Oral and Maxillofacial Surgery (2022) 26:161–170
https://doi.org/10.1007/s10006-021-00967-7

ORIGINAL ARTICLE

Prediction of mortality in severely injured patients with facial bone fractures

Ievgen Shumynskyi[1] · Vitaliy Gurianov[2] · Oleksandr Kaniura[3] · Andrey Kopchak[1]

Received: 16 December 2020 / Accepted: 2 May 2021 / Published online: 8 June 2021

Abstract

Purpose Identify the most common concomitant injuries associated with facial trauma, and compare the efficacy of various scoring systems in estimation of mortality risks in this category of patients.

Methods The study evaluated patients with facial and concomitant injuries, who received the multidisciplinary treatment in a specialized trauma hospital. Values of New Injury Severity Score, Glasgow Coma Scale, Facial Injury Severity Scale, age, and length of hospital stay were statistically analysed to determine presence of relationships between these indicators and define factors that significantly associated with lethal outcome.

Results During 6-year observation period, 719 patients were treated with multiple or combined maxillofacial trauma, brain injuries and polytrauma. Mainly with isolated midface bones (49.7%), pan-facial (34.6%), mandible (12.9%), and frontal bone and walls (2.8%) fractures. Mortality was (2.2%). The mortality rates in patients with severe pan-facial fractures were higher ($p = 0.008$) than in single anatomical area (6% vs 1.5%). Age, GCS, and NISS were the most reliable indicator of lethal outcome.

Conclusion Age, Glasgow Coma Scale and New Injury Severity Score main factors, that predicts lethal outcome with high accuracy. New Injury Severity Score value ≥ 41 is a critical level for survival prognosis and should be considered in treatment planning and management of this category of patients.

Keywords Maxillofacial trauma · Fracture · Mortality · New Injury Severity Score · Glasgow Coma Scale · Facial Injury Severity Scale

✉ Ievgen Shumynskyi
shuminsky@icloud.com
http://www.scopus.com/inward/authorDetails.url?authorID=57211061788&partnerID=MN8TOARS

Vitaliy Gurianov
i_@ukr.net

Oleksandr Kaniura
Kaniura@ukr.net

Andrey Kopchak
kopchak@ua.fm

1 Department of Dentistry, Institute of Postgraduate Education, O. Bogomolets National Medical University, 34, Peremohy Avenue, the 2nd floor of the "physical-chemical" building, Kyiv, Ukraine

2 Health Management Department, O. Bogomolets National Medical University, 13, T. Shevchenko Blvd., Kyiv 01601, Ukraine

3 Department of Orthodontics and Prosthetic Dentistry, O. Bogomolets National Medical University, 13, T. Shevchenko Blvd., Kyiv 01601, Ukraine

Introduction

Traumatic injuries remain one of the main causes of death, morbidity, and disability worldwide [1, 2]. Adequate diagnostics and hospital care increase the chance of survival in patients with polytrauma. Maxillofacial injuries are often responsible for irreversible damage or mortality in patients, especially when they are associated with other concomitant severe injuries [3]. The initial assessment and management of a patient with multiple injuries is critical for decreasing both morbidity and mortality and promoting recovery [4].

According to the literature, the incidence rate of brain trauma in patients with facial fractures was as high as 11–79.4% depending on the ethno-social and geographic conditions and principles of emergency care adopted to treat such patients [5]. Most often, brain trauma is associated with midfacial fractures and fractures with naso-orbitoethmoid complex (NOE) or frontal sinus involvement; brain trauma is less frequently associated with mandibular fractures. In addition to involvement of the head, other concomitant injuries can involve the cervical spine (from 0.3 to 4%) and other body parts (abdomen, thorax, extremities) [6].

There have only been a few reports on the risk of mortality associated with maxillofacial trauma [7]. According to the literature, isolated maxillofacial trauma is rarely associated with death, while in patients with concomitant injuries, the mortality rate is dramatically elevated. The main life-threatening conditions associated with facial injuries are massive bleeding and airway obstruction caused by foreign body aspiration or airway-compromising oedema. In some cases, severe maxillofacial injuries can divert attention from other concomitant injuries that are less evident but potentially life-threatening. Arajärvi et al. [7] reported that in fatally injured victims of motor vehicle accidents, facial injury was the definitive fatal trauma in 24%. In all other patients, severe brain injuries, cervical spine injuries, and thoracic trauma were the causes of death.

Quantifying the survival rate and prognosis of trauma patients is important for facilitating the proper treatment of life-threatening complications and prevention of irreversible damage. At present, a number of trauma scoring systems can be effectively used for evaluation and prognosis. Among them, the Abbreviated Injury Scale (AIS), the Injury Severity Score (ISS), the New Injury Severity Score (NISS), the Acute Physiology and Chronic Health Evaluation II (APACHE II), and the Trauma and Injury Severity Score (TRISS) are used not only to assess the severity of trauma and the patients' physiological health but also to predict the outcomes [8–12].

