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High Preoperative Canal Compromise as Risk Factor for Worse Neurological Outcome in Patients with Thoracolumbar Burst Fracture After Spinal Decompression and Stabilization Surgery

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ABSTRACT

Introduction: Canal compromise (CC) has been associated with neurological outcomes in thoracolumbar burst fractures, with some suggestions indicating a direct correlation with a relatively worse prognosis even after surgical intervention. This study attempted to reveal the association between the preoperative CC in thoracolumbar burst fracture undergoing posterior spinal decompression – stabilization – fusion, with postoperative neurological outcome.

Methods: This study adopts a retrospective design, utilizing the medical and radiological records of total of 50 patients (41 males and nine females), with an average age of 42.4 ± 13.57 years. It divided into a case group (comprising 25 patients without neurological improvement) and a control group (consisting of 25 patients with neurological improvement). Consecutive sampling was applied to individuals meeting the predefined inclusion and exclusion criteria. Canal compromise (CC) and the initial neurological function of all participants were assessed in the preoperative period, with a subsequent evaluation of the final neurological function conducted at a minimum of six months postoperatively. Statistical analysis involved descriptive analysis and the Chi-Square test, with the cut-off point determined through Receiver Operating Characteristic (ROC) analysis.

Results: The Receiver Operating Characteristic (ROC) analysis identified 40% as the cut-off point distinguishing between low and high canal compromise (CC). Univariate Chi-Square test analysis revealed a statistically significant difference in CC as a risk factor for postoperative neurological deficit. CC exceeding 40% is significantly associated with a relatively worse postoperative neurological outcome ($p < 0.001$; odds ratio [OR] 21).

Conclusion: A high preoperative canal compromise (CC) emerges as a direct risk factor for the absence of neurological improvement in patients with thoracolumbar burst fractures, indicating that higher CC is significantly associated with a relatively poorer prognosis.

Keywords: *thoracolumbar burst fracture, canal compromise, neurological deficit*

INTRODUCTION

Burst fracture is the most common manifestation of trauma and is subjected to severe disability in the spine. The thoracolumbar region is particularly prone to such fractures due to its distinctive mobility characteristics. A defining morphology of the burst fracture is the evidence of the retropulsion of vertebral body to spinal canal, compress the spinal cord which is considered to be the pathophysiology of the disease. Acute compression of the spinal cord which was resulted from severe axial loading is associated with disabling neurological deficit.[1,2]

Several previous studies attempted to reveal the association between specific medical and radiological characteristic, to assess the risk factors and prognosis of the disease with vague conclusion.[3] Since paralyzing unstable burst fracture requires surgical intervention, to date there is no study which directly evaluate the preoperative CC we proposed a method to predict the postoperative neurological outcome by utilizing the preoperative radiological status.[4,5]

MATERIAL AND METHODS

This study has been registered and approved by the Committee of Research Ethic, Faculty of Medicine, Udayana University, Denpasar, Bali, Indonesia (Registration Number 842/UN14.2.2.VII.14/LT/2023). Given that this research solely relied on the medical records of the participants without direct interaction between the researchers and the subjects, obtaining informed consent was deemed unnecessary.

This study employed a case-control design with 25 patients in case group (patients without neurological improvement) and 25 patients in control group (patients with neurological improvement). Consecutive sampling was applied based on inclusion and exclusion criteria. Inclusion criteria stipulated: (1) Patient with single level thoracolumbar burst fracture at level Th10 – L2 underwent posterior decompression stabilization and fusion procedures following AO guidelines; (2) Patient with age above 18 years; (3) BMI between 18.5-25 kg/m^2; (4) complete availability of preoperative CT-Scan images; (5) Surgery conducted by a senior orthopedic spine surgeon consultant with minimum experience of 5 years; and (6) minimum follow-up period of six months. Exclusion criteria encompassed: (1) Associated head injuries; (2) Spinal cord injury (SCI) due to transection of the spinal cord; (3) Congenital musculoskeletal abnormalities; (4) Cauda Equina Syndrome; (5) Conus Medullaris Syndrome; (6) The development of early and late onset of deep or superficial surgical site infection and (7) Burst fracture classified as Frankel grade E. Preoperative medical data were collected consist of initial neurological function (evaluated using Frankel Classification), body mass index, and CC which were measured using patients CT scan data.

