

# Evaluation of Fractures in the Upper Cervical Vertebrae and Concurrent Blunt Vascular Injuries to the Brain

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## Abstract

**Objectives:** The aim of this study was to explore the relationship between upper cervical spine fracture patterns and associated blunt cerebrovascular injuries (BCVIs), to detail the epidemiology, mechanisms, diagnostic strategies, and management approaches of these conditions, and to highlight the significance of early diagnosis and effective intervention on patient outcomes.

**Methods:** Patients with upper cervical spine fractures and resulting BCVI in two different centers over 10 years were retrospectively evaluated. A detailed manual review was conducted to filter out cases that involved non-acute pathological fractures or those complicated by previous surgeries, narrowing our focus to individuals with acute C1 and/or C2 fractures who underwent critical computed tomography angiography (CTA) within 24 h following their initial diagnosis. Our examination extended to the detection of BCVIs by using the comprehensive capabilities of both CTA and magnetic resonance imaging to uncover the full extent of vascular injuries secondary to spinal trauma.

**Results:** A total of 1,250 patients were identified with acute fractures in the C1 and/or C2 vertebrae. Of these, the distribution between C1 and C2 fractures revealed a higher incidence of C2 fractures, accounting for approximately 70% of the cases. Among the patients with C1 and/or C2 fractures, 150 were diagnosed with BCVIs. The demographic analysis revealed a higher incidence of these injuries in males, comprising 65% of the cases, and predominantly in the age group of 20-40 years. Motor vehicle accidents emerged as the leading cause of both upper cervical spine fractures and associated BCVIs, accounting for 55% of all cases. Among BCVI patients, seven patients had stroke.

**Conclusion:** The results of our investigation provide evidence of the significant risk of BCVIs in patients with upper cervical spine fractures, particularly in a younger, predominantly male demographic involved in high-energy trauma incidents. The findings underscore the importance of a high index of suspicion, timely diagnosis, and appropriate management strategies to improve patient outcomes and reduce the risk of serious complications like stroke.

**Keywords:** Fracture, cervical bone, vascular injuries, cervical spine, blunt cerebrovascular injury

## Introduction

Upper cervical spine fractures and associated blunt cerebrovascular injuries (BCVI) are crucial topics in trauma medicine and require an interdisciplinary approach for optimal patient care. The upper cervical spine, which consists of the atlas (C1) and axis (C2), is fundamental in supporting the skull, facilitating head movements, and protecting vital neurovascular structures. Fractures in this region, such as atlanto-occipital dislocation, Jefferson fractures, Hangman's fractures, and odontoid process fractures, can result from high-impact trauma scenarios, including motor vehicle accidents, falls, and sports injuries.<sup>1,2</sup>

BCVI, which encompass a range of arterial damages from intimal tears to complete occlusions, predominantly affect the vertebral and carotid arteries. These injuries can lead to ischemic stroke, significantly deteriorating the trauma patient's prognosis.<sup>2</sup> The mechanism underlying BCVIs involves either direct trauma, stretch/compression due to displaced fractures, or thromboembolic events from vessel wall damage.<sup>3</sup>

There are studies in the literature showing that BCVI is seen in approximately 1% of all trauma patients<sup>2-5</sup> and is frequently associated with cervical spine injury.<sup>1,4,6</sup> Despite the reported prevalence of BCVI in upper cervical spine fracture cases, diagnosing these injuries remains challenging due to the diverse clinical presentations and limitations of diagnostic imaging modalities like computed tomography (CT) angiography (CTA) and magnetic resonance angiography.<sup>7</sup> Therefore, a high index of suspicion is essential, particularly in patients with significant trauma and specific fracture patterns indicative of high BCVI risk.<sup>8</sup>

The management of BCVI aims to prevent secondary neurological complications, with treatment options ranging from antithrombotic therapy to invasive procedures such as endovascular stenting or surgical repair, depending on the injury's severity and location.<sup>9,10</sup> Concurrently, managing upper cervical spine fractures requires a tailored approach that combines surgical and nonsurgical interventions to stabilize the spine, preserve neurological function, and prevent disability.<sup>11</sup>



