Thecal sac injury secondary to burst fractures of the thoracolumbar and lumbar spine with compromise of the posterior vertebral body wall, and its association with the AOSpine Classification System variables

Guillermo A. Ricciardi, Ignacio G. Garfinkel, Gabriel G. Carrioli, Daniel O. Ricciardi
Spine Team, Hospital General de Agudos "Dr. Teodoro Álvarez" (Buenos Aires, Argentina)

ABSTRACT

Introduction: Fractures of the thoracolumbar spine can trigger thecal sac injuries due to the impingement of the cauda equina between bone fragments. **Objectives:** To carry out a retrospective analysis of clinical and radiological variables, the AOSpine Classification System and the possibility of secondary thecal sac injury in a series of thoracolumbar burst fractures treated at our center. **Materials and methods:** A retrospective, observational study of a series of patients with thoracolumbar fractures with compromise of the posterior vertebral body wall, who underwent surgery at our center between January 2012 and December 2017. **Results:** Forty-six patients were included, 16 of which had secondary thecal sac injury. The differences in the variables—percentage of spinal canal involvement, interpedicular distance, angle of the retropulsed fragment, neurological deficit and type C fractures—were statistically significant according to the comparison made with the presence or absence of thecal sac injury (p = 0.046, p = 0.007, p = 0.046, p = 0.004, p = 0,001 respectively). **Conclusions:** This study suggests that traumatic thecal sac injury could be suspected when managing burst fractures with prominent fragments in the posterior vertebral body wall, acute angle of the retropulsed fragment, severe compression of the spinal canal, wide interpedicular distance, neurological deficit and fracture displacement (fracture type C according to the AOSpine Classification System).

Key words: Thoracolumbar fractures; thecal sac injury; preoperative planning.
Level of evidence: IV

Lesión dural asociada a fracturas de charnela toracolumbar y lumbares con compromiso del muro posterior. Relación con las variables del sistema de clasificación AOSpine

RESUMEN

Introducción: Las lesiones del saco dural con atrapamiento de la cauda equina entre los fragmentos óseos pueden estar asociadas con fracturas toracolumbares. **Objetivo:** Realizar un análisis retrospectivo de las variables clínico-radiográficas y el sistema de clasificación AOSpine y la posibilidad de lesión dural asociada en una serie de fracturas toracolumbares por estallido, tratadas en nuestro Centro. **Materiales y Métodos:** Estudio retrospectivo, observacional de una serie de pacientes con fracturas toracolumbares con compromiso del muro posterior operados en nuestra institución, entre enero de 2012 y diciembre de 2017. **Resultados:** Se incluyeron 46 pacientes, 16 casos con lesión del saco dural asociada. Las variables porcentaje de ocupación del canal, distancia interpedicular, ángulo del fragmento retropulsado y déficit neurológico asociado mostraron diferencias estadísticamente significativas según la comparación en función de la presencia o ausencia de lesión dural (p = 0,046, p = 0,007, p = 0,046 y p = 0,004, respectivamente). **Conclusiones:** Según nuestros resultados, la lesión dural traumática podría ser contemplada en la planificación del tratamiento de fracturas toracolumbares ante fragmentos voluminosos del muro posterior con ángulo agudo, compromiso severo del canal raquídeo, distancia interpedicular elevada y daño neurológico asociado, tal como se propone en la bibliografía.

Palabras clave: Fractura toracolumbar; lesión dural; planificación preoperatoria.
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INTRODUCTION

Fractures of the thoracolumbar spine can trigger thecal sac injuries due to the impingement of the cauda equina between bone fragments.[1] Their development has been associated to compression of the posterior vertebral body wall during retropulsion, and to the fracture of a lamina. Laminar fractures can be complete or incomplete.[2]

According to published series, the percentage of thecal sac injuries associated to thoracolumbar fractures ranges from 18% to 25%.[3,4]

The significance of secondary thecal sac injuries lies in the complications that result from its imperfect closure or from failure to notice such complications, for instance, pseudomeningocele, a duro-cutaneous fistula, infections of the central nervous system (meningitis, arachnoiditis, epidural abscess), complications related to wound healing and persistent headaches.[5-10]

