracture, varied between 6° and 40°, with a mean value of 20.7°. Group 1 (T1-T10) presented kyphosis ranging from 10° to 40°, with a mean value of 25.8°. Group 2 (T11 and T12) had variations in the angle between 6° and 34°, with a mean value of 19.4° (Table 2).

Narrowing of the vertebral canal (%)

We found that the spinal canal stenosis values measured in the thoracic vertebrae varied from 5% to 55%, with a mean of 20.7%. In Group 1 (T1-T10), the minimal narrowing of the vertebral canal was 5% and the maximum was 35%, with a mean of 15%. In Group 2 (T11-T12), the minimum was 5%, the maximum was 55%, and the mean was 22.2% (Table 3).

DISCUSSION

Knight et al.,[15] reported that approximately 90% of all spinal fractures are located between T11 and L4, and 14 to 17% of these are classified as the burst type. Loss of stability, caused by the absence of ribs and thoracic musculature, is cited as one of the reasons that this region is more prone to injuries. The authors also stated

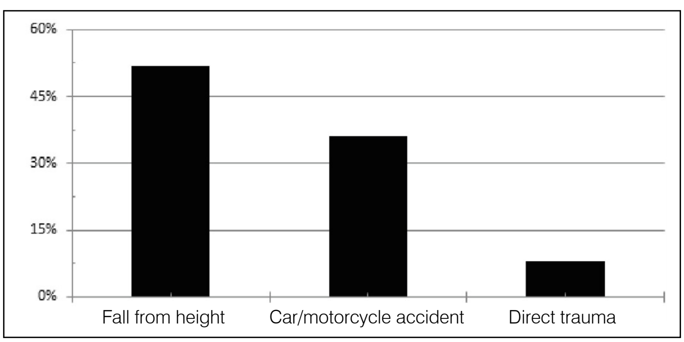

Figure 1. Sagittal and axial MRI cuts ULDH.

Table 1. Mean vertebral body collapse (%), by fracture region.

Fracture region	Mean	Standard Deviation	Minimum	Median	Maximum
T1 to T10	38.3	16.8	18.5	38.9	66.7
T11 and T12	37.0	13.4	18.0	35.2	64.7
Total	37.3	13.8	18.0	36.05	66.7

p = 0.845, Mann-Whitney test.

Table 2. Mean kyphosis (degrees) by fracture region.

Fracture region	Mean	Standard Deviation	Minimum	Median	Maximum
T1 to T10	25.8	11.7	10.0	27.5	40.0
T11 and T12	19.4	7.4	6.0	20.0	34.0
Total	20.7	9.0	6.0	20.0	40.0

p = 0.106, Mann-Whitney test.

Table 3. Mean vertebral canal narrowing (%) by fracture region.

Fracture region	Mean	Standard Deviation	Minimum	Median	Maximum
T1 to T10	15.0	10.5	5.0	12.5	35.0
T11 and T12	22.2	10.9	5.0	25.0	55.0
Total	20.7	12.5	5.0	20.0	55.0

p = 0.160, Mann-Whitney test.

that the anatomy of transition from the kyphotic thoracic curve to lumbar lordosis and the change in the orientation of the facet joints from coronal, in the thoracic spine, to sagittal, in the lumbar spine, are additional factors to justify the higher occurrence of injuries in this region. According to Magerl et al.,[16] 62% of spinal fractures occur between T11 and L2, only 20% of which are found at the T11 and T12 level. They also observed that 23% of all the fractures occurred between T1 and T10. As for classification, approximately 28% of all fractures were burst-type fractures. In the present study, we found that only 29% of the 97 thoracic and lumbar spine burst-type fractures diagnosed occurred in the thoracic spine, most of them being diagnosed in T11 and T12 (23%). Only 6% of all the burst-type fractures hospitalized in that period were located between T1 and T10. When considering only the 28 cases of burst-type thoracic spinal fractures, vertebrae that had true and false ribs (T1 to T10) were involved in 21% (6 cases) and vertebrae that had floating ribs (T11 and T12) were involved in 79% (22 cases) of these injuries. We also verified that, according to the classification by Vaccaro et al.,[10] most of the injuries were considered A3 and there were no patients with neurological deficit. These findings are indications that the energy dissipated in the vertebra by the axial trauma generates less severe injuries, even if they are located in the region of the vertebral canal occupied by the spinal cord. We observed that fractures of the thoracic spine that presented greater retropulsion of bone into the vertebral canal, greater kyphosis, and greater vertebral collapse were usually associated with a component of distraction or dislocation. These fractures were not selected for the respective study because they are classified as types B and C by Vaccaro et al.[10] We confirmed that the fractures classified according to Vaccaro et al.,[10] as types A3 and A4 in the present study, which only evaluated thoracic spine fractures, were infrequent and generally of low severity.