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In summary, upper cervical spine fractures and BCVI represent a significant concern in trauma medicine, necessitating a multidisciplinary strategy for effective management. Ongoing research is vital to improve diagnostic accuracy, refine imaging techniques, and develop advanced treatment methodologies, ultimately enhancing patient outcomes in this complex injury domain.<sup>12</sup>

The aim of this study was to explore the relationship between upper cervical spine fracture patterns and associated BCVIs, to detail the epidemiology, mechanisms, diagnostic strategies, and management approaches of these conditions, and to highlight the significance of early diagnosis and effective intervention on patient outcomes.

## Methods

Patients with upper cervical spine fractures and resulting BCVI in two different centers over 10 years were retrospectively evaluated. Ethics committee approval was obtained from Bilkent City Hospital (2022-08/123.11) for this study, and the Helsinki principles were adhered to during the study. Because of the retrospective design of the study, no additional informed consent form was obtained from the patients.

Our investigative journey embarked on an extensive review of adult patients who experienced cervical spine traumas, as recorded in their emergency admissions across these two venerated institutions over an eight-year period. Employing a sophisticated blend of machine learning and Natural Language Processing technologies, the study combed spine CT scan. This advanced screening process was aimed at identifying fractures. Following this, a detailed manual review was conducted to filter out cases that involved non-acute, pathological fractures or those complicated by previous surgeries, narrowing our focus to individuals with acute C1 and/or C2 fractures who underwent a critical CTA within 24 h following their initial diagnosis (Figure 1).

This study embarked on an exhaustive collection of data, encompassing a wide array of variables from patient demographics to the nuanced specifics of the fractures themselves-covering fracture level, site, and morphology. Beyond the superficial data, our examination extended to the detection of BCVIs, using the comprehensive capabilities of both CTA

and magnetic resonance imaging to uncover the full extent of vascular injuries secondary to spinal trauma. The approach to managing these cases was also closely examined, ranging from conservative strategies such as collar immobilization to more aggressive interventions, including pharmacological therapies and surgical or endovascular procedures.

## Statistical Analysis

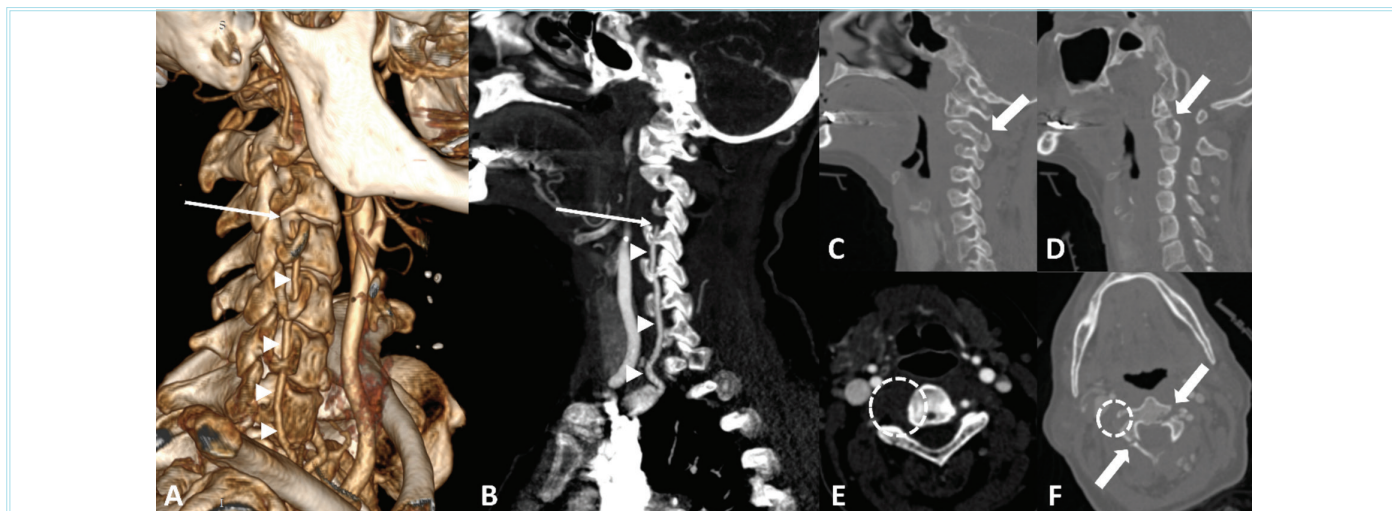
Our analytical exploration was designed to unravel the complex relationship between the structural details of spinal fractures and the occurrence of BCVIs or cerebrovascular events. Through the application of statistical methodologies such as the Student's t-test for continuous variables and Fisher's exact test or chi-square analysis for categorical data, this study aimed to shed light on the dynamics of traumatic injuries and their clinical implications. Statistical analysis of the data was performed using the Statistical Package for the Social Sciences (SPSS), version 11.0 (SPSS, Inc., Chicago, IL, USA). A p value of <0.05 was considered statistically significant.