Preoperative Neurological Status and Clinical Diagnosis

The initial neurological status of patients following trauma was evaluated on day 0 post-trauma or upon the patient's arrival at the Emergency Department (ED). After obtaining the patient's medical history, neurological status was assessed and graded using the Frankel classification system for spinal cord injury. The Frankel classification includes: Frankel A, indicating complete motor and sensory loss; Frankel B, denoting complete motor loss with incomplete sensory loss; Frankel C, signifying incomplete motor loss without practical use; and Frankel D, representing incomplete motor loss with the ability to ambulate, with or without walking aids.

Canal Compromise Evaluation

Canal compromise (CC) is evaluated using axial view from spinal CT-scan at level of vertebral body. The evidence of a burst fracture is indicated by a fracture extending to the middle column in conjunction with retropulsion of the vertebral body into the spinal canal, thereby compressing the spinal cord. CC essentially reflects the extent to which the offending vertebral body obliterates the spinal canal. In that essence, higher CC percentage resulted in more severe spinal canal compression. The CC was determined by the following equation:

$$CC = \left[1 - \left(\frac{dx \times 2}{da + db}\right)\right] \times 100\%$$

CC : canal compromise (%)

dx : remaining anterior-posterior canal length at fractured level (*mm)*

da : anterior-posterior canal diameter of one adjacent level above fractured vertebrae (*mm*)

db : anterior-posterior canal diameter of one adjacent level below fractured vertebrae (*mm*)

Spinal Decompression – Stabilization – Fusion Surgery

Surgical procedures were performed by a senior orthopedic spine surgeon with a minimum of five years of experience in the field. Surgical procedure utilizing indirect posterior decompression through total laminectomy of the fractured vertebrae, followed by stabilization and fusion by posterior instrumentation and bone grafting after restoring the spine physiological alignment.[6–8]

Post Operative Care and Neurological Follow Up Testing

Postoperative period comprises of prophylactic course of antibiotic for three days, observation of drain production, a thorough neurological examination, wound care, restoring bowel and bladder function, and appropriate pain management. A good collaboration with nutritionist and physiotherapy team is essential to implement appropriate post operation care and rehabilitation protocol. Early and gradual mobilization exercises are encouraged since day one after surgery starting with elevation of the head in the supine position, until eventually sitting with supportive orthosis. Spinal orthosis is recommended to be maintained at least for six months after surgery until spinal fusion is achieved.

All patients were advised to regularly visit the outpatient clinic twice a week in the first month to receive wound care, observation of any complication manifestations, and physical rehabilitation. After the wound completely healed without any evidence of infection, a regular visit was still encouraged at least once every month to monitor patient's neurological function and rehabilitation. We assessed the neurological function of the samples at least six months after surgery, and considering it as the final outcome for this research.

STATISTICAL ANALYSIS

All retrieved data were tabulated for analysis of CC as a risk factor using Microsoft Excel® software and SPSS for Windows (Version 24; IBM Corp, Armonk, NY, USA). Descriptive analysis was performed to define subject characteristics as well as research variables in case and control group. Since this study is non-paired categorical comparative data with 2x2 cross-tabulation, we utilized the Chi-square (x^2) test with Yates correction. If x^2 criteria are not met, then Fisher exact test will be used. A p value of < 0.05 was considered to be statistically significant.

Several studies have proposed diverse cut-off points to differentiate between low and high canal compromise, yet none have exclusively focused on the South East Asia population as their subject.[9] By adopting cut-off points from the Caucasian population is considered inappropriate; hence, we endeavored to formulate a suitable cut-off point using Receiver Operating Characteristic (ROC) test performed using SPSS for Windows (Version 24; IBM Corp, Armonk, NY, USA). If the area under the curve is less than 0.3 or exceeds 0.7, it is deemed statistically appropriate to apply it as the cut-off point in this study.

RESULT

Descriptive Analysis

The total samples were 50, 25 patients in case group or group A (without neurological improvement), and 25 patients in control group or group B (with neurological improvement). Demographic and baseline characteristics highlighted an average age of 42.4 ± 13.57 years, with 82% males and 18% females (Table 1) and Table 2 described subject characteristic distribution.

