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Outcome of Surgical and Intensive Care Treatment of Patients with Traumatic Cervical Spinal Cord Injury: A Single Center, Cross-Sectional, Retrospective Study

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ABSTRACT

Aim: In this study, we aimed to evaluate the surgical process, anesthesia management and intensive care follow-up of patients with traumatic cervical spinal cord injury (TCSCI) admitted to the Intensive Care Unit (ICU) and to determine the factors affecting patient outcomes.

Study Design and Methods: This study was carried out as a single-center, cross-sectional, retrospective study. Surgically treated patients with TCSCI were retrospectively evaluated in terms of age, sex, etiology of trauma, fracture side, Glasgow coma scale (GCS), Acute Physiology and Chronic Health Evaluation II score (APACHE II), neurological outcome, mechanical ventilation requirement, inotropic therapy requirement, nosocomial infections, ICU length of stay, ward length of stay and ICU mortality.

Results: A total of 41 patients were included in the study. There were 10 (24.39%) female patients in our study and the median age was 48(33.5–66.0) years. The most common cause of trauma was fall from height in 14 patients (34.14%), followed by traffic accidents in 12 patients (29.26%). The most common involvement was C7 fracture in 7 (17.07%) patients and C4-C5 listhesis in 8 (19.52%) patients. Fourteen (34.14%) of the patients underwent 360-degree stabilization (both anterior and posterior), 24 (58.53%) underwent only anterior stabilization, and 3 (7.31%) underwent only posterior stabilization and the median APACHE II score was 10.16 (4–26). The median duration of ICU stay was 2 (1.0–5.5) days. The mortality rate was 12.9%; it was 36.4% in patients with neurologic deficits and 3.3% in patients without neurologic deficits (p=0.014)

Conclusions: Surgical approach, anesthesia management and intensive care management are complementary for TCSCI patients. The severity of the neurological deficit has a direct effect on the survival of the patients.

Keywords: Cervical vertebra trauma, anterior and posterior stabilization, ICU, neurosurgery

Introduction

Trauma causes 10% of deaths worldwide and is the leading cause of death in young people (5–44 years) in developed countries. (1). Spinal cord injuries (SCI) account for one-third of all spine injuries. More than 60% of these injuries involve the lower cervical spine (C3–7). Mechanically, lower cervical fracture dislocations are often caused by flexion-tension injuries and can involve different levels of the spinal cord (2). On the other hand, loss of neurological function and disability may occur in most patients. This adversely affects the quality of life of patients. It is acknowledged that this challenging condition, which affects both patients and their families, also places a substantial financial burden on households and the overall national economy (3). Intensive care management is essential for monitoring, mechanical ventilation, inotropic support to prevent secondary injury during the acute short-term state and for secondary complications that may occur in the long term (4) However, there is still a lack of information about the outcomes of traumatic cervical spinal cord injury patients in intensive care units (ICU).

The objective of this study was to examine the causes, and surgical interventions in patients with cervical trauma, and to assess the outcomes and complications during ICU stay. We anticipate that the findings from our study will provide valuable insights into the management of patients with cervical fractures.

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Methods

This study was carried out as a single-center, cross-sectional retrospective study. The cases with cervical trauma who were operated in our clinic between 2017 and 2023 were included in the study if they were C3-C7 (subaxial) cervical TSCI cases. All patients were admitted to short-term postoperative ICU and general ICU. Upper cervical trauma patients (C1-C2 fracture) were also excluded from the study because they did not have deficits and were not followed up in ICU. Patients under the age of 18 years were excluded from the study. This study was approved by the Akdeniz University Clinical Research Ethics Committee and obtained data usage permission (Approval number: KAEK 332 Approval dated: April 26, 2023). The confidentiality of patient data was maintained throughout the study and the ethical principles of clinical studies were adhered to according to the Declaration of Helsinki.

The hospital and/or ICU follow-up data of the patients were recorded by the information management system 'MiaMed®' used in our hospital. Daily neurologic examinations of the patients were performed and preoperative and postoperative deficits were recorded in the electronic files as well as the laboratory data.

