Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 4, 2320-2330
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i4.1601

Surgery do save life in cervical spinal injury: 5 years study of a tertiary care in East Java, Indonesia

Ilham Pratamanugroho[1], Komang Agung Irianto[1]*, Lukas Widhiyanto[1], Pudji Lestari[2]
1,2,3Department of Orthopedic and Traumatology, Dr. Soetomo General Academic Hospital/ Faculty of Medicine, Airlangga University, Surabaya, Indonesia; ilhamprat@gmail.com (I.P.), komang168@yahoo.com (K.A.I.), lukas-w@fk.unair.ac.id (L.W.).
4Department of Public Health-Preventive Medicine, Faculty of Medicine Airlangga University, Surabaya, Indonesia; pudjilestari70@fk.unair.ac.id (P.L.)

Abstract: Cervical spine has the most movement in spine therefore it has high risk of injury which may involve vertebrae, soft tissue and spinal cord. Trauma to cervical has highest risk of neurologic deficits due to spinal cord injury (SCI) causing high number of morbidity and mortality. Retrospective study was conducted with descriptive-analytic design by total sampling of cervical spinal injury patients in Dr. Soetomo General Academic Hospital from January 2018 to June 2023. Patient demographic and survival analysis of patients was described using Kaplan-Meier chart and logistic regression test to find factors contributing to patients' survival. Gender, age, mechanism of injury, surgical approach, duration, intra-operative bleeding, lesion level, time to surgery, and initial blood laboratory had no significant impact while neurological status and operative treatment have significant survival probability. Patients with American Spinal Injury Association Impairment Scale (AIS) A score have lower survival rate which associated with respiratory muscle weakness, cardiovascular and autonomic nervous system dysfunction. Any unstable cervical fracture is advised for surgery while decompression surgery is recommended for improving outcome and ease of rehabilitation. Clinical implication of this study recommends surgery for cervical spinal injury with 5.6 times more chance of survival than non-operative patients. Initial AIS neurological status and surgery performed contributes to survival. Level of cervical lesion, age, gender, mechanism of injury, surgical approach, duration, blood laboratory tests do not have a significant impact on survival while fastest time admission to surgery does not reflect higher chance of survival probability.
Keywords: *Cervical spinal injury, Kaplan-Meier, Logistic regression, Survival.*

1. Introduction

Trauma in the cervical region carries the highest risk of neurological deficits due to SCI and results in significant morbidity and mortality. Approximately 20.8% of spinal trauma occurs in the cervical area, with up to 34% of cervical injuries leading to death [1], [2].

Some of the most common mechanisms of injury in cervical injury cases are traffic accidents, falls from heights, diving, and contact sports. The incidence is higher in males compared to females, with a ratio of 2:1 in the United States, 7:1 in Greece, 6:1 in Ireland, 8:1 in Qatar, and 3:1 in Sweden. These results may be attributed to males more frequently consuming alcohol, high speed driving, and high-risk sports participation[3], [4].

The cervical spine has the most movement of spine, making it highly susceptible to injury. Cervical injuries can affect all structures from the vertebrae to the soft tissues and the spinal cord [1]. The leading causes of death in cervical trauma cases are respiratory failure and sepsis [2], [5]. Several risk

* Correspondence: komang168@yahoo.com

factors that can increase mortality in patients with cervical injuries include age, gender, initial neurological status, and tracheostomy status [5], [6].

Initial management of cervical injuries involves the principles of the Advanced Trauma Life Support (ATLS) protocol. Specific management of cervical injuries follows several basic principles, including decompression of neural structures, restoring vertebral column integrity, preventing and addressing complications, and providing adequate rehabilitation. Management of cervical injury patients can be either conservative or operative. Patients with cervical injuries can undergo conservative therapy, with various therapeutic modalities ranging from orthoses to reduction using halo traction and stabilization with a halo jacket. Several considerations must be made for operative therapy, including patients who fail closed reduction, unstable injuries, and those with progressive neurological deficits. Cervical injuries can be decompressed and/or stabilized from the anterior or posterior surgical approach, depending on several factors [7]. Secretome usage in vivo animal model studies for regeneration of spinal cord has been studied as latest advancement in treatment of spinal cord injury [8], [9]. This study aims to analyze the factors that contribute to survival of cervical spinal injury patients and describe demographic data of the patients of a single tertiary hospital.

