ORIGINAL ARTICLE

Is there a difference between narrowing of the spinal canal and neurological deficits comparing Denis and Magerl classifications?

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Study design: Retrospective chart review.

Objectives: The objective of the current study was to evaluate the correlation between neurological deficits and the severity of narrowing of the spinal canal in patients with thoracic, thoracolumbar and lumbar burst-type fractures by comparing the classifications of Denis and Magerl. From 1989 to 2005, a total of 227 patients with burst fractures following Denis' criteria were studied.

Setting: Tertiary teaching institution.

Methods: Computed tomographic scans of the fractured spine were analyzed to assess the narrowing of the spinal canal. Following Magerl's criteria, patients were later subdivided into two groups according to the presence of associated ligament injuries, out of which 185 patients had no such injuries and the remaining 42 patients were classified as Magerl group B.

Results: Results were evaluated based on the initial neurological status of patients according to Frankel and based on the midsagittal diameter of the fractured vertebra. A significant correlation was found between the narrowing of the spinal canal and neurological deficits in both classifications, with no significant differences between either.

Conclusion: The percentage of narrowing of the spinal canal proved to be a pre-disposing factor for the severity of the neurological status in thoracolumbar and lumbar burst-type fractures according to the classifications of Denis and Magerl. The greater the bone fragment in the spinal canal, the greater will be the probability of neurological deficits in both fracture classifications, equally.

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Introduction

Thoracolumbar burst-type fractures were first described by Denis¹ as a compromise of the midspine segment associated with dislocation or rotation of the posterior cortical bone of the vertebral body. Computed tomographic studies of these fractures show bone fragments from the posterior wall of the vertebra dislocated posteriorly into the spinal canal.¹

The relationship, proposed by Denis, between the narrowing of the spinal canal caused by the retropulsed bone fragments and severity of neurological deficits has been greatly emphasized in literature.^{1–3} However, another interesting approach to these fractures, proposed by Magerl,² has been poorly explored. This latter classification reflects a progressive α -numerical scale of the morphological damage related to the severity and instability of the spine

in burst-type fractures. It seems very important to address other possible trauma mechanisms in these complex fractures. Thus, one hypothesizes that these different approaches to the mechanisms of trauma in burst-type fractures of the spine may translate into distinct correlations between the narrowing of the spinal canal and neurological deficits.

There is a consensus in literature regarding the surgical decompression of the spine and removal of the retropulsed bone fragment in patients with neurological deficits.^{1–4} Controversy remains in the management of burst-type fractures that are not associated with neurological deficits. Should surgical decompression be carried out to assure repair of ligament injuries of the posterior elements? Literature has not been able to establish the best approach to such cases.^{2,3,5}

The objective of the current study was to try to establish a correlation between the narrowing of the spinal canal and the presence of neurological deficits in patients with thoracic, thoracolumbar and lumbar burst-type spine fractures according to the classifications of Denis and Magerl.^{1,2}

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Materials and methods

From 1989 to 2005, a total of 260 patients with burst-type fractures of the spine, according to Denis' classification,¹ were treated at a tertiary teaching institution. Following Institutional Review Board approval, a systematic chart review, as well as a blinded review of the plain radiographs and computed tomographic scans of the spine were carried out. Only 227 cases with an acute history of less than 10 days from the trauma were included in this study. Exclusion criteria were also pathological fractures, gun-shot wounds and fractures at more than one vertebral level.

According to Fontijne's classification,³ 8 patients (3.5%) had injuries of the thoracic spine, 143 patients (63%) of the thoracolumbar spine and 76 patients (33.5%) had lumbar fractures. Neurological status was established following Frankel's criteria.⁴ In order to establish the severity of narrowing of the spinal canal, the midsagittal diameter of the canal was established using a millimetric ruler.⁵ The normal diameter of the spinal canal was estimated by measuring the midsagittal diameter of the spinal canal of the vertebrae adjacent to the fracture.⁵

On the basis of imaging examinations (plain radiographs and computed tomographic scans), patients were also classified according to Magerl's criteria.² To differentiate Magerl type A and type B fractures, the distance between the spinous processes was established by using the cranial portion of the tear-shaped image of the spinous process on the anterior-posterior view and measuring the distance between the adjacent processes above and below the fractured vertebrae.⁶ This distance was expressed in millimeters and percentages.

Out of 227 patients, 42 patients had Magerl type B fractures and were analyzed separately. Thus, a new group of 185 patients was studied for the variables of age, mechanism of trauma, level of injury, presence of neurological deficits and classification of this deficit using the Frankel score,⁴ as well as the severity of narrowing of the spinal canal.