The patients were retrospectively evaluated in terms of age, sex, etiology of trauma, fracture site, Glasgow coma scale (GCS), APACHE II (Acute Physiology and Chronic Health Evaluation II) score, neurological examination, mechanical ventilation requirement, inotropic agent requirement (noradrenalin, dopamine, dobutamine, adrenaline), nosocomial infections, ICU length of stay, ward length of stay and ICU mortality.

In the operating room, patients were premedicated with atropine 0.5 mg, midazolam 0.07 mg/kg i. v. and remifentanil 0.1 µg/kg/min i. v. throughout the procedure for sedation. Pre-oxygenation was provided with 100% oxygen using closed circuit and awake nasal intubation with fiberoptic was performed by experienced anesthesiologists and then it was switched to general anesthesia protocol. For the maintenance of the anesthesia total intravenous anesthesia was administered with propofol and remifentanil. During the operation, basic monitoring (pulse oximetry (SpO2), electrocardiogram (ECG), non-invasive blood pressure, and end-tidal CO2 monitoring was maintained as recommended by the American Society of Anesthesiologists.

Three surgical techniques were used. The first is stabilization with a cervical anterior approach, the second is stabilization with a cervical posterior approach, and finally the third is stabilization with a combined 360-degree approach of anterior and posterior.

For anterior stabilization, patients were placed on the operating table in the supine position. After determining the level with fluoroscopy, the operation was started with a vertical incision in the right cervical anterior at a distance appropriate to the level of the injury. The anterior surface of the vertebra was reached by performing a deep neck dissection, leaving the trachea and esophagus medially and the carotid sheath and jugular vein lateral. The damaged vertebra was repaired in the most appropriate anatomical position and the neural structures were decompressed. The spine was fixed with an anterior cage and plates.

For posterior stabilization, the patient was placed on the operating table in the prone position. The level was checked with fluoroscopy and the operation was started with a vertical incision in the midline of the neck at an appropriate distance from the injury. After the paraspinal muscles were separated from the vertebra, decompression was performed with laminectomy at the level of injury, and spinal stabilization was performed with posterior lateral mass screws and rods.

The combined technique of performing these two surgical techniques one after the other is a 360-degree stabilization procedure.

Patients with severe hypotension due to neurogenic shock were treated with sympathomimetic agents and careful fluid loading. Norepinephrine was used as a sympathomimetic agent at a rate of 8 mcg to 12 mcg per minute and titrated to the desired target mean arterial pressure (MAP) value of 85 mm Hg and above. Hypotension was avoided throughout the treatment process.

Extubation of all patients was performed with a guidewire under intensive care conditions under expert supervision.

All patients were evaluated for decubitus ulcer and physical therapy was started after stabilization. All patients were started on nutritional protocols after ICU admission. Medical supportive treatment was given for gastrointestinal symptoms such as diarrhea and constipation. Daily neurologic examinations of the patients were performed. In terms of respiratory system problems, the head of the bed was elevated at 30–45 degrees, and respiratory physiotherapist support was provided.

Patients were evaluated daily by the infectious diseases physician during the ICU. Only nosocomial infections were included in the study by excluding infections that were present or incubating during hospitalization.

If necessary, the tracheostomy was opened by an ICU specialist using the Griggs technique. Gastroenterology consultation was made for patients who needed Percutaneous Endoscopic Gastrostomy (PEG) and the procedure was performed by gastroenterologists.

Statistical analysis

Nominal variables were presented as numbers and percentages, whereas continuous variables were presented as the median and interquartile range (IQR). Numerical variables were analyzed using the Student's T test or the Mann-Whitney-U test. Pearson Chi-square or Fisher's exact test was used for categorical variables. The significance level for all hypotheses was accepted as 0.05. IBM Statistical Package for Social Sciences (SPSS) program version 24.0 (IBM Corp., USA) was used for all statistical analysis.