2. Materials and Methods

This study is a retrospective study with descriptive-analytic design. Secondary data was total sampling of patients' database for 5.5 years from January 2018 to June 2023, with inclusion criteria are cervical spinal injury patient due to trauma who were treated by orthopaedic surgeon at Dr. Soetomo General Academic Hospital. While exclusion criteria are patients who underwent prior cervical spinal surgery in other referral hospital, patients who was discharged against medical advice or refused any kind of treatment on the hospital. This data were then processed through calculation and tabulation, resulting in the characteristics and survival analysis of cervical spinal injury cases. Initial laboratory condition was described and analyzed to assess correlation between initial condition and survival of patients with cervical spinal injury. Demographic data was described and analyzed using Kaplan-Meier graph, then logistic regression test was used to analyze which significant factors that contributes to survival of patients [10].

3. Results

Patient demographic data of total 127 patients are shown in Table 1. There are 116 patients classified as male accounting for 90%. Meanwhile, the female population in this study are 11 patients, representing 10% with a *Sig* value of 0.201. In this study, age groups are divided into seven categories: 0-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, and 70-79 years. Based on these age groups, the 50-59 age group has the highest number of individuals with 36 patients (28.3%), whereas the 70-79 age group has the fewest number with 6 patients accounting for 4.7%. The average age in this study is 47.01 ± 15.5 years with *Sig* value of more than 0.250 on all age group.

Based on the AIS classification of patients for neurological status, this study shows AIS A group, the lowest neurological status, has the highest number of individuals with 57 patients and accounting for 44.9%. In this study, patient group with the best neurological status (AIS E) has population of 14 individuals, representing 11%, with *Sig* value less than 0.250 for the AIS A, B, and C while AIS D and E has *Sig* value more than 0.250.

Mechanism of injury occurred on the patients are also described. Traffic accidents are the most common with 57.5% of cases followed by fall from ceiling-height with 39.4%, while standing-height fall or slipped injury and massaged cause is much less common. The mechanism of injury all had *Sig* value of more than 0.250. According to level of cervical lesion, 115 patients (90.6%) have lower cervical (C3-C7) lesion while 12 patients (9.6%) have upper cervical (C1-2) lesion with *Sig* value 0.330.

There are two treatment groups for patients with cervical injuries. The operative group, which is divided into anterior or posterior surgical approaches, and the non-operative group. Operative treatment was performed on 73 individuals (57.5% cases) with *Sig* value 0.003, compared to non-operative treatment which was done in 54 patients (42.5% cases). There are 17 patients underwent surgery by anterior approach (23.3%) and 56 patients was performed posterior approach (76.7%) with *Sig* value 0.390. Surgery was completed in less than 3 hours on 43 patients while 9 patients has longer than 3 hours surgery with *Sig* value 0.591, meanwhile 1 patient has no surgery duration data.

Intra-operative bleeding of less than 300cc occurred in 43 patients while more than 300cc intra-operative bleeding was occurred in 9 patients with *Sig* value 0.623, however 21 patients have no intra-operative bleeding data.

Blood laboratory result of hemoglobin, leukocyte, C-Reactive Protein (CRP), blood gas analysis shows no significant result on patient survival with *Sig* value of more than 0.250 on all variables.

Based on time from admission to surgery, there are 8 patients (11%) who were operated within 1 day with *Sig* value 0.264, 15 patients (20.5%) were operated between 1 and 3 days with *Sig* value 0.010, 14 patients (19.2%) were operated within 4-7 days with *Sig* value 0.060, and 36 patients (49.3%) were operated 7 days after admission with *Sig* value 0.000.

Most common cause of death was sepsis in 50 patients, accounting for 71.5% death case followed by respiratory failure which was also a significant cause with 15 patients, representing 21.4% death case, while shock and aspiration was much less frequent with 4 and 1 case respectively.

Table 1.
Demographic data of the study.

