ORIGINAL ARTICLE

Evaluate the Risk of Multilevel Non-Contiguous Spinal Fractures in Patients with Traumatic Cervical Spine Injury: A 12-Year Retrospective Study

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Objective: To understand the risk factors and incidence of multilevel non-contiguous spinal fractures is crucial for improving diagnosis, management, and outcomes.

Materials and Methods: The 12-year retrospective observational study included 588 patients with traumatic cervical spine fractures admitted at Maharaj Nakorn Chiang Mai Hospital between January 2011 and December 2022. Patients were categorized into two groups, those with multilevel non-contiguous spine fractures and those without multilevel non-contiguous spine fractures. Outcomes were analyzed using multivariable analysis. Results were presented as adjusted odd ratio (AOR) and 95% confidence interval (CI).

Results: Among 588 patients, the incidence of multilevel non-contiguous spine fractures was 17.01% (100 out of 588 patients). Independent factors associated with multilevel non-contiguous spine fractures were motor weakness (AOR 1.89, 95% CI 1.19 to 3.01, p=0.007), intracranial injuries (AOR 2.61, 95% CI 1.61 to 4.23, p=0.000), intrathoracic injuries (AOR 2.88, 95% CI 1.77 to 4.69, p=0.040), and intraabdominal injuries (AOR 1.91, 95% CI 1.03 to 3.55, p=0.000).

Conclusion: The present study identified critical risk factors for multilevel non-contiguous spine fractures in patients with traumatic cervical spine fracture. Those risk factors were motor weakness, intracranial injuries, intrathoracic injuries, and intraabdominal injuries. These findings can help guide clinical decision-making and improve patient outcomes.

Keywords: Risk factor; Multilevel non-contiguous spinal fractures; Cervical spine injury

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Traumatic cervical spine injuries are a significant cause of morbidity and mortality[1,2]. Patients with cervical spine injury can present with multilevel spine fractures in either a contiguous or non-contiguous pattern. While contiguous spinal fractures are common, multilevel non-contiguous spinal fractures, particularly those occurring at two or more non-adjacent spinal levels, present unique diagnostic, and therapeutic challenges[3-5]. Major causes of injuries can result from various mechanisms such as motor vehicle accidents (MVA), falls, and sports-related activities[3,4,6]. In addition, these injuries are associated with intracranial, intrathoracic, intra-abdominal, and skeletal injuries[7,8].

The incidence of cervical spine injury with multilevel non-contiguous spinal fractures varies. Studies reported the incidence ranged from 2% to 15%[9-11]. Gupta & el Masri reported that half of the multilevel non-contiguous spinal fractures presented with incomplete neurological symptoms[12]. Vaccaro et al. also reported that patients with cervical spine injury had a high incidence of multilevel non-contiguous spinal fractures, which was found in about 41% and 77%. Those were investigated by whole spine computed tomography (CT) scan and magnetic resonance imaging (MRI) scan, respectively[13].

Kanna et al. reported the incidence of missed multilevel non-contiguous fracture with unstable spine fractures at up to 20%[14]. Traumatic cervical spinal lesions can conceal other lesions such as thoracic injury or thoracolumbar injury. Additionally, associated injuries such as intracranial, intrathoracic, intraabdominal injuries, and skeletal fracture, can

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obscure other lesions[15]. Reports suggested that additional CT imaging be done to identify other spinal lesions[16], and whole spine imaging be done in all cases[17,18]. The goal of treatment is surgical stabilization, neural decompression, and restoration of alignment[19,20]. Nevertheless, missed diagnosis of cervical spine injuries with multilevel non-contiguous spinal fractures can lead to further spinal instability, neurological impairment, and death[5,9,19]. Detection of these injuries is critical as they can significantly impact clinical management and prognosis. However, the incidence and risk factors associated with multilevel non-contiguous spine fractures in patients with traumatic cervical spine fracture remain poorly understood.

The present study aimed to evaluate the risk factors and incidence of multilevel non-contiguous spinal fractures in patients with traumatic cervical spine injury. By identifying key predictors, the authors hoped to enhance the early diagnosis and treatment of these complex injuries.

Materials and Methods

The present study was a retrospective observational cohort study conducted at the orthopedic department of the academic university hospital. It included patients admitted with traumatic cervical spine injury between January 2011 and December 2022. The study was approved by the Hospital Institutional Review Board (ORT-2566-0363). Records of all patients were analyzed to identify multilevel non-contiguous spinal fractures. Three investigators manually performed retrospective chart reviews to collect the data, and a board-qualified radiologist confirmed the radiographic diagnosis.