Results

From January 2017 to July 2023, we enrolled 41 patients who underwent neurosurgical procedures following traumatic incidents as participants in our study. Thirty-two C1-C2 fracture

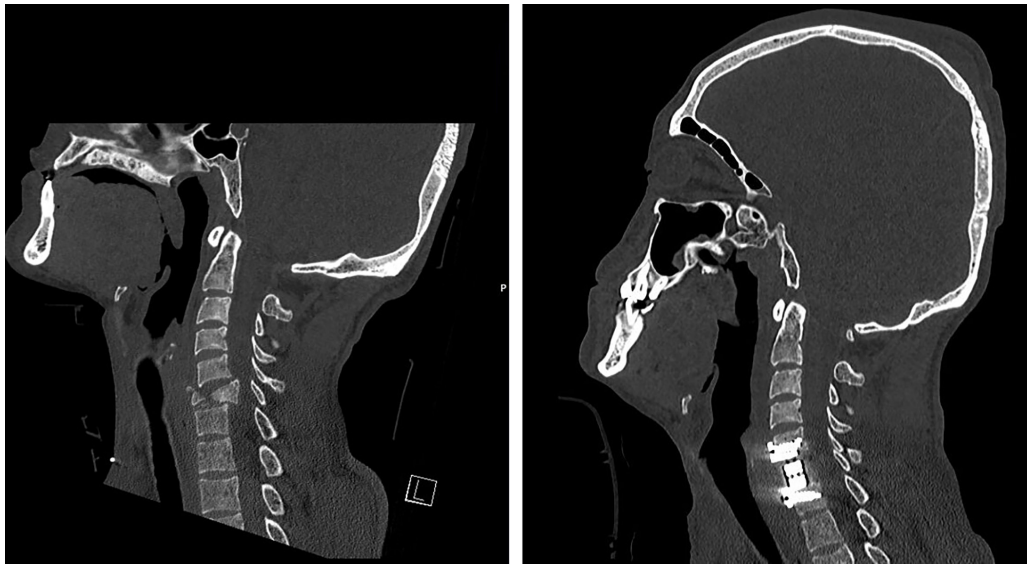

Figure 1. C6 fracture and correction with anterior stabilization

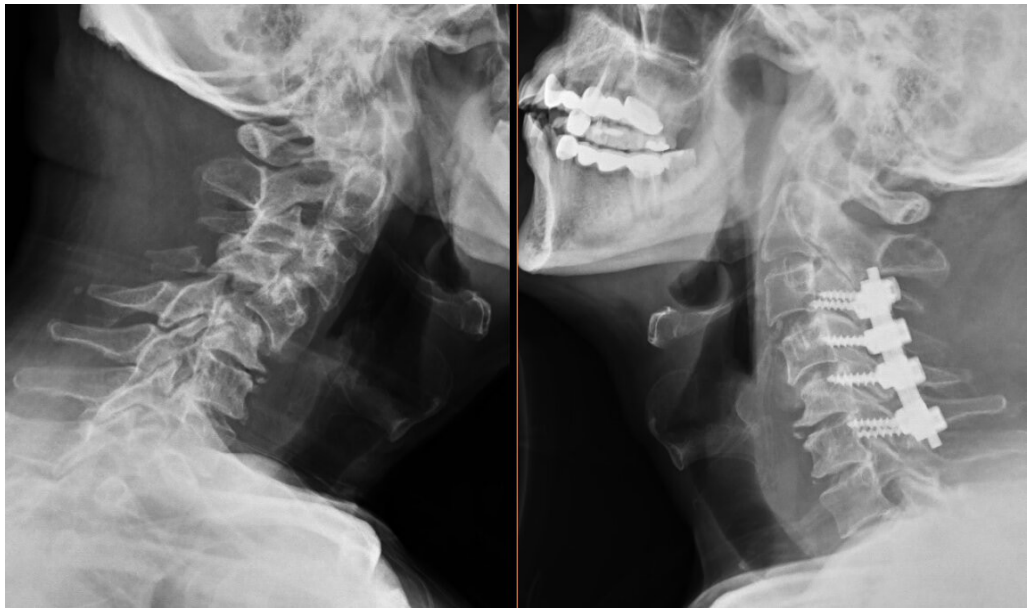

Figure 2. C4-5 listhesis and correction with posterior stabilization

and listhesis cases who had no deficits were excluded from the study because they were not admitted to the ICU. Two patients were excluded because they were under 18 years of age, although they were operated.