Factors	n	%	Condition		Sig*
			Survived	Deceased	
Gender					
Male	116	90	50	66	0.201
Female	11	10	7	4	
Group age					
≤ 30	22	17.3	12	10	0.413
31-40	19	15	8	11	0.959
41-50	22	17.3	9	13	0.890
51-60	36	28.3	16	20	0.899
> 60	28	22.1	12	16	0.899
Mean ± SD		47.01	± 15.5		
AIS grade					
A	57	44.9	9	48	0.000
B	22	17.3	10	12	0.008
C	30	23.6	20	10	0.000
D	4	3.1	4	0	0.999
E	14	11.0	14	0	0.998
Injury mechanism					
Traffic accident	73	57.5	35	38	0.756
ceiling-height fall	50	39.4	19	31	0.276
standing-height fall	3	2.3	3	0	0.999
Massage	1	0.8	0	1	1.000
Lesion level					
Upper cervical	12	9.4	7	5	0.330
Lower cervical	115	90.6	50	65	
Surgical approach					
Anterior	17	23.3	8	9	0.390
Posterior	56	76.7	33	23	
Duration of surgery					
≤ 3 hours	43	59.0	25	18	0.591

Factors	n	%	Condition		Sig*
			Survived	Deceased	
> 3 hours	29	39.7	15	14	
no data	1	1.3			
Intra-operative bleeding					
≤ 300 cc	43	58.9	23	20	0.623
> 300 cc	9	12.3	4	5	
No data	21	28.8			
Admission time to surgery					
≤ 1 day	8	11.0	2	6	0.264
1-3 days	15	20.5	4	11	0.010
4-7 days	14	19.2	6	8	0.060
More than 7 days	36	49.3	29	7	0.000
Hemoglobin initial					
Normal (≥10)	104	81.9	46	58	0.515
< 10	9	7.1	5	4	
no data	14	11.0			
Leukocyte initial					
≤ 11.000	54	42.6	24	30	0.812
>11.000	60	47.2	28	32	
No data	13	10.2			
C-Reactive protein (CRP) initial					
Normal (≤ 1)	35	27.6	15	20	0.808
Elevated (> 1)	35	27.6	14	21	
No data	57	44.8			
Blood gas initial					
Normal	52	40.9	25	27	0.708
Not normal	54	42.6	24	30	
No data	21	16.5			
Main cause of death					
Sepsis	50	71.5			
Respiratory failure	15	21.4			
Shock	4	5.7			
Aspiration	1	1.4			

Note: *Binary logistic regression test.

The Kaplan-Meier graph in each AIS class is shown in Figure 1. There is significant separation among AIS class of A, B, And C while patients with AIS D and E tend to survive throughout the length of treatment.

Analysis for the survival of patients who underwent surgery and those who did not, is shown in Kaplan-Meier graph in Figure 2. It shows that patients who underwent surgery had a better prognosis with more than 60% patients compared to 20% patients who did not undergo surgery would survive after 20 days or more.

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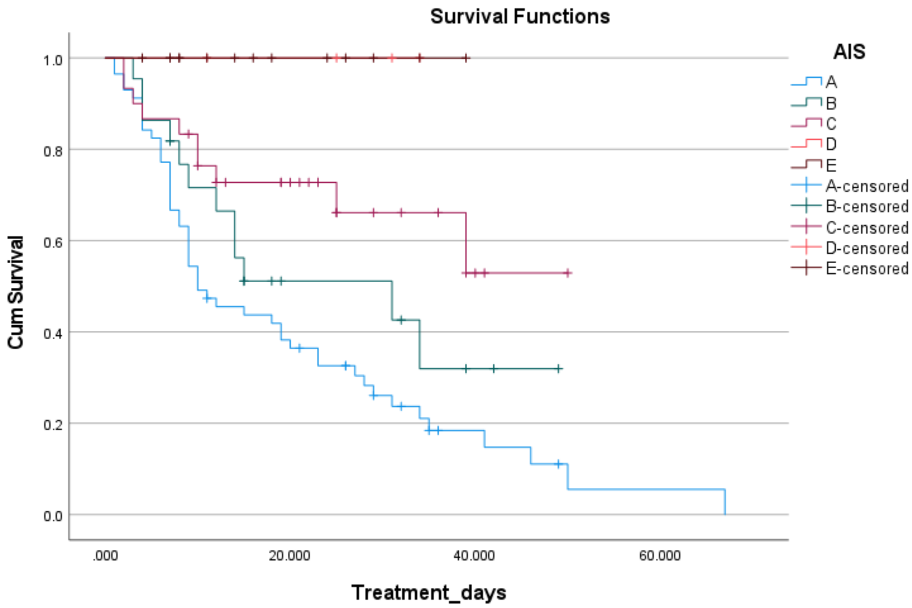

Figure 1.
Kaplan-Meier analysis results for each AIS class through duration of treatment in hospital.