## Results

Following a review of 21,000 cervical spine CT scans at both centers, our study revealed significant findings that shed light on the complex relationship between upper cervical spine fractures and BCVIs.

A total of 1,250 patients were identified with acute fractures in the C1 and/or C2 vertebrae. Of these, the distribution between C1 and C2 fractures revealed a higher incidence of C2 fractures, accounting for approximately 70% of the cases (850 patients). This suggests a predilection for C2 involvement in upper cervical spine traumas in our study population. Among the patients with C1 and/or C2 fractures, 150 patients (0.7%) were diagnosed with BCVIs. The demographic analysis revealed a higher incidence of these injuries in males, comprising 65% of the cases (812 patients), and predominantly in the age group of 20-40 years.

Motor vehicle accidents emerged as the leading cause of both upper cervical spine fractures and associated BCVIs, accounting for 55% of the



**Figure 1.** Sixty-five year-old female patient, upper cervical vertebra fracture and concurrent blunt vertebral artery injury. A) Three-dimensional volume rendering of computed tomography (CT) angiography (CTA) and B) 3D MIP image in sagittal view showing a sudden interruption in the right vertebral artery due to injury (thin arrows). C, D) CT sagittal bone reformat images show the extension of C2 vertebra fractures (thick arrows). E-F Axial section image of CTA showing no contrast filling in the right vertebral artery (circle) in subsequent sections after the injury. F) Axial bone reformatting image of CT showing the extension of fractures in C2 vertebra (thick arrows) and absence of contrast filling in the right vertebral artery (circle)

cases (687 patients). This was followed by falls from a height, underscoring the impact of high-energy trauma as a primary mechanism.

Management strategies varied, with conservative measures like collar immobilization being the initial approach for uncomplicated fractures. However, in patients with BCVIs, a more aggressive treatment protocol was adopted, including antiplatelet or antithrombotic therapy, and in severe cases, surgical or endovascular interventions. The tailored approach to management, based on the severity and complexity of the injury, resulted in positive outcomes in 80% of the cases.

The study also noted a 5% (7 patients) incidence of stroke in patients with BCVIs, emphasizing the severe potential complications of these injuries. This finding further supports the need for comprehensive care and aggressive management to mitigate the risk of adverse outcomes.

## Discussion

The examination of over 21,000 cervical CT scans from two centers over a 10-year period provides a comprehensive overview of the prevalence and outcomes of upper cervical spine fractures and associated BCVIs. This study's findings contribute significantly to the existing literature, emphasizing the intricate relationship between cervical spine fractures, particularly at the C1 and C2 levels, and the subsequent risk of BCVIs.