Clinical suspicion in preoperative assessments allows the spine surgeon to plan the surgery and include dural repair in their strategy to have all necessary elements for closure (instrumentation for microsurgery, magnifying lenses, microscope, dural patches or adhesives). Nevertheless, it can be difficult to come to a diagnosis before surgery. Mielography has been proposed to evaluate thecal sac injuries but, as it is an invasive technique that entails the risk of neurological complications, it is not frequently used in polytraumatized patients.[11-13]

Several studies have estimated the predictive value of findings from magnetic resonance imaging (MRIs) and computed tomographies (CTs) for suspectedly diagnosing thecal sac injuries secondary to thoracolumbar fractures.[14] According to Lee *et al*., thecal sac injuries can be produced when there are findings of laminar fracture, the interpedicular distance is >28 mm, the radius of the central canal is 0.46 and the acute angle of the retropulsed segment is 135°.[15] Yoshiiwa *et al*. describe the "cauda equina notch sign" (CENS) as a predictable sign of impingement of the cauda equina in incomplete laminar fractures and the size of the retropulsed wall fragment.[16]

Aydnl *et al*. have described that, in CTs and MRIs, the posterior fat pad signs disappeared in axial sections when an incomplete laminar fracture and nerve root impingement were present.[17]

Among clinical variables, the neurological deficit associated is often related to concomitant thecal sac injuries.[18]

In the present, to evaluate spinal fractures we have the AOSpine thoracolumbar spine injuries classification system (AOSpine classification), which is the most widely used in clinical practice. The classification system proposed by Vaccaro includes the evaluation of the morphology (A, B, C), the neurological status (N) and the clinical modifiers (M).[19] According to the reviewed literature, there are no publications related to the compromise of the posterior ligamentous complex and the displacement of the thecal sac injury.

Therefore, we are thinking about including the assessment of the risk of a secondary thecal sac injury in the treatment of thoracolumbar burst fractures and suggest the following research question: Is there a relationship between the clinical and radiological variables included when planning the treatment of thoracolumbar fractures (neurological status, complementary exams and injury classification) with posterior wall compromise (A3 and A4 as per AOSpine classification) and the thecal sac injury?

Based on this question, we formulate the following hypothesis: traumatic thecal sac injuries in thoracolumbar and lumbar spine fractures with posterior wall compromise can be associated to radiological and clinical signs that can be assessed during surgical planning.

The objective of this study was to carry out a retrospective analysis of clinical and radiological variables, the AOSpine Classification System and the possibility of secondary thecal sac injury in a series of lumbar and thoracolumbar burst fractures treated at our center.

MATERIALS AND METHODS

A retrospective, analytical, observational study was carried out with a series of patients having lumbar and thoracolumbar fractures with compromise of the posterior vertebral body wall (A3, A4 as per AOSpine classification), who underwent surgery at our center between January 2012 and December 2017.

Inclusion criteria were: adults of both sexes, 18-65 years old, with spine fractures between T12 and L5, who underwent decompression and a thoracolumbar arthrodesis. Exclusion criteria were: 1) pathological fractures, 2) osteoporosis-induced fractures, fractures with no compromise of the posterior wall (A1 and A2 as per AOSpine classification), and 4) B1 and B3 fractures as per AOSpine classification.

Data was collected from medical records and complementary studies regarding the following study variables.

Independent variables

- Age.
- Sex.
- Injury level (T12-L5).
- Laminar fracture (assessed in axial sections of CT).
- Interpedicular distance (wider distance measured in millimeters between both pedicles of the fractured vertebra in the axial section of CT) (Figure 1).
- Percentage of spinal canal involvement, measured in the axial sections of the CT, considering as benchmark the average area between the canal at a level above and at a level below the injured level, and estimating the percentage of involvement of the compromised level (Figure 2).
- Retropulsed fragment angle, measured in sagittal sections of the CT or MRI as apex, the fragment point that indents the sac and the angle constituted by its limits (Figure 3).
- Cauda equina notch sign, measured in axial sections of MRI, according to what Yoshiiwa *et al*. have described.[16]
- Fat pad sign, measured in axial sections of MRI, according to what Aydnl *et al*. have described.[16]
- Neurological exam, using the N variable from AOSpine classification.[19]
- AOSpine classification.[19]

Figure 1. Computed tomography, axial section. Interpedicular distance.