AIS A patients shows significant survival probability for patients who underwent surgery compared to non-operative. More than 50% operated patients survived at 20 days while less than 20% non-operated patients survived at 20 days as shown in Figure 3.

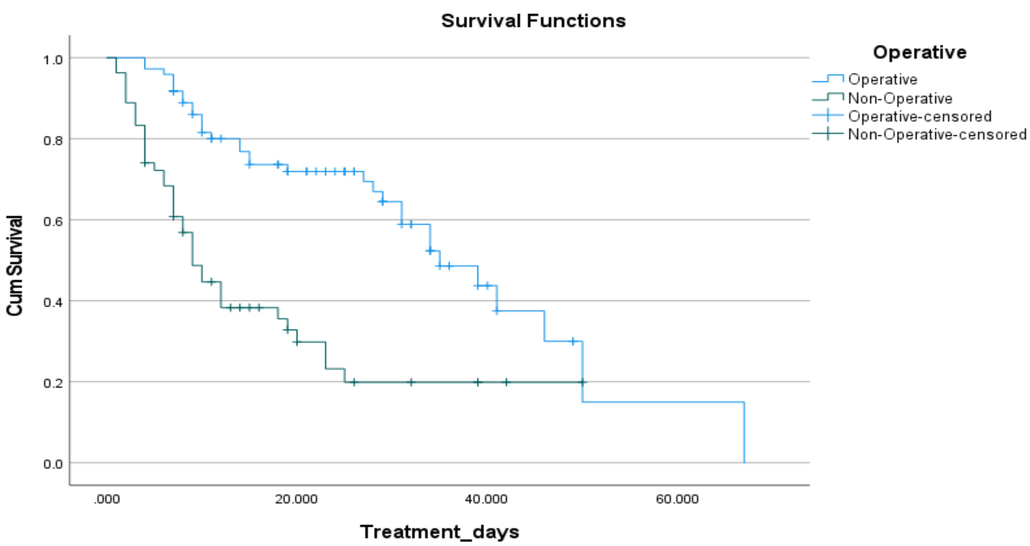

Figure 2.
Kaplan-Meier results for operative and non-operative patients.

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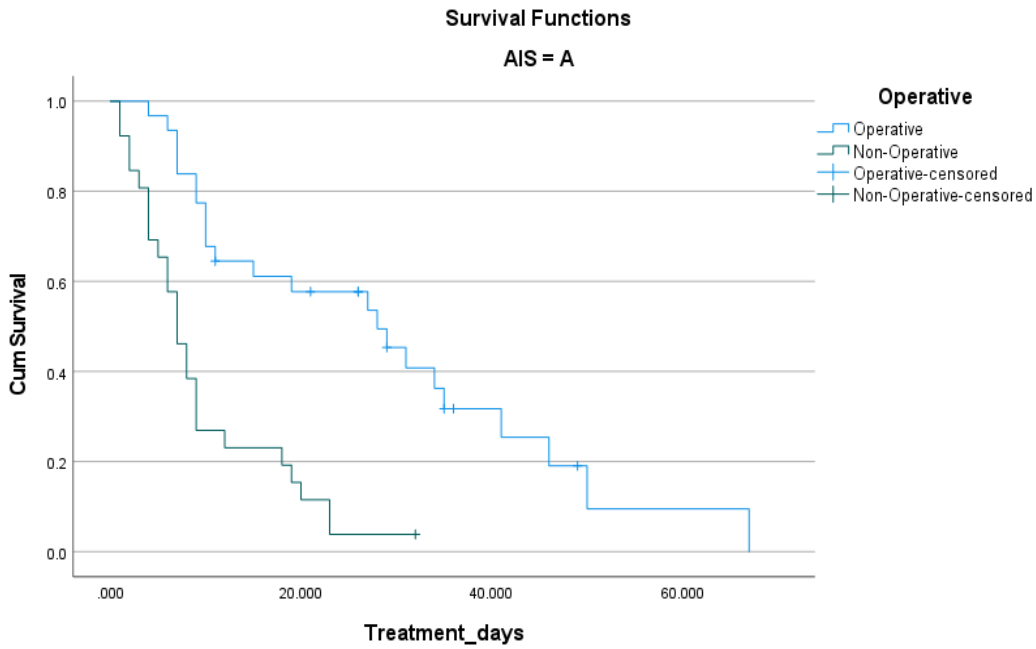

Figure 3.
Kaplan-Meier results for patients with AIS A that underwent operative and non-operative.