The Abbreviated Injury Scale (AIS), which is based on anatomy, was proposed in 1971 and has been revised several times. In 1974, Baker et al. developed the Injury Severity Score (ISS) based on the assumption that the severity of the trauma and risk of mortality can be reflected by the sum of the squares of the three greatest AIS scores for three different body areas. The AIS-ISS system has become the most widely used index of survival in clinical practice [13, 14]. However, it has been criticized by many authors because it considers only one (the most severe) injury in each body region. Rutledge et al. demonstrated that such a scoring system may underestimate the severity of polytrauma in patients who have two of their most severe injuries in the same body region [15]. This is especially significant for patients with head and neck injuries, including severely comminuted facial fractures. In addition, it does not have a linear relationship with death. The modified form of the ISS, the New Injury Severity Score (NISS), was developed by Osler et al. in 1997 to minimize these drawbacks and to predict patient mortality more precisely. The New Injury and Severity Score (NISS) considers the three most serious injuries when calculating the severity of the trauma, regardless of the body region affected [14, 16]. Although the data in the literature concerning the advantages of the NISS are controversial, many studies have shown that the NISS is more effective than the ISS at predicting in-hospital mortality [17–19]. However, there are some articles that reported no differences between these two scoring systems [20–23]. The existing controversies can be explained by the assumption that the AIS-ISS does not account for the differing severity of the injuries in different body regions. For example, a patient with an AIS score of 5 due to head trauma will generally be in a more life-threatening situation than a patient with the same score due to an injury to an extremity [16]. Thus, when predicting death due to trauma, the importance of other risk factors, such as age, general health status, physiologic indicators, trauma mechanism, and injured body area, should be considered. However, there have only been a few reports comparing scoring systems in maxillofacial trauma patients, and none of them analysed the prediction of mortality [5, 24, 25].

Both the AIS-ISS and NISS systems primarily reflect the probability of survival and are not suitable for the estimation of the severity of and patterns in facial trauma [14]. The number of validated scoring systems for various types of maxillofacial injury is limited. The most widely used and internationally accepted is the FISS (Facial Injury Severity Scale), which was proposed by Bagheri et al. in 2006 [26]. It has been shown to be an effective instrument for assessing maxillofacial trauma, but it has not been evaluated with regard to the prediction of mortality.

The aim of the present study was to identify the most common concomitant injuries associated with facial injuries in patients admitted to a specialized emergency trauma centre and to compare the efficacy of various scoring systems with regard to predicting mortality in this category of patients.

Materials and methods

The study evaluated all patients with facial fractures and concomitant injuries to other parts of the body who received multidisciplinary medical care in a specialized trauma centre from 2012 to 2017. Patients were identified by the medical records department. The inclusion criteria were as follows: patients who were admitted to the hospital with signs of contusion or laceration of head or neck soft tissues, patients with fractures of the facial bones, patients with concomitant injuries (defined as any major injury outside the facial region), and patients with complete documentation and a definite outcome.

The exclusion criteria were paediatric trauma (patients aged up to 18 years were usually directly admitted to the children's hospital), patients who primarily received medical care at different hospitals and were treated for complications, and patients who were transferred to other clinical institutions with no possibility of controlling the treatment outcomes. Gunshot injuries were also excluded due to the presence of several characteristics that make it challenging to determine injury severity, leading to an unreliable outcome estimate. Applying the above criteria, we selected 719 patients over the course of the 5 years.

Each patient record was individually reviewed. The following parameters were collected and examined retrospectively: sex, age, patient condition at the time of injury, aetiology and mechanism of the trauma, specific locations and number of fractures, presence of wounds, concomitant injuries identified according to body region and severity, type of treatment given, pre-existing medical conditions, drug and alcohol abuse, date of admission, length of hospital stay (LHS), date and type of intervention provided to patients, overall mortality rate, and cause of death.

All patients were assessed at the time of admission to the hospital according to the Advanced Trauma Life Support guidelines. The clinical examination was performed by a multidisciplinary team including neurosurgeons, anaesthesiologists, trauma surgeons, ENT surgeons, maxillofacial surgeons, and other specialists if necessary. Then, routine laboratory and functional tests and ultrasounds were performed. Facial fractures and brain injuries were diagnosed by multi-slice computed tomography (CT) scans and/or X-ray examinations of the head and face. CT/X-ray examinations were extended to the spine, chest, extremities, or abdomen when concomitant injuries were identified in these locations.

In the present study, the following commonly used scoring systems were selected to grade injury severity: the Abbreviated Injury Scale (AIS), the New Injury Severity Score (NISS), the Facial Injury Severity Scale (FISS), and the Glasgow Coma Scale (GCS). The Abbreviated Injury Scale was used to encode and assess the severity of polytrauma. The basis for assessing each patient's body injury was the diagnosis based on clinical and radiological examinations, the data obtained from the surgical interventions, or the results of the autopsy. The AIS-90 score was used to determine the severity of polytrauma according to the NISS. Information about the level of consciousness according to the GCS was retrieved from the records provided by the first neurosurgeon who examined the patient. Then, the facial injury severity score was calculated as an index of facial trauma severity. The radiological data and the diagnosis from the maxillofacial surgeon were used to calculate the FISS score (Table 1).

Data were collected and organized using Microsoft Excel. Before the final statistical analysis, the data were checked to ensure the necessary data quality. For quantitative variables, mean values and standard deviations (± SDs) in the case of a normal distribution or the median values (Me) and first and third quantiles ($Q_I \div Q_{III}$) in the case of a non-normal distribution were calculated. For qualitative variables, percentages (%) were calculated. Statistical analyses were performed using EZR software 1.50 (R Foundation for Statistical Computing, Vienna, Austria) [27].