There were 10 (24.39%) female patients in our study and the median age was 48 (33.5–66.0) years. The primary cause of trauma in our study was falls from a height, accounting for 14 cases (34.14%), followed closely by traffic accidents, which involved 12 patients (29.26%). Hypertension was the most common comorbidity with 4 (9.75%) patients. Demographic characteristics, cause and site of trauma and type of operation are presented in Table 1.

Table 1. Demographic data

Female gender n (%)	10 (24.39)
Age year, IQR	48 (33.5–66.0)
Trauma etiology n (%)	
Traffic accident*	12 (29,26)
Fall from height	14 (34,14)
Pool or sea diving	5 (12,19)
Trauma (Violence)	3 (7,31)
Others (minor trauma)	7 (17,07)
Gender expressed as number of persons and frequency (%)	

IQR: Interquartile range
*In-vehicle and out-of-vehicle traffic accident both

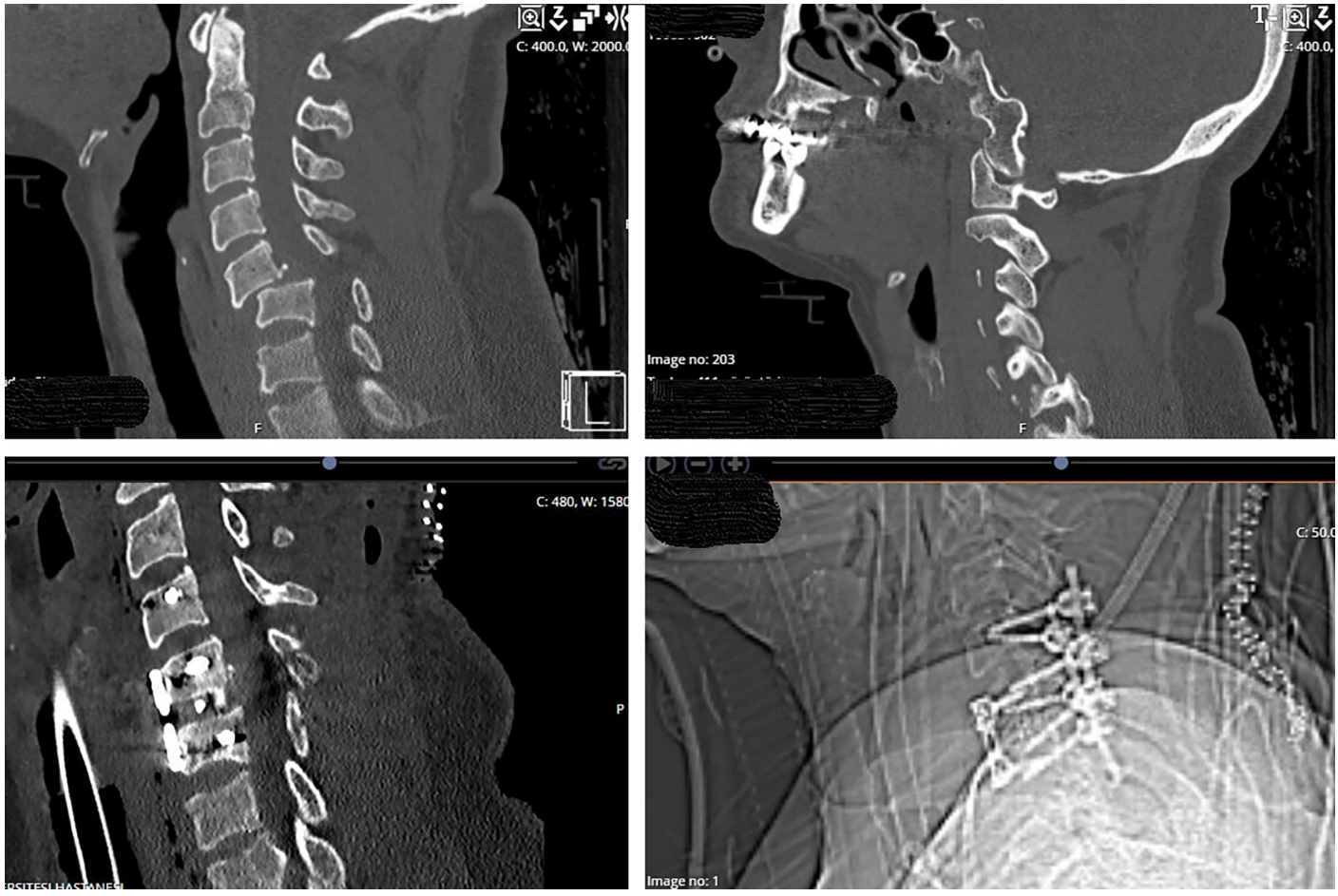

Figure 3. C5-6 Listhesis and facet joint locking, correction with 360 degree stabilization

The most common involvement was C7 fracture in 7 (17.07%) patients and C4-C5 listhesis in 8 (19.52%) patients. Fourteen (34.14%) of the patients underwent 360-degree stabilization (both anterior and posterior), 24 (58.53%) underwent only anterior stabilization, and 3 (7.31%) underwent only posterior stabilization (Table 2).

The choice of surgical intervention was based on whether anterior, posterior or both anatomical structures were damaged at the site of the spinal injury (Figure 1–3). In 14 cases in which facet joint fractures were also involved in the injury, a 360-degree combined stabilization technique was applied. Two cases (4.87%) were reoperated and revision was performed. Both of these cases were operated on from one side in the first operation, but the instability did not improve and even continued to progress. These are the patients whose spinal mechanics were restored by performing 360-degree stabilization with a second surgery (Figures 1 and 2).