Patients with AIS B has higher survival probability for patients who underwent surgery as shown in Figure 4. More than 60% of operated patients survived at 20 days, while only 30% non-operated patients survived at 20 days.

Analysis of AIS C patients shows higher survival probability for patients who underwent surgery compared to non-operative as seen in Figure 5. More than 90% operated patients survived at 20 days while less than 50% non-operated patients survived at 20 days.

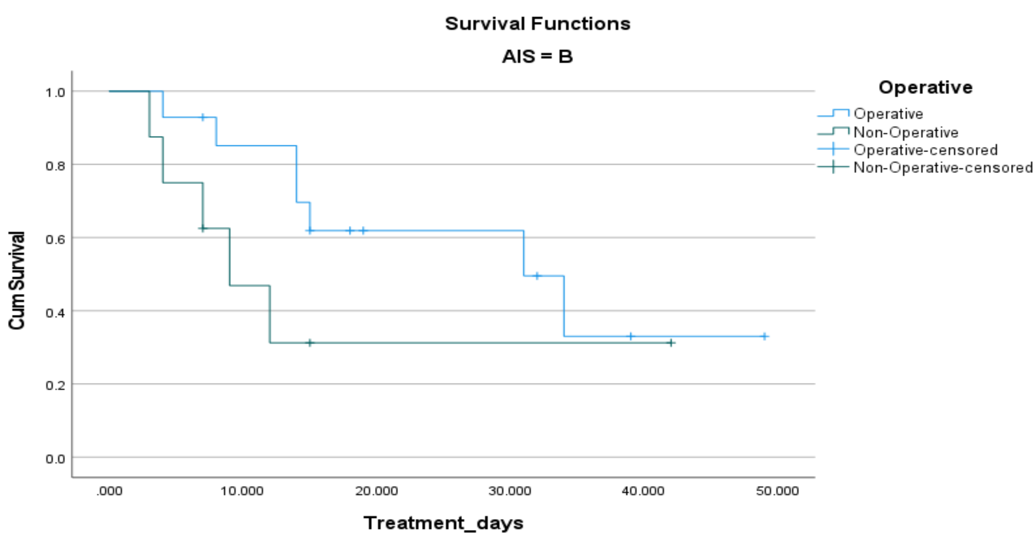

Figure 4.
Kaplan-Meier results for patients with AIS B that underwent operative and non-operative.

DOI: 10.55214/25768484.v8i4.1601

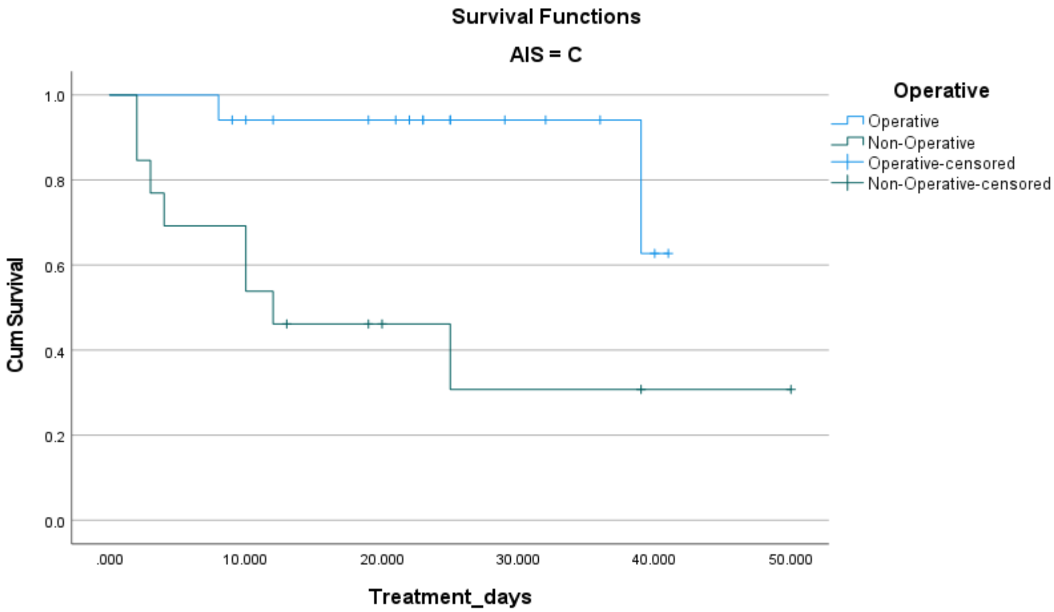

Figure 5.
Kaplan-Meier results for patients with AIS C that underwent operative and non-operative.