Statistical analysis was carried out using the Student's *t*-test for comparison of averages, chi-square test for values expressed in frequencies, Pearson's correlation for numerical data, logistic regression model to establish the probability of neurological deficits related to the severity of narrowing of the spinal canal and median tests to determine wherein the narrowing of the spinal canal became a determining factor for neurological deficits.⁷

Results

The mean age of the studied population ($n=227$) was 39.4 ± 15.3 years, with a prevalence of males (68.3%) over females. Fall from height was the major cause of trauma (78.4%), followed by automobile accidents (10.6%), motorcycle accidents (4.4%) and land sliding (1.3%). Other mechanisms of trauma corresponded to 5.3% of the observed frequencies. The majority of injuries were at the thoracolumbar level (63%), followed by the lumbar segment (33.5%) and the thoracic segment (3.5%) of the spine.

Neurological deficits were observed in 44 patients (19.4%): 4.4% were Frankel type A, 3.2% were Frankel type B, 3.9% were Frankel type C and 7.9% were Frankel type D. The great majority of patients (80.6%) were without neurological deficits and were, therefore, classified as Frankel type E. The mean narrowing of the spinal canal was 36.1 ± 18.9 mm. A greater distance between the spinous processes at the level of the fracture was found in 42 patients (18.5%), with a mean value of 0.96 ± 0.58 mm or $44.3 \pm 27.7\%$ (Magerl type B). Overall, there were 99 patients with Magerl type A3.1 fractures; 86 patients with Magerl type A3.3 and 42 patients with Magerl type B1.2.

The average narrowing of the spinal canal was significantly greater in patients with neurological deficits, both in the group of 227 patients with burst-type fractures classified according to Denis ($P=0.0038$) and in the group of 185 patients with Magerl fractures type A3.1 and A3.3 ($P=0.0020$) (Table 1).

The probability of presenting neurological deficits calculated by logistic regression, when narrowing of the spinal canal was 25, 50 and 75%, was directly correlated to the severity of narrowing in both classification groups (Figures 1 and 2).

Those patients with fractures classified as Magerl A3.3 presented a mean narrowing of the spinal canal significantly greater than patients with fractures classified as Magerl A3.1 and B1.2 (Table 2).

Table 1 Mean and standard deviation of the comparisons between the severity of narrowing of the spinal canal and neurological deficits in patients studied according to Denis and Magerl's classifications

Neurological deficits	Severity of narrowing (mean and s.d.)	
	Burst-type fractures following Denis' criteria ($n=227$)	Magerl fractures type A3.1 and A3.3 ($n=185$)
Present	51.5 ± 19.2	53.8 ± 17.5
Absent	32.3 ± 16.9	33.7 ± 17.3
	$P=0.0038$	$P=0.0020$

Figure 1 Distribution of patients according to the neurological deficit probability and canal narrowing percentage in the studied groups (Denis versus Magerl classifications).

Figure 2 Probability curves of neurological deficits according to the severity of narrowing of the spinal canal in the two studied groups (Denis versus Magerl classifications).

Table 2 Mean and standard deviation of the severity of narrowing of the spinal canal in patients with and without injury of the posterior spine

Injury of the posterior spine	Severity of narrowing (mean and s.d.)	Statistical analysis
Present	26.4 ± 15.3	P = 0.0003
Absent	38.1 ± 19.2	

The group of patients ($n = 42$) presenting with injury of the posterior spine (Magerl fractures type B1.2) were analyzed separately. In total, 9% of these patients had neurological deficits. The narrowing of the spinal canal was significantly greater in this group ($P = 0.003$).

Discussion

Thoracolumbar and lumbar fractures are commonly found in patients with multiple injuries.^{2,8,9} Burst-type fractures may be present in up to 60% of these patients,^{8,9} with a greater incidence of fractures in the thoracolumbar segment of the spine.^{10–12} The same correlations were observed in the present study.

Thoracolumbar burst-type fractures are reported to be most prevalent in males up to 40 years of age.^{2,5,8} In the current series, 155/227 patients (68%) were males with a mean age of 39.4%. Fall from height is considered to be the main cause of these fractures^{5,10} and was found to be the mechanism of trauma in 78.4% of our patients.

In tomography scans, the typical image of a burst fracture, according to Denis,¹ is the narrowing of the spinal canal produced by the fragment of the fractured vertebra. This narrowing, when present, seems to be the main mechanical reason for neurological injury.^{13–15} In this situation, surgical removal of the fragment is mandatory.

Narrowing of the spinal canal in such cases has been reported in 17–82% of patients^{10,16,17} and was found in 36.1% of the patients in the current study. Narrowing of the

lumbar spine is usually more common than that of the other segments of the spine^{8,10} and was found in 41.2% of the patients, compared with 21.8% in the thoracic and 33.8% in the thoracolumbar segments of the spine. A significant direct correlation was found between the percentage of narrowing of the spinal canal and neurological deficits found upon initial examination. A negative correlation was found between the Frankel score and narrowing of the spinal canal ($r = -0.3274$; $P < 0.05$), wherein patients classified as Frankel E (without neurological deficits) had significantly less narrowing of the spinal canal than those classified as Frankel A, B, C and D.