Table 1 Facial Injury Severity Scale (FISS) scores

Mandible	
Dento alveolar	1 point
Each fracture of body/ramus/symphysis	2 points
Each fracture: condyle/coronoid	1 point
Mid-face	
Each midfacial fracture is assigned one point, unless part of a complex	
Dento alveolar	1 point
Le Fort I	2 points
Le Fort II	4 points
Le Fort III	6 points
(Unilateral Le Fort fractures are assigned half the numeric value)	
Naso-orbital Ethmoid (NOE)	3 points
Zygomatico-maxillary complex (ZMC)	1 point
Nasal	1 point
Upper face	
Orbital roof/rim	1 point
Displaced frontal sinus/bone fractures	5 points
Non-displaced fractures	1 point
Facial laceration	
Over 10-cm long	1 point

To analyse the presence of significant relationships between patterns of facial injury and the severity of traumatic brain injury (TBI), all patients were divided into four groups. The first group (Gr1) included patients with isolated mandibular fractures. The second group (Gr2) included patients with fractures of the midface, including fractures of the maxilla (Le Fort I, II, III), bony orbit, zygomatico-maxillary complex (ZMC), and naso-orbitoid (NOE) complex. The third group (Gr3) included patients with isolated frontal bone and sinus wall fractures. The fourth group (Gr4) included patients with pan-facial fractures (a combination of midfacial, frontal bone, and mandible fractures). The differences between groups with regard to parameters such as GCS, NISS, FISS, and LHS were estimated using the Kruskal–Wallis test and Steel–Dwass test for pairwise comparisons. Qualitative variables were compared using the Chi-squared test or Fisher's exact test, and the risk ratio (RR) and 95% CI were calculated.

Further analysis was performed to identify the factors that were significantly associated with mortality. The following parameters were selected as possible risk factors for mortality: age (years), sex (male/female), NISS score, GCS score, and FISS score. Logistic regression models were constructed. To identify the factors associated with the risk of mortality, the Akaike information criterion (AIC) was used. Based on these factors, a multiple logistic regression model was constructed, and their threshold/critical values for the risk of mortality were determined using ROC curve analysis and the Youden index [27, 28]. The area under the ROC curve (AUC) and 95% CI were estimated. Odds ratios (ORs) with 95% CIs were calculated to evaluate the effects of the risk factors.

A probability value < 0.05 was considered statistically significant.

Results

The age of the patients with facial trauma ranged from 18 to 91 years. The median age was 30.5 years (25 ± 37). There was a male predominance (84.4%) in the study sample. The main causes of injury were assaults (43%), followed by accidental falls (20.5%) and motor vehicle accidents (16%). Other aetiologies were industrial trauma (0.5%), sports (1%), and unknown causes (19%). Alcohol or drug use at the time of trauma was noted in 31.2% of the patients.

Overall, 719 patients were included. Facial fractures occurred in 70.7% (509 patients), with 847 fracture sites. In Gr1 (isolated mandibular fractures), there were 84 patients (16.5%). In Gr2 (isolated midface fractures), there were 290 patients (56.9%). In Gr3 (isolated frontal bone and sinus wall fractures), there were 19 patients (3.7%). In Gr4 (pan-facial fractures), there were 116 patients (22.9%). With regard to the fractured areas of the facial skeleton, most of the patients who were treated in the neurosurgery and polytrauma departments with isolated or multiple injuries had fractures in the midface zone 49.7%, which included fractures of the maxilla, ZMC, NOE, and orbital bones. Simultaneous damage to several areas of the face occurred in 34.6% of the patients. Isolated fractures of the mandible occurred in 12.9% of the patients, and the walls of the frontal sinus and frontal bone were fractured in 2.8%.

The FISS score ranged from 1 to 14 (in patients with multiple comminuted fractures of the frontal sinus, both walls; orbital rims; Le Fort II; coronoid process; symphysis; and ZMC). The median FISS score was 3.36 (1–5). The LHS in patients included in the study was highly variable and ranged from 1 to 111 days, with a median of 14.1 days (7–17). A GCS score ≤ 13 was identified in 23.6% of the patients. The minimum score was 3. The NISS ranged from 1 to 66. The GCS, NISS, and FISS scores and the LHS were non-normally distributed, and further statistical analysis was performed using non-parametric tests [28] (Table 2).

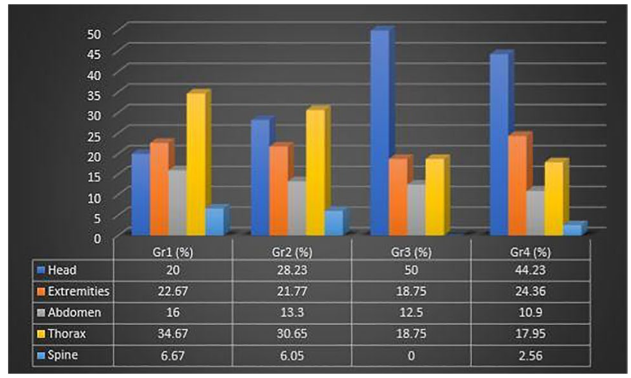

Fig. 1 Percentage of patients with concomitant injuries among patient groups

Patient's concomitant injuries are presented in Fig. 1. Among concomitant head injuries, only severe traumatic brain injuries (TBIs), such as intracranial haemorrhages, severe contusions, and open craniocerebral trauma, were taken into account. The second group (extremities) included contusions, wounds, fractures, luxations, and vascular damage. The third (abdomen) included contusions, ruptures of internal organs, and penetrating wounds. The fourth (thorax) included contusions, wounds, rib fractures, haemothorax, pneumothorax, and heart and lung contusions. Vertebral fractures were counted as spine injuries in the fifth group (spine).