There were no patients with postoperative worsening of neurologic status compared to preoperative neurologic status. In preoperative evaluation; ten of the patients (24.39%) were tetraplegic, two patients (4.87%) were paraplegic, two patients (4.87%) were monoplegic, and four patients (9.75%) had sensory loss. There was no neurologic deterioration in any patient in the post-operative period. During post-operative follow-up, 5 of 10 tetraplegic patients (50%) recovered to tetraparesis with at least 3/5 motor recovery in the upper extremity. One of the two monoplegic patients (50%) had a complete recovery, and 3 of the 4 patients with sensory loss (75%) had a complete recovery. The patients had similar findings during follow-up visits. When the mortality rate of these patients was analyzed, it was found to be 4(36.4%) in patients with neurologic deficits and 1(3.3%) in patients without neurologic deficits (p=0.014).

Table 2. Trauma levels and type of surgery

Fracture level n, (%)	
C3	1 (2.43)
C4	–
C5	2 (4.87)
C6	6 (14.63)
C7	7 (17.07)
Dislocation levels n, (%)	
C2-C3	1 (2.43)
C3-C4	3 (7.31)
C4-C5	8 (19.52)
C5-C6	4 (9.75)
C6-C7	7 (17.07)
C7-T1	2 (4.87)
Type of surgery n, (%)	
360-degree (anterior and posterior both) stabilization	14 (34.14)
Anterior stabilization	24 (58.53)
Posterior stabilization	3 (7.31)

Table 3. Characteristics of patients in intensive care

Glasgow coma scale	15 (15–15)
APACHE II	10.2 (5.0–11.5)
Duration of intensive care unit stay, days, IQR	2.0 (1.0–5.5)
Duration of mechanic ventilation, days, IQR	4.0 (0–9.0)
Tracheostomy n, (%)	7 (17.07)
Percutaneus endoscopic gastrostomy n, (%)	2 (4.87)
Vasopressor need n, (%)	14 (34.14)

IQR: Interquartile range
APACHE II: Acute Physiology and Chronic Health Evaluation

The median APACHE II was 10.16 (5.0–11.5). Fourteen patients received inotropic therapy due to hypotension that developed during follow-up. Tracheostomy was performed in seven patients and PEG was necessary for 2 patients. The median duration of ICU stay was 2(1.0–5.5) days. Five of the patients lost their lives. Intensive care complications and their relation with mortality are given in Table 3.