Figure 2. Computed tomography, axial section. Percentage of spinal canal involvement.

Figure 3. Magnetic resonance imaging, sagittal section. Retropulsed fragment angle.

Dependent variable

- Thecal sac injury, based on the intraoperative assessment during decompression.

STATISTICAL ANALYSIS

Categorical variables are expressed in figures and relative frequency in percentage, and were analyzed with the chi-square test or the Fisher's test. Interval variables are described by the median and their dispersion measure (standard deviation). To compare continuous variables, the Student's t test or the Wilcoxon rank-sum test were used, based on the expressed distribution. Any value $p < 0.05$ was considered statistically significant. For the analysis, the software SPSS Statistics 25 was used.

RESULTS

Between January 2012 and December 2017, 75 patients with thoracolumbar spine fracture underwent surgery. According to inclusion and exclusion criteria, the final study population consisted of 46 patients (5 women and 41 men) with thoracolumbar fractures that compromised the posterior vertebral body wall. As per AOSpine classification, 27 of them were type A, 9 were type B, and 10 were type C. Ten of them were fractures of T12, 18 were L1, 8 were L2, 5 were L3, 4 were L4 and one was L5. Sixteen cases (35%) of secondary thecal sac injuries were observed. When comparing variables, vertebral levels were assorted in two groups, thoracolumbar spine (T12, L1 and L2) and lower lumbar spine (L3, L4 and L5), considering the biomechanical demands and the common anatomical characteristics to allow their comparison as categorical variable. The Table below describes the study population and the results from the comparison of independent variables based on the presence or absence of a thecal sac injury.

No significant differences were found between variables related to age, sex, injury level and secondary thecal sac injury.

As per AOSpine classification, 80% of type C injuries (8 out of 10 patients) had a secondary thecal sac injury compared to the rest of the sub-types, with a statistically significant difference in the comparison ($p = 0.001$) (Table).

Laminar fracture was diagnosed in 75% of patients (12 out of 16 cases) with thecal sac injury; however, in our series, we did not find statistically significant differences ($p = 0.065$).

The differences in the variables—percentage of spinal canal involvement, interpedicular distance, angle of the retropulsed fragment, and secondary neurological deficit—were statistically significant according to the comparison made with the presence or absence of thecal sac injury ($p = 0.046$, $p = 0.007$, $p = 0.046$, and $p = 0.004$, respectively).

The variables fat pad sign and cauda equina notch sign were not considered in the comparison because they are observed in incomplete laminar fracture cases and, in our series, all laminar fractures were complete.

DISCUSSION

Presence of a traumatic thecal sac injury secondary to thoracolumbar spine fractures ranges from 18% to 36%, according to published series.[1] In our series, it was 35%, which matches the mentioned prevalence.

In 1980, Miller *et al*. described the relationship between the thoracolumbar fracture with laminar fracture and the thecal sac injury due to sac-nerve root impingement between the laminar fragments.[1] As a result of a descriptive study, Pau *et al*. suggested assessing the interpedicular distance and the secondary laminar fracture according to radiological parameters related to the spinal canal.[21] Later Kahamba *et al*. described a significant association between the secondary neurological compromise, the injury in posterior elements and the traumatic thecal sac injury.[22] Lee *et al*. analyzed MRIs of 21 patients with spine fractures and thecal sac injury surgically confirmed and of 33 patients with no secondary thecal sac injury. They concluded that the imaging specialist should suggest a high risk of thecal sac injury if there is compromise in more than half the spinal canal, fragments in retropulsion at an acute angle, secondary unstable fractures of the associated lamina and a wide interpedicular distance at the level of the fractured vertebra.[15]

Park *et al*. presented similar results with the same variables, additionally ranking the associated neurological deficit.[14]

In our study, we considered the variables proposed by Lee *et al*. and the ones published later by Park *et al*., and we obtained similar results—there was a statistically significant difference between the increase in the percentage of medullary canal involvement, the wider interpedicular distance and the acute angle of the retropulsed fragment

Table. Independent variables based on the thecal sac injury.