In all groups of patients with different patterns of facial trauma, the median FISS scores were significantly different and increased from the first to the fourth group. This finding provides evidence that the FISS score correctly represents the severity and pattern of facial fractures and has both statistical and clinical significance. At the same time, there were no significant differences in GCS scores, NISS scores, and LHS among the first, second, and third groups with isolated fractures of the facial bones. However, all these parameters were significantly higher in Gr4. This result demonstrated that the presence of pan-facial fractures with a combination of fractures in several zones was associated with more severe polytrauma and a reduced state of consciousness. In these cases, a higher FISS score indicated a more complex condition and a longer period needed for treatment and rehabilitation (Table 3, Figs. 2, 3, 4, and 5).

Table 2 Median value and the first and third quantiles of facial, brain trauma, and polytrauma severity indicators and the duration of treatment in all patients

Indicators / Value	FISS	GCS	NISS	Length of hospital stay
Me (Q_I÷Q_{III})	3.36 (1÷5)	13.8 (14÷15)	15.5(6÷24)	14.1 (7÷17)

Table 3 Median value and the first and third quantiles of facial, brain, and polytrauma severity indicators and the duration of treatment among groups

Group number / Indicator	Gr1 (n=84)	Gr2 (n=290)	Gr3 (n=19)	Gr4 (n=116)
FISS	$3^{2,3,4}$ (2;3)	$3^{1,3,4}$ (1;3)	$5^{1,2,4}$ (5;5)	$7^{1,2,3}$ (5;9)
GCS	15^{4} (14;15)	15^{4} (14;15)	15^{4} (15;15)	$14^{1,2,3}$ (13;15)
NISS	6^{4} (6;14)	6^{4} (3;21)	5^{4} (2;28.5)	$21^{1,2,3}$ (9;36)
LHS (days)	10.5^{4} (7;15.25)	10^{4} (6;15)	15 (9.5;19)	$17^{1,2}$ (11;23)

[1]The difference compared with Gr1 is statistically significant, $p < 0.05$

[2]The difference compared with Gr2 is statistically significant, $p < 0.05$

[3]The difference compared with Gr3 is statistically significant, $p < 0.05$

[4]The difference compared with Gr4 is statistically significant, $p < 0.05$

Among 719 patients, there were 16 deaths (2.2%). The mean age was 47.8 ± 14.7 years. The main causes of death were cerebral oedema (75%), multiple organ dysfunction syndrome (MODS (12.5%)), post-traumatic pneumonia (6.25%), and acute heart failure (6.25%). The time to death differed, ranging from 1 to 15 days from after admission. The mean LHS was 7.7 ± 3.4 days. The mortality rate was higher in patients with severe pan-facial fractures ($p = 0.008$)

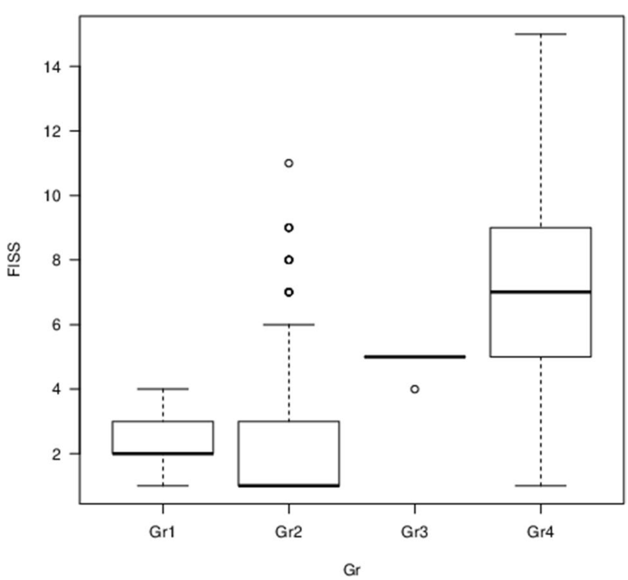

Fig. 2 Minimum, median, first and third quantiles, and maximum value of the FISS score among groups of patients

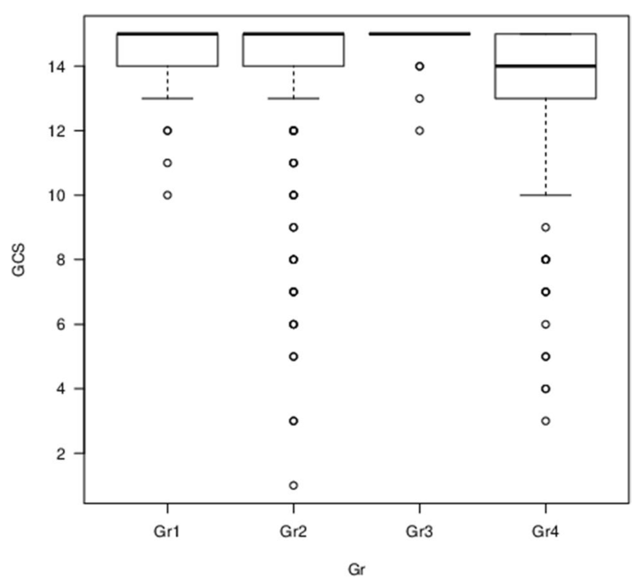

Fig. 3 Minimum, median, first and third quantiles, and maximum value of the GCS score among groups of patients