In 1994, Magerl *et al.*² proposed a pathomorphological classification for thoracolumbar fractures that contemplated a greater number of injuries than those observed in Denis' score. This classification observed the presence of ligament injuries associated with fragments from the posterior portion of the vertebrae (Magerl type B1.2 and B2.3) and injuries caused by sheering or rotation of the vertebral body (Magerl type C1.3). Those cases that lack clear anatomical injuries according to the Denis score can be classified as flexion–distraction injuries (Magerl type B) or fracture dislocations (Magerl type C).

One of the hypotheses that motivated the current study was the possibility of better expressing the correlation between narrowing of the spinal canal and neurological status through a score that offered a detailed analysis of the mechanism of trauma with a better subclassification of the injuries presenting with bone fragments inside the spinal canal. One hypothesized that by analyzing those fractures caused exclusively by compression (Magerl type A3), thus excluding Magerl fractures types B and C, a significant correlation would be found between narrowing of the spinal canal and neurological deficits. Our data supported this hypothesis. Our study found a correlation of the presence of a posterior fragment in the spinal canal with any type of Magerl fractures (A3, B or C). Thus, decompression of the spinal canal in these cases is imperative.

The literature, to date, had not shown a correlation of each of the Magerl fracture subtypes and spinal canal stenosis with neurological impairment. The indication of surgical decompression of the spinal canal may depend on this finding. In our study, patients with A3.3 Magerl fractures had a mean stenosis level that was significantly greater (45.3%) than that of patients with A3.1 (31.7%) and B1.2 (26.8%) fractures. Contrary to this, Eberl *et al.*¹⁵ observed 32% of patients with narrowing in the group of subtype A, 55% in subtype B and 44% in subtype C. In these cases, neurological impairment might be due to factors other than the spinal canal narrowing and thus the indication of decompression surgery could be questioned. In our study, we found a correlation between the spinal canal narrowing and presence of neurological impairment (narrowing greater than 33% pre-disposes neurological deficits), and this confirms the importance of the narrowing as a contributing factor to the neurological injury, independent of the fracture sub-type classification. The surgical removal of the fragment is suggested in fractures type A3.3 and, to a lesser extent, in type B1.2.

Diagnosing and defining a ligament injury of the posterior elements of the spine in burst-type fractures is a challenge.^{13,14,18,19} Even though conservative treatment is usually advocated for burst-type fractures that present without neurological deficits, patients with associated ligament injuries should be considered as surgical candidates, due to the risk of mechanical instability. Magerl's classification takes into consideration indirect data such as tenderness on palpation of the inter-spinous spaces and radiographic signs of widening of the distance between the spinous processes, both on plain radiographs and on sagittal-tomographic reconstructions. However, Magerl never mentioned the criteria used to take these measurements or its validation.² Several frustrated attempts have been made to establish objective ways of assessing the presence of ligament injuries of the posterior elements of the spine, a number of them through magnetic resonance imaging.^{14,18,19} The current study established the distance between the spinous processes using Neumann's method⁶ that takes into consideration patients' individual anatomical parameters by comparing the adjacent levels above and below the fracture. A total of 42 patients (18.5%) were found to have injuries of the posterior ligament elements and were classified as Magerl type B. There were no cases with Magerl type C fractures in the current series, as sheering and rotation injuries (that is, fractures-dislocations) are not contemplated in Denis' criteria for burst-type fractures. The majority of patients ($n = 185/81.5\%$) presented Magerl type A fractures.

Contrary to Magerl's findings, in the current series patients without injuries of the posterior spine presented a significantly greater narrowing of the spinal canal. The spinal canal of patients with Magerl type A3.3 injuries was significantly narrower, on average 45.3%, than that of patients with Magerl type A3.1 (31.7%) and B1.2 (26.8%) injuries. In 2003, Eberl *et al.*¹⁵ published the only other study that reported such correlation finding greater narrowing of the spinal canal in patients with Magerl types B and C. Although their results are the exact opposite of ours regarding the type of injuries that presented greater narrowing of the spinal canal, these authors also found a direct correlation between the narrowing of the spinal canal and the severity of neurological deficits. In the current study, not only was a greater narrowing of the spinal canal in patients with Magerl type A fractures found, but also these patients presented more severe neurological deficits than those classified as Magerl type B.

These findings support the importance of assessing the narrowing of the spinal canal in burst-type fractures of the thoracolumbar spine, regardless of the classification system adopted. It was found that narrowing of the spinal canal by greater than 33% is a predisposing factor for neurological deficit.

A significant correlation was found between narrowing of the spinal canal and neurological deficits in both the Denis and Magerl classifications, with no significant differences between them. The presence of the bone fragment in the spinal canal was found to be a pre-disposing factor for the severity of the neurological deficits in thoracolumbar and

lumbar burst-type fractures and should be considered to be an important factor in the management of these traumas, even when associated with ligament injuries of the posterior elements of the spine.

The greater the bone fragment in the spinal canal, the greater will be the probability of neurological deficit in both fracture classifications, equally.

Conflict of interest

The authors declare no conflict of interest.

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