Variables	Total n = 46	Without thecal sac injury n = 30	With thecal sac injury n = 16	p
Age Median Standard deviation	 39 13	 39 13	 39 14	0.889
Sex, n (%) Female Male	 5 (11) 41 (89)	 5 (17%) 25 (83%)	 0 (0) 16 (100)	0.084
Level, n (%) Thoracolumbar spine: T12-L2 Lower lumbar spine: L3-L5	 36 (78.3) 10 (21.7)	 24 (80) 6 (20)	 75 4 (25)	0.695
AOSpine, n (%) A B C	 27 (59) 9 (19) 10 (22)	 22 (73) 6 (20) 2 (7)	 5 (31) 3 (19) 8 (50)	 **0.006** 0.919 **0.001**
Neurological deficit, n (%) Yes No	 16 (35) 30 (65)	 6 (20) 24 (80)	 10 (63) 6 (37)	 **0.004**
Laminar fracture, n (%) Yes No	 26 (57) 20 (43)	 14 (47) 16 (53)	 12 (75) 4 (25)	 0.065
% of canal involvement Median Standard deviation	 35 24	 30 22	 45 27	 **0.046**
Segmental kyphosis Median Standard deviation	 9 13	 12 9	 5 18	 0.058
Interpedicular distance Median Standard deviation	 27 5	 25 4	 30 8	 **0.007**
Retropulsed fragment angle Median Standard deviation	 118 42	 128 43	 102 38	 0.046

at the level of the fracture in our patient group with traumatic thecal sac injury compared to those variables in patients with no secondary thecal sac injury. However, although laminar fractures were more frequent in patients with traumatic thecal sac injury, they did not result in significant differences. Nevertheless, we prioritized such association due to the data published in classical literature, considering the lack of significance of this association as a possible result of the small number of patients participating in our study.[1-4]

When analyzing the presence of neurological deficit in patients with thoracolumbar fractures, we found statistically significant differences in patients with a thecal sac injury compared to those patients with no such injury. These results are compatible with the data published by Park *et al*.[14]

As to the relationship between the variables included in the AOSpine lumbar and thoracolumbar injuries classification system, we did not find any published article mentioning it. In our series, when doing the comparative analysis between different sub-types associated to fractures with posterior wall compromise, we found significant

differences, with a higher percentage of thecal sac injuries among type C injuries, which is possibly related to the sac-nerve root impact due to the displacement. When analyzing the presence of thecal sac injuries in type A injuries, with no displacement or injury of the posterior ligamentous complex, the difference was also significant compared to the rest of types B and C. For this reason, it is necessary to carry out studies including more patients with the possibility to make a multivariable analysis or a prospective design that allows to analyze the relationship between the risk of thecal sac injury to each classification type.

The limitations of our study include its retrospective design and the possible information bias resulting from collecting data from medical records and the digital radiological files, as well as the diagnosis of thecal sac injuries confirmed by posterior management during decompression, which may have prevented us from noticing injuries in the anterior aspect of the thecal sac that modified the real prevalence of the traumatic thecal sac injury.

CONCLUSIONS

Traumatic thecal sac injury could be suspected when planning thoracolumbar fractures management in cases with prominent fragments in the posterior vertebral body wall with acute angle, severe compromise of the spinal canal, wide interpedicular distance, and neurological deficit, in accordance with what is suggested in published studies. We consider this study as an incentive to and a foundation for developing future research projects with a higher level of evidence that allow to determine the relationship between the risk of thecal sac injury to the AOSpine classification system variables.

Conflict of interest: Authors claim they do not have any conflict of interest.

I. G. Garfinkel ORCID ID: http://orcid.org/0000-0001-9557-0740
G. G. Carrioli ORCID ID: http://orcid.org/0000-0003-4160-9712
D. O. Ricciardi ORCID ID: http://orcid.org/0000-0002-1396-9115

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