Nosocomial infections were diagnosed in 10 (2%.43) patients, 19 causative microorganisms were detected and polymicrobial infection was present in 8 patients. The causative microorganisms and the sites of infection are presented in Table 4.

Discussion

Cervical injuries are an important cause of morbidity and mortality in both developed and developing countries. In this article, a single-center experience on patients with cervical trauma is presented. Evaluation and treatment of patients with cervical trauma needs a multidisciplinary team including surgical teams, anesthesiology, and intensive care teams. The study has revealed that prompt surgical management is necessary for favorable neurological outcomes and the severity of the remaining neurological deficit has a direct effect on the survival of the patients.

In this study, we discussed the choice of surgical method in patients with TCSCI, the anesthetic techniques applied during the operation, the points to be taken into consideration during the post-operative intensive care period, the importance of infection, in the light of the literature, and the results of our patients in methods.

Similar to our patients, in Adigun et al.'s (5) series of 32 patients, the female: male ratio was the same as ours yet the mean age was 38.2±16.16, which is lower than ours, since their study included patients under 18 years of age.

In our study, the most common cause of trauma was falls from a height, followed by traffic accidents (in and out of the vehicle) and jumping into a pool or sea. In a multicenter study conducted by Karacan et al. (6) traffic accidents and falls from height were found to be 48.8% and 36.5%, respectively. In our study, we can regard sea and pool accidents as risks associated with the Antalya region. Etiologic factors may depend on age and region as we observed in our study.

Table 4. The causative microorganisms seen in patients with infections and the site of sample

Site of sample	Number of Infections (% of all infections)
Urine culture	*Staphylococcus aureus* (1) *Klebsiella pneumoniae* (1) *Candida topicalis* (1) *Pseudomonas aeruginosa* (1)
Blood culture	*Pseudomonas aeruginosa* (2) *Acinetobacter baumannii* (1)
Catheter culture	*Klebsiella pneumoniae* (1) *Staphylococcus aureus* (1)
Endotracheal aspirate culture	*Stenotrophomonas maltophilia* (2) *Acinetobacter baumannii* (7) *Acinetobacter lwoffii* (1) *Klebsiella pneumoniae* (2) *Staphylococcus aureus* (3) *Pseudomonas aeruginosa* (3) *Proteus mirabilis* (1) *Streptococcus pneumoniae* (1)
Wound culture	*Escherichia coli* *Acinetobacter baumannii*

Spinal instabilization was present radiologically in all patients. Neurologic damage was present in only 43.91% of patients. All patients were operated on. Fourteen patients underwent 360-degree stabilization, 24 patients underwent only anterior stabilization, and 3 patients underwent only posterior stabilization. The choice of surgical intervention was based on whether anterior, posterior or both anatomical structures were damaged at the site of spinal injury. In a study by De-Chao Miao et al. (7) comparing surgical techniques in 24 patients, spinal stabilization was achieved in all patients and the neurological status of all patients did not worsen, similar to our study. In a study conducted by H ElSaghir et al. (8) involving 60 patients, the comparison between anterior and posterior stabilization revealed that 7 out of 30 patients (23.33%) in the anterior stabilization group experienced instrument failure. This was not seen in our study. Richard S Woodworth et al (9) treated posterior spinal injuries by anterior stabilization. They achieved successful results in 15 of 17 patients. In 1 patient, they experienced instrument failure and one patient developed difficulty in swallowing and hoarseness. In our study, surgical interventions were tailored to the specific pathology and the direction of the spinal injury. Successful fusion was achieved in all patients. At the same time, none of our patients had worsening neurologic symptoms.

The mortality rate was 26% in the study by Neuman et al. (10) and 21% in the study by Claxton et al. (11). In our study, the mortality rate was 5 (12.9%), which is notably lower when compared to the existing literature. One of the most important reason for this is that patients with isolated spinal trauma were included in the study, but patients with multiple trauma were not included.

In our study, five of the patients lost their lives. There were 11 patients with neurological deficits after the operation and 5 of them were tetraplegic. All of these 5 patients were tetraplegic with neurological deficit and were tracheostomized and mechanically ventilated. The severity of the neurological deficit directly influences the prognosis for patient survival. When the mortality

rate of these patients was examined, it was found to be higher in those with neurological deficits than those without neurological deficits.