All variables with *Sig*. value of less than 0.25 from Table 1 was analyzed as one calculation by logistic regression as shown in Table 2, which consist of AIS neurological status, surgical intervention, and gender. Patients with AIS grade B and C has 5 times and 15.1 times more probability of survival than AIS A respectively, while patient with operative treatment has 5.6 times more probability of survival than non-operative patients. However, gender has no significant effect on survival of cervical spinal if compared to other variables due to *Sig*. value more than 0.250 (*Sig* = 0.320). The timing of admission to surgery was not included in this calculation due to risk of bias that occur because surgery was performed depending on limited Intensive Care Unit (ICU) availability, prolonged time to Magnetic Resonance Imaging (MRI) examination because of long queue that might take 3-7 days, and no initial time of trauma to hospital admission data.

Table 2.
Results of logistic regression.

Variable	Sig.	Exp. (β)
AIS A	0.000	1
AIS B	0.008	5
AIS C	0.000	15.1
Operative	0.001	5.6
Gender	0.320	2.5

4. Discussion

In this study, approximately 90% of cervical injuries occur in male population. Men are more likely to suffer neck injuries than women because of men's association with motorcycle riding, construction work, impatience, aggressiveness, and poor concentration therefore men tend to be involved in traffic accidents, work accidents, and falls [11].

Age distribution in this study appears to be evenly spread across productive ages between 20-59 years, with an average age of 47 years. This contrasts with the bimodal distribution found in traumatic

SCI studies, where the first peak in younger ages is due to traffic accidents and the second peak in age over 65 is due to trivial standing-height falls [12]. In this study, it was observed that age is not correlated with patient survival, which is similar to previous study [13].

No significant effect was found between the lesion level of injury and patient survival. The majority (90.6%) of patients had lower cervical injuries (C3-7), with upper cervical injuries representing only a minority (9.4%). The higher number of cases in the lower cervical area is due to biomechanical weaknesses in the cervical bones and greater movement in this region [14], although there are rare cases of intact neurological status after unstable cervical dislocation [15].

Traffic accidents are the main cause of cervical fractures in this study. Traffic accidents accounted for 60% of cervical fractures, while falls from heights were the second most common cause at 35%. These findings are consistent with previous meta-analytic study that found traffic accidents are the leading cause in nearly all countries [16]. The incidence of traffic accidents in developing countries is considerably more due to the large quantity of motor vehicles, low compliance with road safety regulations, and poor road infrastructure [17]. However, there was no significant relationship found between the mechanism of injury and patient survival.

Based on neurological status, the majority of patients had AIS scale A. The analysis results indicate that patient survival is significantly influenced by the neurological status, with the highest number of death cases occurring in patients with AIS scale A, and the number of deaths decreasing as neurological status improves. This is due to respiratory muscle weakness during the spinal shock phase, cardiovascular and autonomic nervous system dysfunction in cervical injuries. Weakness in the intercostal and abdominal muscles leads to paradoxical breathing, reduced lung capacity, cough dysfunction, and increased parasympathetic activity due to loss of sympathetic nerve activity [18].

Surgical option is recommended than non-operative for cervical spinal injury based on this study result and increase survival chance of patient with cervical spinal injury. Any unstable cervical fracture is advised to undertake surgical stabilization of the spine while spinal decompression surgery is recommended for cervical spinal cord injury for improving outcome and ease of rehabilitation [14].

The surgical approach, whether anterior or posterior, can be used to stabilize unstable cervical injuries or decompress the spinal canal depending on the surgeon's preference, specific indications, and the patient's condition. In this study, the posterior approach (76.7%) is performed more frequently than anterior approach (23.3%). However, there was no relationship found between the surgical approach and patient survival. This is consistent with previous study comparing anterior and posterior approaches where no significant differences were found in improvement of neurological status or overall outcome. Either anterior or posterior approach are acceptable choice and decision to use a particular approach may be based on decompression and fusion location, fracture pattern and tailored according to patient condition [14].