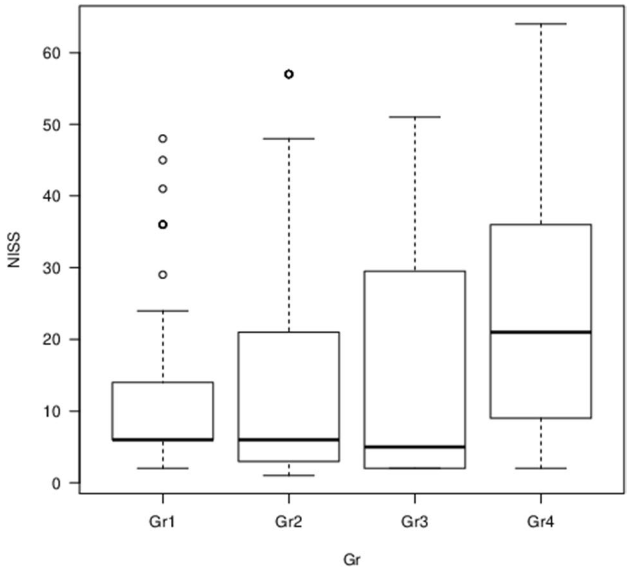

Fig. 4 Minimum, median, first and third quantiles, and maximum value of the NISS score among groups of patients

than in those with injuries isolated to a single anatomical area (6% vs 1.5%; RR = 4.0, 95% CI 1.5–10.6).

Further statistical analysis identified that among all the potential risk factors for mortality that were assessed, age, the GCS score, and the NISS score were the most reliable. Sex and the FISS score were excluded from further analysis based on the AIC. Figure 6 shows a curve of the operational characteristics of a three-factor model (age and the GCS and NISS scores; AUC = 0.98, 95% CI 0.96–1.00). This indicates a strong relationship between the risk mortality death and the identified risk factors, with the optimal threshold yielding a sensitivity of 93.3% and a specificity of 93.9%.

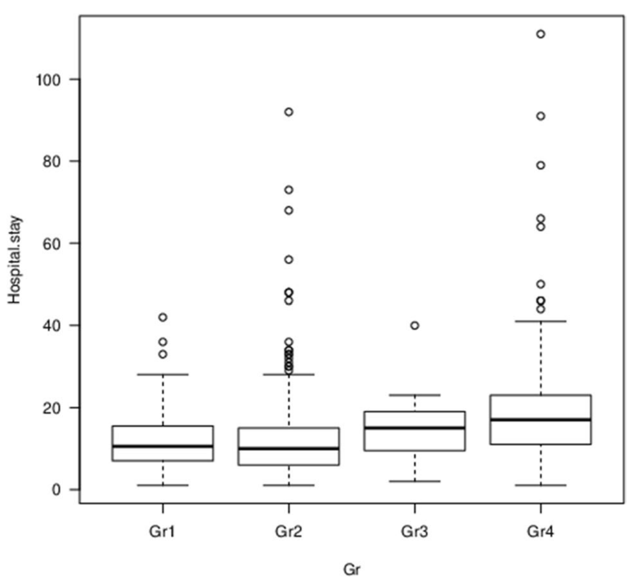

Fig. 5 Minimum, median, first and third quantiles, and maximum value of the LHS among groups of patients

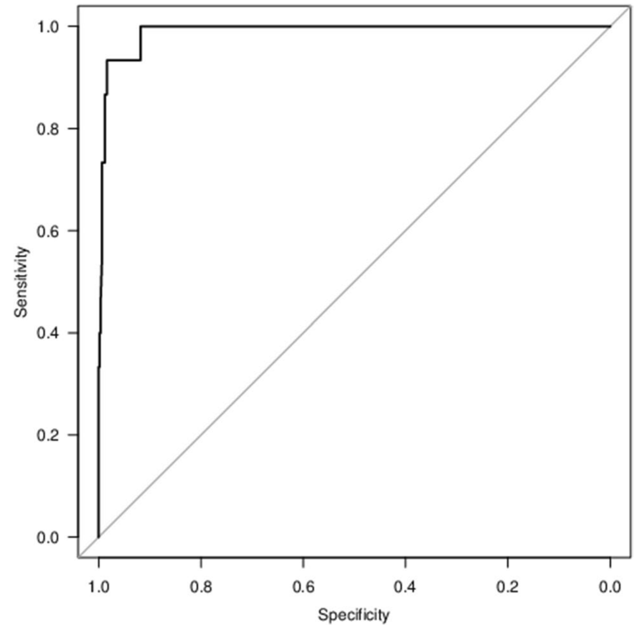

Fig. 6 Characteristics of the three-factor model (age and the GCS and NISS scores)

It has been established that with increasing age, the risk of mortality also increased ($p = 0.021$; OR 1.07, 95% CI 1.01–1.14). On the contrary, with an increase in the GCS score, the risk of mortality decreased ($p = 0.008$; OR 0.69, 95% CI 0.52–0.9), because a lower GCS score indicates a more severe condition. Finally, an increase in the NISS score was associated with an increased risk of mortality ($p = 0.002$; OR 1.15, 95% CI 1.05–1.26). In general, the use of these three indicators together improved the accuracy of the prediction of survival, and they can be used to predict the risk of mortality in daily clinical practice (Table 4).