Vertebral body collapse is one of the most evident characteristics of burst fractures because there is circumferential fragmentation of the vertebral body, which can compromise the upper portion or the entire vertebral body. It is considered an important criterion for defining therapeutic conduct and an indication for surgical treatment when the collapse is greater than 50%.[17-21] Mumford et al.,[18] in their evaluation of 41 patients with burst-type thoracolumbar fractures but without neurological deficit, measured a mean vertebral collapse of 38.5% (6.1 to 76%). In their evaluation of 42 patients with burst-type lumbar fractures, Seybold et al.[6] reported a mean vertebral collapse of 27.9% (10 to 80%). In the present study, the mean collapse was 38.3% (18.5 to 66.7%) in Group 1 and 37% (18.0 to 64.7%) in Group 2. We found no statistically significant difference between the groups (p=0.845). Although there was no statistical significance, we believe that the greater mean collapse percentage in Group 1 may be due to the fact that these vertebrae are located in a region of greater kyphosis, with the axial trauma being more significantly directed to the anterior portion of the vertebral body, the region where the collapse was measured. This same explanation also justifies a greater mean collapse value in the thoracic segment than in the thoracolumbar transition and the lumbar segment. If there were no ribs, we believe that the anterior collapse in the thoracic segment would be significantly greater.

The degree of kyphosis in region of the fracture is one of the key factors for determining the severity of the injuries. Some authors suggest that angulation greater than 30° causes a poor functional outcome and, thus, an indication for surgical treatment would be more appropriate.[17-21] Other authors add that angulations above this value are a sign of instability.[15,20,22] Cantor et al.,[23] evaluated

18 patients with burst-type thoracolumbar fractures and found a mean initial kyphosis of 19° (9° to 28°). Mumford et al.,[18] evaluated 41 cases of burst-type thoracolumbar fractures and the mean initial kyphosis was 16° (0° to 47°). Aligizakis et al.,[24] analyzed 60 patients with spinal burst fractures and obtained a mean initial kyphosis of 6° (2° to 12°). Shen et al.,[25] in their evaluation of 38 cases of burst-type thoracolumbar fractures, measured a mean initial kyphosis of 20° (10° to 35°). The present study reported a mean kyphosis of 20.7° (6° to 40°). Although this mean kyphosis value is similar or even higher than that measured by some of the authors cited above, we must not forget that the thoracic segment is already in kyphosis. In the studies mentioned above, mean kyphosis was influenced by measurements taken in the lumbar spine. In this way, the kyphosis values are many times negative or slightly positive. In the present study, in Group 1 (T1-T10) the mean kyphosis was 25.8° (10° to 40°) and in Group 2 the mean value was 19.4° (6° to 34°). The higher mean kyphosis in Group 1 (T1-T10) contradicted the expectation that the costal framework was a protective factor for kyphosis in the vertebrae referenced. However, these data were not statistically significant ($p=0.106$). We believe that this finding may be related to the fact that the vertebrae located between T1 and T10 are in an anatomical segment of greater kyphosis than vertebrae T11 and T12, in which the kyphosis gradually decreases the closer the vertebra is to the thoracolumbar transition. Thus, a slight increase in physiological kyphosis in Group 1 (T1-T10) could present a greater measurement than a significant increase in the physiological kyphosis in Group 2 (T11 and T12).