In this study, more surgery cases are performed for duration of less than 3 hours, however this surgery duration did not significantly affect patient survival. This contrasts with previous research that explains longer operation durations pose a greater risk of complications due to increased anesthesia time, greater bleeding, and longer hospital stays [19], [20]. The amount of intra-operative bleeding does not significantly affect the survival chance of cervical spinal injury. Meanwhile, fastest time from admission to surgery performed of less than 1 day on the patient does not reflect survival probability of patient with cervical spinal injury in this study. The difference between developed or high-income country and low-income country could affect the waiting time between trauma and surgery. However this factor does not affect the duration of hospitalization while outcome and ICU stay between surgery performed within 24 hours after trauma and 7 days after trauma does not differ significantly [21].

Causes of death in this study show that the majority are due to sepsis, followed by respiratory failure. Respiratory failure in SCI is thought to be due to various factors, including paralyzed respiratory muscle during spinal shock phase, autonomic nervous system dysfunction, cardiovascular or hemodynamic disturbance, pulmonary oedema, prolonged immobility, and cough dysfunction. Weakness in the intercostal and abdominal muscles leads to paradoxical breathing and reduced lung capacity.

Above the sixth thoracic level, sympathetic activity decreases and parasympathetic activity through the vagus nerve increases excessively, resulting in hypotension and cardiac arrhythmias or bradycardia. Increased parasympathetic nerve activity also causes bronchoconstriction. The patient's ability to cough effectively is severely impaired. Patients who lose innervation of abdominal and intercostal muscles lose the ability to produce adequate expiration that disturb proper respiration [18]. Sepsis in patients with cervical injury can be attributed to various conditions which include urinary tract infections due to bladder emptying disorders or Foley catheter use, skin and soft tissue infections such as pressure ulcers, and retention of sputum which cause pneumonia [22].

The results of this study indicate that neurological status and surgical intervention significantly influence patient survival. Previous study which analyzed data from 1,163 patients and found that early mortality occurred in 9.4% of patients, influenced by the level and severity of SCI, and whether surgical intervention was performed, while patients presenting with AIS grade A had higher mortality rates compared to others [23]. The time interval between surgery and patient arrival did not significantly affect patient survival. This is because preoperative factors such as hemodynamic disorders due to neurological shock or other trauma may render the patient's condition suboptimal for surgery, but the timing of surgery itself does not significantly impact overall patient survival [24]. Initial blood laboratory tests which include hemoglobin, leukocyte, CRP, and blood gas value has no significant effect on survival of patients with cervical spinal injury in this study. However, in other studies, laboratory test such as leukocyte, CRP, and blood gas value may have prognostic value on improvement of neurological status [25], while low hemoglobin value would show poor general status of patients' initial condition [26].

However, this study has limitations where the medical records data obtained in this study were incomplete due to two times change from paper-based to electronic-based record and then change of software provider in the medical records system in the last 5 years. As a result, some data on surgery reports, duration of ventilator use, antibiotics and other important data could not be attained completely.

5. Conclusion

The study indicates several key findings regarding patient survival in cervical spinal injury cases. The initial neurological status assessed by the AIS scale significantly influences survival outcomes. In addition, patients who undergo surgical intervention show improved survival rates compared to those who do not undergo surgery. Furthermore, the study reveals that factors such as age, gender, injury mechanism, level of injury, surgical approach, duration of surgery, intra-operative bleeding and initial blood laboratory does not exhibit significant association with patient survival in cervical spinal injury cases, while fastest time admission to surgery does not reflect higher chance of survival probability.

Moving forward, it is recommended to implement comprehensive and integrated medical record systems to ensure complete and accurate documentation, which would facilitate more thorough analysis of patient data. Additionally, further research involving larger and multicenter datasets is encouraged. Such studies would provide more robust insights and evaluations into the optimal management strategies for patients with cervical spinal injuries.

Ethical Consideration:

This study has been approved for ethical clearance by the Research Ethical Board of Dr. Soetomo General Academic Hospital number 1348/LOE/301.4.2/VI/2023

Acknowledgments:

The authors would like to show gratitude to seniors and colleagues at Department of Orthopaedics and Traumatology, Faculty of Medicine, Universitas Airlangga/ Dr. Soetomo General Academic Hospital, Surabaya, Indonesia, for their guidance and support during this study.

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