The average value of canal compromise (CC) as the risk factor was 42.40 ± 12.42, the median was 41.69, with the majority of the sample was Frankel D. Additional statistical analyses were conducted to assess several variables which have potential to be a confounding variable. Chi-square analysis was performed for age, kyphotic angle, vertebral body height loss. Fisher Exact test for initial neurological function (complete and incomplete motor loss) and gender. Statistical analyses revealed there were no significant different to all of those variables, thus they were not considered to be the confounding variables.

Table 1 General demographic characteristic

Variable	Number (%)	Mean ± Standard Deviation
Age		42.4 ± 13.57
Gender		
• Male	41 (82)	
• Female	9 (18)	

Table 2. Subject Characteristic Distribution

	Group A	Group B
Preoperative Neurologic State		
• Frankel A • Frankel B	4 3	5 5
• Frankel C • Frankel D	5 13	9 6
Age		
• < 40 • ≥ 40	13 12	8 17
Gender		
• Male • Female	22 3	19 6
Motor function		
• Complete motor loss • Incomplete motor loss	9 16	10 15

Table 3. Area Under Curve

Area Under the Curve				
Test Result Variable(s): Canal Compromise				
Area	**Std. Error[a]**	**Asymptotic Sig.[b]**	**Asymptotic 95% Confidence Interval**	
			Lower Bound	**Upper Bound**
.818	.078	.003	.666	.970
a. Under the nonparametric assumption				
b. Null hypothesis: true area = 0.5				

Table 4. Coordinate of the Curve

Test Result Variable(s): Canal Compromise		
Positive if Greater Than or Equal To[a]	**Sensitivity**	**1 - Specificity**
11.9600	1.000	1.000
17.7300	1.000	.933
24.8200	1.000	.867
27.7350	1.000	.800
28.6700	1.000	.733
31.6700	1.000	.667
34.6200	1.000	.600
35.2150	1.000	.533
35.7450	.933	.533
36.0450	.867	.533
36.1250	.800	.533
36.5250	.800	.467
38.1400	.800	.400
39.4650	.800	.333
39.7600	.800	.267
41.5650	.800	.200
43.5500	.733	.200
44.2450	.667	.200
45.1050	.600	.200
46.1200	.533	.200
46.8450	.533	.133
48.1100	.467	.133
49.8450	.467	.067
51.0200	.400	.067
53.2850	.333	.067
55.3150	.267	.067
56.8500	.267	.000
60.7200	.200	.000
63.3950	.133	.000
65.7850	.067	.000
69.0600	.000	.000

Receiver Operating Characteristic (ROC) Curve of Canal Compromise

The ROC curve has been plotted to assess the cut-off value of canal compromise, determining the presence or absence of neurological deficits in patients. Based on the ROC curve, it was found that the cut-off point for canal compromise corresponds to a sensitivity value of 0.84 and a 1-specificity value of 0.20 (Specificity = 0.80). From the coordinate table of the curve, the identified cut-off point in this study is at a value of 40.29%. This implies that a poor post-operative neurological outcome is more frequent among patients with a canal compromise greater than 40% (Figure 1).

Canal Compromise > 40% as a Risk Factor for No Neurological Improvement after Decompression-Stabilization Fusion Surgery in Patients with Thoracolumbar Burst Fracture

The analysis of preoperative canal compromise and its association with patient outcomes was conducted using the Chi-Square Test with a 95% confidence interval. With a p-value of <0.001, well below the conventional significance threshold of 0.05, and. the Odd Ratio of 21.00 (4.924 – 89.561), provide strong evidence to conclude that patients with canal compromise exceeding 40% are 21 times greater chance of no neurological improvement even following spinal decompression and stabilization surgery.

These results emphasize the critical role of preoperative canal compromise assessment in predicting postoperative outcomes and can inform clinical decision-making to optimize patient care and mitigate potential risks.

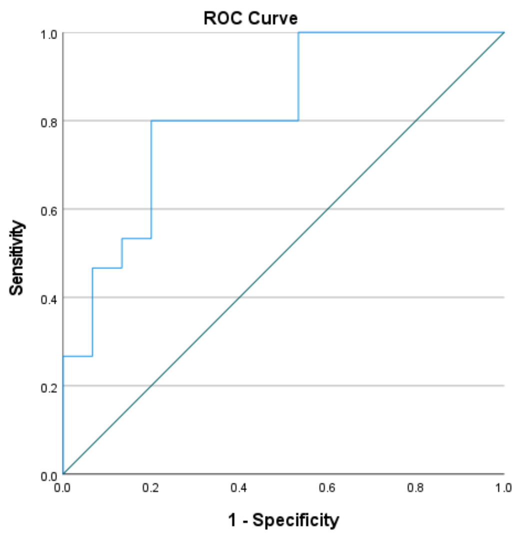

Figure 1. Receiver Operating Characteristic (ROC) Curve to Find the Cut Off Point Value of Canal Compromise Percentage