Patient data were extracted from the hospital's electronic medical records by using International Classification of Disease 10 (ICD-10) codes: S120, S121, S122, S127, and S131 represented patient with cervical spinal injuries. The inclusion criteria were patients aged 18 years or older and confirmed traumatic cervical spine injury by whole spine imaging as CT or MRI to prevent the missed diagnosis of multilevel non-contiguous spinal fractures. The exclusion criteria were pathologic fractures, osteoporotic fractures, non-traumatic cases, and incomplete medical records. The term "multilevel non-contiguous spinal fractures" in the present study was limited to cervical spine injuries in both upper and lower cervical spine. Thoracolumbar spine injuries with multilevel non-contiguous spinal fractures were excluded.

Demographic data including age, gender, motor weakness, associated injuries such as intracranial lesions, intracerebral hemorrhage, or skull fracture, intrathoracic lesions such as hemothorax, pneumothorax, or rib fractures, intraabdominal lesions such as intraabdominal hemorrhage or visceral organ injuries, and skeletal fractures were recorded manually from the retrospective chart reviews. Associated injury data from physical examination and simple investigations as radiographic study or extended focused assessment with sonography in trauma (E-FAST) were also recorded.

Primary outcome: Multilevel non-contiguous spine fractures in patients with traumatic cervical spine fracture diagnosed by whole spine imaging such as MRI scan or CT scan.

Potential predictors:

- Age more than 60 years
- Gender: male
- Mechanism of injury: MVA and fall from height more than three meters.
- Configuration of cervical spine injury: fracture, dislocation, and fracture-dislocation
- Motor weakness: motor power less than grade 5 and classified by American Spinal Injury Association (ASIA) score A-D[21]
- Intracranial injury: intracerebral hemorrhage or skull fracture
- Intrathoracic injury: rib fracture, hemothorax, or pneumothorax
- Intraabdominal injury: visceral organ injuries
- Skeletal fracture: peripheral limb fracture

Sample size determination

According to the rule of thumb for logistic models, potential factors should have a minimum of 10 events per predictor variable (EPV) for an adequate sample size[22-25].

Statistical analysis

Statistical analyses were performed using Stata Statistical Software, version 15 (StataCorp LLC, College Station, TX, USA). Categorical data were reported as counts and percentages. Continuous variables were presented as means and standard deviations (SD). For inferential statistics, chi-square test or Fisher's exact test was used for categorical variables and Student's t-test for continuous variables.

Both univariable and multivariable logistic regression were performed to identify dependent and independent risk factors for cervical spine injury with multilevel non-contiguous spinal fractures,

respectively. Results were presented as odds ratios (OR).

Multivariable analysis was used for cervical spine injuries with multilevel non-contiguous spinal fractures using backward elimination to minimize the number of risk factors and to help preserve the residual risk factors' discrimination power. The results were reported as coefficient values and 95% confidence intervals (CI). In the multivariable analysis, adjustment was made for all risk factors. Statistical significance was set as p-value less than 0.05.

Table 1. Baseline characteristics of traumatic cervical spine injured patients with and without non-contiguous spine fracture (n=588)

Characteristic	Without non-contiguous spinal fracture (n=488)	Non-contiguous spinal fracture (n=100)	p-value
Age (years); mean±SD	46±19.0	42.63±15.9	0.098
Male; n (%)	396 (81)	81 (81)	0.973
Pattern of injury; n (%)			0.002
Fracture	367 (75)	91 (91)	
Dislocation	83 (17)	5 (5)	
Fracture-dislocation	38 (8)	4 (4)	
Cause of injury; n (%)			0.123
Vehicle accident	352 (72)	82 (82)	
Fall from height >3 m	89 (18)	12 (12)	
Low energy trauma	47 (10)	6 (6)	
ASIA scores; n (%)			0.009

SD=standard deviation

Results

During the study period, 588 patients were admitted with traumatic cervical spine fracture. The incidence of traumatic cervical spine injury with multilevel non-contiguous spinal fractures was 17% (100 out of 588 patients). The average age was 45.43±18.54 years. Four hundred seventy-seven patients (81%) were male. The most frequent pattern of injury was fracture in 458 patients (78%). Vehicle accidents were the most common cause of injury with 434 patients (74%). Demographic data are shown in Table 1.

The results of the univariable analysis to identify dependent risk factors revealed that dislocation pattern, motor weakness, and associated injuries including intracranial injury, intrathoracic injury, intraabdominal injury, and skeletal fractures were significant variables ($p<0.05$) (Table 2). The multivariable analysis to identify independent risk factors associated with multilevel non-contiguous spinal fractures in traumatic cervical spine fracture patients showed that motor weakness had an adjust odds ratio (AOR) of 1.89 (95% CI 1.19 to 3.01), intracranial injury had AOR of 2.61 (95% CI 1.61 to 4.23), intrathoracic injury had AOR of 2.88 (95% CI 1.77 to 4.69), and intraabdominal injury had AOR of 1.91 (95% CI 1.03 to 3.55) (Table 3).