APACHE II scoring is one of the scoring systems used to determine expected mortality in ICU patients. In our study, the median APACHE II score of the patients was found to be 10.16 (IQR: 5.0–11.5). In the study by Ulger et al. (12) mean APACHEII score was found to be between 8.1±1.7 (ranging between 4–12) with a mortality of 61.9%. While our findings align with the existing literature, it's important to note that the low APACHE II scores observed in this patient group may be expected due to their unique characteristics and APACHEII score might not serve as a reliable indicator of mortality in this group of patients.

A wide spectrum of problems await us in cervical trauma patients. They frequently need interventions other than surgical stabilization. Tracheostomy is a procedure frequently performed with different indications in the ICU (13). The diaphragm is fed by nerves between C3–5 levels. This level injuries result in paralysis of the respiratory muscles. Patients whose cough reflex is suppressed and who cannot create sufficient tidal volume require intubation, and the need for tracheostomy increases in these patients (14). We performed tracheostomy procedure on seven patients (17.07%) due to long-term mechanical ventilator dependence due to insufficient respiratory effort.

In our study, 34.1% of patients required vasopressors/ inotropes for hemodynamic instability. In the study of Levi et al. (15), hypotension was present in eight (16%) patients and required inotropes. Although guidelines recommending increasing MAP to >85 mmHg for patients with acute TSCI have been available for over 20 years, there is still no consensus on which vasopressor should be used to achieve this MAP target (16). The most recent AANS/CNS Joint Committee guidelines do not make a specific recommendation regarding the choice of the vasopressor to use for their recommendation of elevated MAP goals of 85–90 mm Hg (17). Treatment was started in our intensive care clinic in accordance with this recommendation. In our study, we observed a higher incidence of patients needing vasopressor therapy compared to what is typically reported in the medical literature.

Infection developed in 2.43% of the patients. *Acinetobacter baumania* was the leading agent, followed by *Staphylococcus aureus* and *Pseudomonas aeruginosa*. In the study of Ulger et al. (12), A. baumannii was found in 30.5%, *P. aeruginosa* in 19.5%, E. coli in 13.4%, Enterobacteriaceae in 4.3% and other agents in 32.3%. In the study by Han et al. (18), 30 (49.2%) patients had respiratory tract infections. And the most frequently isolated microorganism was *Staphylococcus aureus*. The pattern of microorganisms in our patients aligns with the hospital's overall microbiological profile.

Respiratory complications in the acute phase of cervical fractures are the leading cause of morbidity and mortality, accounting for 80.0% of mortality. Complete respiratory paralysis is observed especially in injuries above the C3-C5 levels. Within a month after injury, lung compliance decreases. The cause of the early decrease in lung compliance is unclear but has been attributed partly to decreased lung volume and partly to changes in the mechanical properties of the lung from changes in surfactant that can occur rapidly with low lung volume ventilation. Chest wall compliance was probably also reduced in tetraplegia (19).

Limitations

Our study is a single-center, retrospective study describing our experience. The results cannot be generalized. Larger multicenter prospective studies are needed to study prognostic factors for morbidity and mortality.

Conclusions

Collaboration between surgical and intensive care teams plays a crucial role in the management of cervical injuries. The selection of the surgical approach should align with the direction of the injury. Importantly, our study has revealed that the degree of neurological deficit directly impacts the patients' survival prognosis; mortality rates of patients with neurologic deficits were higher.

AUTHOR CONTRIBUTIONS:

Concept: HC,OC; **Design:** OC; **Supervision:** HC, NB; **Materials:** HC, UAY; **Data Collection and/or Processing:** OC, UAY; **Analysis and/or Interpretation**: OC, NB; **Literature Search:** HC, UAY; **Writing Manuscript**: HC, OC; **Critical Review:** OC, NB.

Ethics Committee Approval: The study was carried out with the permission of Ethical Committee of Akdeniz University Faculty of Medicine (Decision No: 26.04.2023-Kaek 332).

Informed Consent: Retrospective

Peer-review: Externally peer-reviewed.

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