DISCUSSION

This research consists a total of 50 patients who had undergone spinal decompression-stabilization-fusion surgery for thoracolumbar burst fractures was examined. The participants, meeting specific inclusion and exclusion criteria, were provided with a thorough explanation of the study and subsequently signed informed consent forms. The study's subjects had an average age of 42.4 ± 13.57 years, with a majority being male (82%). The age distribution aligns with previous epidemiological reports, indicating a higher incidence of thoracolumbar burst fractures in males over 40 years old. This demographic information provides a foundational understanding of the patient population under investigation, laying the groundwork for the subsequent analyses examining various factors related to neurological outcomes post-surgery.[10–12]

The study delved into the significance of canal compromise as a predictor of neurological deficits following decompression-stabilization-fusion surgery for thoracolumbar burst fractures.[13,14] The findings indicated a strong correlation between canal compromise exceeding 40% and an increased risk of postoperative neurological deficits.[15] Our finding aligns with other studies where the degree of canal compromise correlates with vertebral body involvement, retropulsion, and corresponds to mechanical pain.[16,17] This explains how canal compromise can impact neurological outcomes.[18,19] Other studies found that patients with neurological deficits had an average canal compromise of 50%, whereas those without deficits had 36%. Similarly, in a study by Mohanty et al.[20], the degree of canal compromise significantly correlated with the severity of neurological deficits (p=0.08).[20] Other studies have found that patients with burst fractures are significantly at risk of experiencing neurological deficits if there is canal compromise ≥35% at T11 and T12, ≥45% at L1, and ≥55% in the lumbar region.[21]

We obtained one study discussing and indicating that there is no relationship between the degree of canal compromise and neurological clinical outcomes. The study concluded that spinal cord injury occurs during the trauma rather than due to pressure from fragments remaining in the canal afterward (recoil effect), rationalizing that radiological tomographic images taken several hours after the injury only reflect the final resting position of the offending fragments after the trauma.[20]

Recognizing the constraints inherent in this study, it is acknowledged that the synchronization of surgical timing in relation to the onset of accidents for each sample was not feasible. The briefest duration between accident and surgery among the samples was 14 hours, while the longest waiting period observed was 82 hours. Despite existing literature suggesting a favorable neurological outcome associated with early surgical intervention within 12 hours, our institution faces inherent limitations that preclude the execution of prompt surgical procedures. These constraints are attributed to fundamental issues within our hospital infrastructure, and some may be attributable to variations in the patient referral system, particularly among rural healthcare facilities.

CONCLUSION

In the context of spinal decompression – stabilization – fusion surgery in patients with thoracolumbar burst fractures, several factors have been identified as potential risks for neurological deficits.[22,23] Canal compromise (CC) is the main factor contributing to the risk of neurological deficits after decompression stabilization fusion surgery in patients with thoracolumbar burst fractures, with CC greater than 40% is strongly associated with worse neurological outcome.

Declarations

- **Ethic approval and consent to participate**
  This study was approved by the Research Ethics Committee Faculty of Medicine Udayana University, Denpasar, Bali, Indonesia. The Ethical Clearance is provided under the approval of the Chairman of the Committee, Prof. Dr. I Gde Raka Widiana, Sp.PD-KGH (No: 2881/UN14.2.2.VII.14/LT/2002).
- **Consent for publication**
  Consent for publication was obtained from study participants.
- **Availability of data and materials**
  The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.
- **Competing Interests:** We have no competing interests.
- **Funding:** No funding was obtained for this study
- **Authors' contributions**
  MHA, DSK, and SY identified the background problem and designed the research protocol. KVN and ZIO collected all the data and performed statistical analysis, KVN and ZIO performed pathological examination and evaluate statistical analysis results. MHA, DSK, SY, BRM, ASW and LAW discussed the results and formulate the discussion section.
  DSK, SY, BRM, ASW, LAW evaluate the final paper and gave correction and inputs on the final manuscript.
  All authors have read and approved the manuscript.
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