Table 2. Univariable analysis of potential risk factors of traumatic cervical spine-injured patients with and without noncontiguous spine fracture (n=588)

Potential risk factors	Without non-contiguous spine fracture (n=488); n (%)	Non-contiguous spine fracture (n=100); n (%)	Univariable analysis	
			OR (95% CI)	p-value
Age at least 60 years	121 (25)	17 (17)	0.62 (0.35 to 1.08)	0.096
Male	396 (81)	81 (81)	1.01 (0.58 to 1.75)	0.973
Pattern of injury				
Fracture	367 (75)	91 (91)	Reference	
Dislocation	83 (17)	5 (5)	0.24 (0.10 to 0.62)	0.003
Fracture-dislocation	38 (8)	4 (4)	0.42 (0.15 to 1.22)	0.112
Cause of injury				
Vehicle accident	352 (72)	82 (82)	Reference	
Fall from height	89 (18)	12 (12)	0.58 (0.15 to 1.22)	0.099
Low energy trauma	47 (10)	6 (6)	0.55 (0.23 to 1.32)	0.182
Motor weakness	185 (37.9)	52 (52)	1.77 (1.15 to 2.74)	0.009
Intracranial injury	163 (33)	65 (65)	3.70 (2.26 to 6.58)	<0.001
Intrathoracic injury	111 (23)	54 (54)	3.99 (2.55 to 6.23)	<0.001
Intraabdominal injury	40 (8)	23 (23)	3.35 (1.99 to 5.90)	<0.001
Skeletal fractures	113 (23)	40 (40)	2.12 (1.41 to 3.48)	0.001

CI=confidence interval; OR=odds ratio

Table 3. Risk factors for cervical spine injuries with multilevel non-contiguous spinal fractures

Predictors	Adjusted OR (95% CI)	p value
Motor weakness		0.007
Yes	1.89 (1.19 to 3.01)	
No	1.00 (reference)	
Intracranial injury		
Yes	2.61 (1.61 to 4.23)	<0.001
No	1.00 (reference)	
Intrathoracic injury		
Yes	2.88 (1.77 to 4.69)	0.040
No	1.00 (reference)	
Intraabdominal injury		
Yes	1.91 (1.03 to 3.55)	<0.001
No	1.00 (reference)	

CI=confidence interval; OR=odds ratio

Discussion

The findings of the present study provide valuable insights into the risk factors and incidence associated with cervical spine injury with multilevel non-contiguous spinal fractures in traumatic cervical spine fracture patients. The identification of significant predictors can aid clinicians in early diagnosis and appropriate management of these complex injuries.

Multivariable analysis showed cervical spine injury with multilevel non-contiguous spinal fractures associated with four key factors, which were motor weakness less than grade 5, intracranial injury, intrathoracic injury, and intraabdominal injury. The most valuable predictive factor is intrathoracic injury (AOR 2.88). Age, gender, pattern of injury, cause of injury, and skeletal fracture were not significant factors. Recent reports of cervical spine injury with multilevel non-contiguous spinal fractures were associated with intracranial, intrathoracic, and intraabdominal injuries[26]. The most common cause was high energy trauma from MVA or fall from height[3,4,12], which was same as the present report.

The present study highlights the importance of thorough radiographic evaluation in patients with traumatic cervical spine injuries to detect multilevel non-contiguous spinal fractures. The presence of multilevel non-contiguous spinal fractures can significantly impact treatment decisions, including the need for surgical intervention and the extent of spinal stabilization required. In addition, previous studies have suggested performing further investigations, such as CT scans or MRI of the whole spines when patients presented with cervical spine injuries to decreased missed diagnosis of multilevel non-contiguous cervical spine fractures[16-18].

While the present study offers important contributions, it is not without limitations. The retrospective design and reliance on available medical records may introduce selection and information bias. Future prospective studies with larger sample sizes are needed to validate the present study findings.

Conclusion

The present study identified key risk factors for multilevel non-contiguous spine fractures in patients with traumatic cervical spine fracture, which were motor weakness, intracranial injuries, intrathoracic injuries, intraabdominal injuries. Understanding these predictors can improve clinical decision-making and enhance patient outcomes. Further research is warranted to develop targeted strategies for the early detection and management of multilevel non-contiguous spine fractures.

What is already known on this topic?

According to previous studies, multilevel contiguous spinal fracture is associated with motor weakness and extraspinal injuries. However, none of the studies showed correlation between risk factor of multilevel non-contiguous spine fracture with traumatic cervical spine injury patients.

What does this study add?

In patients with traumatic cervical spine fractures, this research revealed that motor weakness (AOR 1.89, 95% CI 1.19 to 3.01), intracranial injuries (AOR 2.61, 95% CI 1.61 to 4.23), intrathoracic injuries (AOR 2.88, 95% CI 1.77 to 4.69), and intraabdominal injuries (AOR 1.91, 95% CI 1.03 to 3.55) were the main risk factors for multilevel non-contiguous spine fractures. These findings can help guide decision-making to provide further whole spine imaging such as CT or MRI scan, decreasing the risk of missed diagnosis of these injuries.

Conflicts of interest

The authors declare no conflict of interest.

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