After the regression analysis, we decided to focus on the NISS, which has a wide range of numerical values and can easily have a threshold value that could be used to accurately predict the risk of mortality. In all patients with cranio-maxillofacial trauma, the polytrauma level as indicated by the NISS ranged from 1 to 66 points. The median score was 9 (6–24). The NISS score was significantly higher in patients who died than in those who survived. In patients who died,

Table 4 Coefficients of the regression model with age, the GCS, and the NISS

Indicator	Coefficient of the model b + m	*p*	OR (95% CI)
Age	0.070 + 0.030	0.021	1.07 (1.01–1.14)
GCS	-0.38 + 0.14	0.008	0.69 (0.52–0.9)
NISS	0.14 + 0.05	0.002	1.15 (1.05–1.26)

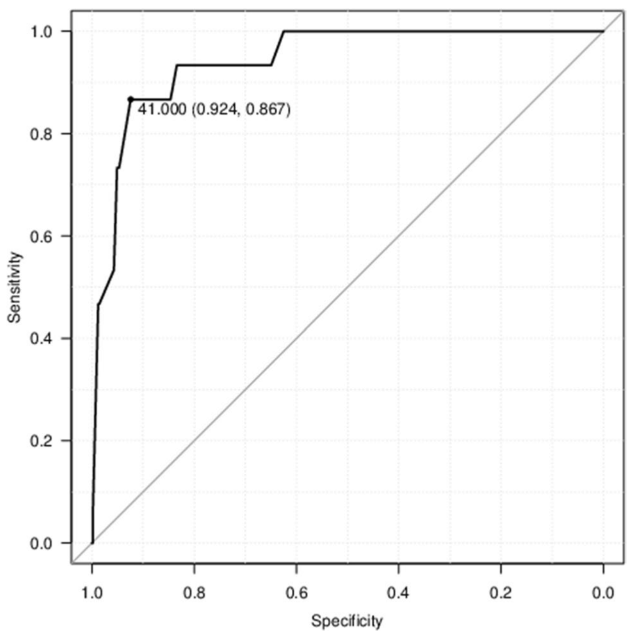

Fig. 7 Characteristics of the ROC curve analysis. Cut-off value of the NISS score

the score ranged from 11 to 64, with a median of 52.5 (44–57). To determine the value of the NISS score for the prediction of mortality in patients with maxillofacial trauma, ROC curve analysis was used, and the optimal cut-off value for the NISS score was determined. $NISS_{critical} = 41$ had a specificity of 92.4% and a sensitivity of 86.7% (AUC = 0.92, 95% CI 0.89–0.99) (Fig. 7).

Discussion

Facial trauma has major medical and socioeconomic consequences that are determined by significant aesthetic and functional deficits, psychological derangements, social disabilities, and high costs associated with treatment and rehabilitation. Facial injuries vary in type, severity, and clinical presentation. They may also be associated with simultaneous trauma to the other parts of the body. The presence of multiple severe injuries in the maxillofacial area is associated with a high complication rate, unsatisfactory clinical outcomes, and even mortality [26]. The main causes of death in patients with facial trauma are asphyxia due to compromised function of the upper airways and critical bleeding from the major vessels of the head and neck. These factors are responsible for 24% of the deaths of motor vehicle accident (MVA) victims [7]. At the same time, in our study, the specific causes of death in all cases were associated with concomitant injuries and not with the direct influence of the facial trauma. This corresponds to the results of the study by You et al. and provides evidence that the multidisciplinary approach to airway control and bleeding management based on the Advanced Trauma Life Support protocols applied in specialized trauma centres is quite effective for the prevention of mortality. Arajärvi et al. also reported that the direct risk of mortality from maxillofacial trauma is low. However, the indirect influence of facial injuries on general survival rates may be significant for the following reasons: (1) some concomitant potentially life-threatening conditions may be overlooked or misdiagnosed when there is severe facial trauma. In the literature, missed concomitant lesions have been reported in up to 22% of the cases. (2) Facial trauma inhibits normal breathing and may cause systemic hypoxia. (3) Maxillofacial trauma is a potential route of infection, including with highly virulent odontogenic microflora. (4) According to the data from emergency units reported by Lavoie et al. [16], polytrauma is usually more severe, and the risk of mortality is therefore higher in cases of head and neck involvement. In the study by Domingues et al. [29], 70.7% of all patients who died due to polytrauma had head or neck injuries.

However, in the literature, there is a lack of information about the use of scoring systems to predict mortality in patients with combined maxillofacial trauma and polytrauma. In the present study, the overall mortality rate was 2.2%. This corresponds with the data in the studies by You et al. and Domingues et al. [5, 30]. However, it was less than that reported by Plaisier et al. [24]. The study by Arajärvi et al. demonstrated that isolated facial fractures are rarely associated with death. In our study, the data were collected in a specialized trauma centre and included only cases of multiple maxillofacial trauma. Concomitant injuries were present in all cases, and head (20–44.2%) and thoracic (17.9–34.7%) injuries were predominant in all groups. The median NISS score was 15.5 (6 ÷ 24), and it was higher than 15 in 31% of the patients. Such patients were considered to have polytrauma or multiple trauma according to Pape et al. [31]. For such patients, special attention was given to the adequate diagnosis of all injuries in different body areas. If necessary, the facial and brain CT was extended to the spine, neck, chest, and abdomen, which allowed a more precise diagnosis of potential life-threatening lesions to other organ. The aetiology of the trauma and the patterns of concomitant injuries reported in our study correspond to those in Brucoli et al. [32]; the death rate in our study agrees with that in the study by You et al. and differs from that in the studies by Domingues et al. [29], Lavoie et al. [16], Pappachan et al. [25], and Brucoli et al. [33]. The main differences were the aetiology of the trauma and the distribution of the sites of the fractures. Pappachan et al. [25] and Domingues et al. [29] reported that the main causes of trauma were MVA, followed by falls, assaults, and other causes, while in our study, the main cause of trauma was assault.

In the present study, a significant association was found between the severity of facial injury and polytrauma or brain injury. The NISS, FISS, and GCS scores were significantly higher in patients with multiple fractures involving different anatomical zones of the face than in patients with injuries isolated to a single anatomical zone. Haug et al. (1992) also demonstrated that combinations of fractured facial bones tended to be associated with more severe intracranial injury, as indicated by the GCS and brain injury index, than when single bones were fractured [34]. The authors believed that in cases of severe trauma to the midfacial bones, the forces appear to be transmitted directly to the cranium and are not absorbed by the area of impact. In our study, the vast majority of patients who died had isolated or multiple midfacial injuries, reflecting the clinical and physiological importance of this anatomical area for the prediction of survival.