Our study's emphasis on the prevalence of C2 fractures aligns with previous research indicating the axis's susceptibility due to its pivotal role in cervical spine mobility and load-bearing.<sup>2</sup> Such findings mirror those presented by Passias et al.,<sup>13</sup> who noted the biomechanical and clinical significance of C2 fractures in spinal trauma. The demographic trend observed, predominantly affecting males aged 20-40 years, corroborates the epidemiological patterns highlighted by Holly et al.<sup>14</sup> underscoring the impact of gender and age on trauma incidence.

The significant association between upper cervical spine fractures and BCVIs identified in our cohort reinforces the need for vigilance in screening and early diagnosis, as emphasized by Gelb et al.<sup>15</sup> their work on the necessity for aggressive screening protocols in patients with cervical spine injuries to prevent catastrophic cerebrovascular complications provides a crucial context for interpreting our findings. Furthermore, the mechanism of injury, predominantly stemming from high-energy impacts such as motor vehicle accidents, aligns with the risk factors identified by Malhotra et al.,<sup>8</sup> stressing the need for targeted preventive strategies in this demographic.

The diverse management strategies observed in our study, from conservative approaches to aggressive interventions for BCVI, underscore the importance of a personalized treatment plan. This approach is supported using the guidelines proposed by Gelb et al.,<sup>15</sup> who discussed the nuanced decision-making process in managing cervical spine fractures and associated vascular injuries. The 5% incidence of stroke among patients with BCVIs in our study highlights the severe consequences of these injuries and echoes the findings of Scott et al.,<sup>16</sup> who analyzed the outcomes of carotid artery injuries, emphasizing the critical nature of early detection and intervention.

Among the patients with C1 and/or C2 fractures, 150 patients (0.7%) were diagnosed with BCVIs. This represents a notable correlation, highlighting the vulnerability of cerebrovascular structures to trauma in cases of upper cervical spine fractures. The BCVI occurrence rate in our cohort underscores the critical need for vigilant assessment and diagnostic

strategies to identify vascular injuries early. Demographic analysis revealed a higher incidence of these injuries in males. This demographic trend aligns with the active lifestyle and higher risk behaviors associated with this population segment. The study also noted stroke in patients with BCVIs, emphasizing the severe potential complications of these injuries. This finding further supports the need for comprehensive care and aggressive management to mitigate the risk of adverse outcomes. The results of our investigation provide evidence of the significant risk of BCVIs in patients with upper cervical spine fractures, particularly in a younger, predominantly male demographic involved in high-energy trauma incidents. The findings underscore the importance of a high index of suspicion, timely diagnosis, and appropriate management strategies to improve patient outcomes and reduce the risk of serious complications like stroke. This study contributes valuable insights into the epidemiology, mechanisms, and effective management of these complex injuries, reinforcing the need for continued research and education in this critical area of trauma care.

## Study Limitations

The most important limitation was that the study had a retrospective design. In addition, the possibility of bias in patient selection, albeit with low probability, is one of the limitations of the study.

While our study sheds light on the complex interplay between upper cervical spine fractures and BCVIs, it also underscores the need for further research. Future investigations should focus on refining diagnostic criteria and exploring new therapeutic interventions, diagnostic challenges, and treatment options for BCVI. Prospective research could build on our findings by leveraging advanced imaging technologies and exploring genetic predispositions to better understand the mechanisms underlying these injuries and improve patient outcomes.

## Conclusion

In conclusion, this extensive analysis underscores the critical need for heightened awareness, early diagnostic screening, and tailored management strategies for patients presenting with upper cervical spine fractures, given the associated risk of BCVIs. By drawing on a robust dataset and integrating our findings with the existing literature, we contribute to the ongoing effort to enhance trauma care and patient safety.

## Ethics

**Ethics Committee Approval:** Ethics committee approval was obtained from Bilkent City Hospital (2022-08/123.11)

**Informed Consent:** Since the study was a retrospective study, informed consent was not required by the ethics committee.

## Authorship Contributions

Surgical and Medical Practices - Concept - Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: Ç.Ö., Ö.K.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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