Narrowing of the vertebral canal is considered a predictive factor for neurological damage.[26] Measuring it is valuable as it allows a more accurate assessment of the severity of the injury. Narrowing of the spinal canal greater than 50% has been indicative of surgical treatment, even in neurologically normal individuals, given the risks of advanced neurological deficit, advanced degenerative spinal stenosis, and the possibilities of associated damage to the lamina and dural sac. It is worth mentioning that none of the patients in this study presented any alteration in neurological function at the time of admission to the hospital. All patients were classified as Frankel E, even though one patient had 55% narrowing of the spinal canal. Several studies, such as the one by Tisot et al.,[27] have demonstrated that, for most burst-type thoracolumbar fractures without neurological deficit, conservative treatment is equally or more successful than surgical treatment when the narrowing of the canal is not accentuated (less than 50%). In the present study, most patients underwent conservative treatment with a Jewett brace. Tisot & Avanzi,[7] in their study of 43 burst-type low lumbar fractures, obtained a mean percentage of acute traumatic spinal stenosis of 46.2%. Avanzi et al.[28] studied a group of 143 patients with thoracolumbar burst fractures and found a mean narrowing of the spinal canal of 35% (8 to 100%). It is interesting to note that the mean spinal canal narrowing found in burst-type fractures of the thoracic spine (T1-T12) was only 20.7% in the present study, which is low when compared to the mean in several studies[7,18,28-31] in the literature dedicated to evaluating narrowing vertebral canal in the thoracic and lumbar spines together. In Group 1 (T1-T10), the mean narrowing of the spinal canal was 15%, and in Group 2 (T11 and T12) it was 22.2%, but the difference between them was not statistically significant ($p=0.160$). We believe the difference could have been statistically significant had the number of fractures evaluated been greater. In any case, we confirmed that the T11 and T12 vertebrae tended to have a greater mean spinal canal narrowing. This is probably because the vertebrae with true and false ribs (T1-T10) have circumferential axial protection. These ribs are posteriorly articulated by their costal facets and ligaments in the posterolateral region of the vertebrae and transverse process. In the anterior region of the rib cage, these ribs also are firmly attached to the sternum or costal cartilages. We believe that the energy dissipated in the T1 to T10 vertebrae by axial trauma generates less fragmentation of the posterior portion of the vertebral body. In the case of vertebrae T11 and T12, which have floating ribs, the same energy dissipated in the vertebrae by axial trauma would cause greater fragmentation of the vertebral body and, consequently, greater retropulsion of bone into the spinal canal, given that there is no rib support in the anterior rib cage.

In our study, we found that the protection afforded by the rib cage and the presence of the ribs may be important anatomical factors and probably influence the lower incidence and severity of burst-type fractures of the thoracic spine directly. This is corroborated when compared with statistical data on thoracolumbar and lumbar burst-type fractures researched in the current literature. Although the differences in kyphosis, vertebral collapse, and narrowing of the vertebral canal between the vertebrae with true and false ribs (T1-T10) and the vertebrae with floating ribs (T11 and T12) were not statistically significant, the fact that their mean values were low caught our attention. We also believe that a study with a greater number of cases might encounter a significant difference between the mean narrowing of the vertebral canal values in the two groups evaluated. In addition, we concluded that the term thoracolumbar spinal fracture is only appropriate to refer to fractures located in the thoracolumbar transition. Because the thoracic and lumbar spine segments present distinct anatomical and biomechanical alterations, which influence the frequency and severity of the injuries, we believe that the terminology would be more coherent if fractures that involve the trunk be referred to separately as thoracic and lumbar fractures.

CONCLUSION

The differences between the vertebrae with true and false ribs (T1-T10) and the vertebrae with floating ribs (T11 and T12) in terms of traumatic structural changes, represented by kyphosis, vertebral collapse, and narrowing of the spinal canal, were not significant in the present study.

All authors declare no potential conflict of interest related to this article.

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