We also found that the mortality rate was higher in patients with pan-facial fractures (Gr4) than in patients with injuries in a single anatomical zone (6% vs 1.5%). The accurate prediction mortality in this category of patients is very important for the planning of multidisciplinary treatment and the organization of emergency care. Authors have presented different results in studies aimed at estimating the accuracy of the prediction of mortality in polytrauma patients based on various scoring systems [7, 8, 16–23, 29, 30, 35–37]. The most widely used system is the AIS-ISS, which reflects the severity of polytrauma and has a strong correlation with the survival rate. The ISS is defined as the sum of the squares of the 3 greatest AIS values of 3 body regions. A problem emerges when multiple injuries are present in the same region of the body, which means that only 1 of the AIS values is used. This problem is especially important when assessing head and neck or facial trauma. Injuries in these regions are generally more severe than those in other body regions (median NISS = 26 for head/neck injury and 9 for other injury, median NISS = 14 with facial injuries and 11 without). Additionally, multiple injuries are more likely to occur in cases of head and neck or facial trauma [16].

In our study, the NISS was chosen as a main numerical characteristic of the injury severity because of advantages in mortality prediction, especially in clinical series with high severity [16–23]. However, this scale is not suitable for the assessment of facial trauma patterns and mechanisms of injury that can affect the risk of mortality. To estimate the severity of maxillofacial trauma, we used the Facial Injury Severity Scale (FISS), which was proposed by Bagheri et al. and later used in many publications on this topic. The complexity of the prediction of mortality in patients with facial fractures was also determined by the presence of factors that complicate the examination of the patient (e.g. asphyxia, bleeding, wounds). In some cases, rapid endotracheal intubation performed in the pre-hospital stage makes it impossible to determine the Glasgow Coma Scale (GCS) score and respiratory rate (RR) on hospital admission. Therefore, to improve the accuracy of the prediction of survival, we constructed a modified regression model based on the analysis of the main risk factors/parameters associated with mortality.

In the present study, the main risk factors were the NISS and GCS scores and age. The combined assessment of these variables provided an excellent prediction of survival, with high sensitivity (93.3%) and specificity (93.9%). The authors reported that the use of the NISS score alone to predict outcomes in in polytrauma patients may be non-specific, leading to unexpected results. Our model, in contrast, demonstrated good positive and negative predictive values.

No significant correlation was found between the FISS score and the risk of mortality. The FISS score was reported to be an effective instrument for the assessment of facial trauma severity, and to correlate with the duration of hospitalization, it can be used to assess trauma severity and predict treatment outcomes [38]. Thus, the obtained results can be explained by the fact that all deaths in this study were due to other concomitant injuries. At the same time, it was found that patients with multiple pan-facial fractures had significantly higher NISS and FISS scores and a higher mortality rate. In such patients, particular attention should be paid to the diagnosis of hidden injuries and the assessment of their general state. In such cases, according to our data, an NISS value of 41 or more is the appropriate cut-off for the prediction of survival.

The present study has some limitations. The number of observations was relatively small in the analysis of the influence of different patterns of facial trauma on mortality. The study was performed in a specialized trauma centre where patients with polytrauma and complex injuries of the head and face are concentrated, leading to a population of trauma victims with severe injuries and a higher mortality rate. Further multi-centre studies needed to reflect population segments and to improve the predictive value. These findings should also be verified in other populations before they are widely applied in clinical practice. Our data could not be extrapolated to the general population, as the results may differ in countries with a high level of economic development and in developing countries. At the same time, our research could be useful not only for medical workers but also for those in the socioeconomic sphere and healthcare administration.

Conclusion

The overall mortality rate in severely injured patients with maxillofacial trauma was 2.2%. The main causes of death were cerebral oedema (75%), multiple organ dysfunction syndrome (MODS (12.5%)), post-traumatic pneumonia (6.25%), and acute heart failure (6.25%), which were associated with concomitant injuries to other parts of the body.

The mortality rate was higher in patients with severe panfacial fractures than in those with injuries isolated to a single anatomical area (RR = 4.0, 95% CI 1.5–10.6; 6% vs 1.5%). However, no significant association was found between the FISS score and the risk of death. The variables that were closely correlated with mortality were age and the GCS and NISS scores. The proposed three-factor logistic regression model based on these variables in patients with maxillofacial injuries yielded a highly accurate prediction of mortality, with a sensitivity of 93.3% and a specificity of 93.9% (AUC = 0.98 (95% CI 0.96–1.00)). The cut-off value for the prediction of mortality in polytrauma patients with craniofacial injuries using only the NISS score was 41 (AUC = 0.92; 95% CI 0.89–0.99). This threshold value is a strong indicator of mortality and should be considered in the treatment and management of this category of patients.

Authors' contributions Shumynskyi Ievgen: formal analysis; investigation; writing, original draft preparation. Gurianov Vitaliy: statistical analysis. Kaniura Oleksandr: supervision. Kopchak Andrey: conceptualization, methodology, writing review and editing.

Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval Approval was obtained from the ethics committee of O. Bogomolets National Medical University. The procedures used in this study adhered to the tenets of the Declaration of Helsinki.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests Not applicable.

References

1. Radomski M, Zettervall S, Schroeder ME, Messing J, Dunne J, Sarani B (2016) Critical care for the patient with multiple trauma. J Intensive Care Med 31(5):307–318. https://doi.org/10.1177/0885066615571895
2. Zandi M, SeyedHoseini SR (2013) The relationship between head injury and facial trauma: a case-control study. Oral Maxillofac Surg 17(3):201–207. https://doi.org/10.1007/s10006-012-0368-z
3. Prathigudupu RS, Tiwari RVC, Mathew P, Roy B, Sadique S, Tiwari H (2018) Mortality in maxillofacial trauma – a review. Saudi J Oral Dent Res 3(7):219–223
4. D'Amours SK, Sugrue M, Deane SA (2002) Initial management of the poly-trauma patient: a practical approach in an Australian major trauma service. Scand J Surg 91(1):23–33. https://doi.org/10.1177/145749690209100105
5. You N, Choi MS, Roh TH, Jeong D, Kim SH (2018) Severe facial fracture is related to severe traumatic brain injury. World Neurosurg 111:e47–e52. https://doi.org/10.1016/j.wneu.2017.11.166
6. Haug RH, Wible RT, Likavec MJ, Conforti PJ (1991) Cervical spine fractures and maxillofacial trauma. J Oral Maxillofac Surg 49(7):725–729. https://doi.org/10.1016/s0278-2391(10)80236-8
7. Arajärvi E, Lindqvist C, Santavirta S, Tolonen J, Kiviluoto O (1986) Maxillofacial trauma in fatally injured victims of motor vehicle accidents. Br J Oral Maxillofac Surg 24(4):251–257. https://doi.org/10.1016/0266-4356(86)90089-6
8. Deng Q, Tang B, Xue C, Liu Y, Liu X, Lv Y, Zhang L (2016) Comparison of the ability to predict mortality between the injury severity score and the new injury severity score: a meta-analysis. Int J Environ Res Public Health 13(8):825. https://doi.org/10.3390/ijerph13080825
9. Eid HO, Abu-Zidan FM (2015) New injury severity score is a better predictor of mortality for blunt trauma patients than the injury severity score. World J Surg 39(1):165–171. https://doi.org/10.1007/s00268-014-2745-2
10. Cook A, Weddle J, Baker S, Hosmer D, Glance L, Friedman L, Osler T (2014) A comparison of the injury severity score and the trauma mortality prediction model. J Trauma Acute Care Surg 76(1):47–52; discussion 52–3. https://doi.org/10.1097/TA.0b013e3182ab0d5d
11. Brown JB, Gestring ML, Leeper CM, Sperry JL, Peitzman AB, Billiar TR, Gaines BA (2017) The value of the injury severity score in pediatric trauma: time for a new definition of severe injury? J Trauma Acute Care Surg 82(6):995–1001. https://doi.org/10.1097/TA.0000000000001440
12. Javali RH, Krishnamoorthy, Patil A, Srinivasarangan M, Suraj, Sriharsha (2019) Comparison of injury severity score, new injury severity score, revised trauma score and trauma and injury severity score for mortality prediction in elderly trauma patients. Indian J Crit Care Med 23(2):73–77. https://doi.org/10.5005/jp-journals-10071-23120
13. Baker SP, O'Neill B, Haddon W Jr, Long WB (1974) The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14(3):187–196
14. Chen C, Zhang Y, An JG, He Y, Gong X (2014) Comparative study of four maxillofacial trauma scoring systems and expert score. J Oral Maxillofac Surg 72(11):2212–2220. https://doi.org/10.1016/j.joms.2014.04.035
15. Rutledge R (1996) The Injury Severity Score is unable to differentiate between poor care and severe injury. J Trauma 40(6):944–950. https://doi.org/10.1097/00005373-199606000-00013
16. Lavoie A, Moore L, LeSage N, Liberman M, Sampalis JS (2004) The new injury severity score: a more accurate predictor of in-hospital mortality than the Injury Severity Score. J Trauma 56(6):1312–1320. https://doi.org/10.1097/01.ta.0000075342.36072.ef
17. Brenneman FD, Boulanger BR, McLellan BA, Redelmeier DA (1998) Measuring injury severity: time for a change? J Trauma 44(4):580–582. https://doi.org/10.1097/00005373-199804000-00003
18. Jamulitrat S, Sangkerd P, Thongpiyapoom S, Na NM (2001) A comparison of mortality predictive abilities between NISS and ISS in trauma patients. J Med Assoc Thai 84(10):1416–1421
19. Sacco WJ, MacKenzie EJ, Champion HR, Davis EG, Buckman RF (1999) Comparison of alternative methods for assessing injury severity based on anatomic descriptors. J Trauma 47(3):441–6; discussion 446–7. https://doi.org/10.1097/00005373-199909000-00001
20. Stephenson SC, Langley JD, Civil ID (2002) Comparing measures of injury severity for use with large databases. J Trauma 53(2):326–332. https://doi.org/10.1097/00005373-200208000-00023

21. Grisoni E, Stallion A, Nance ML, Lelli JL Jr, Garcia VF, Marsh E (2001) The new injury severity score and the evaluation of pediatric trauma. J Trauma 50(6):1106–1110. https://doi.org/10.1097/00005373-200106000-00021
22. Husum H, Strada G (2002) Injury severity score versus new injury severity score for penetrating injuries. Prehosp Disaster Med. 17(1):27–32. https://doi.org/10.1017/s1049023x0000008x
23. Meredith JW, Evans G, Kilgo PD, MacKenzie E, Osler T, McGwin G, Cohn S, Esposito T, Gennarelli T, Hawkins M, Lucas C, Mock C, Rotondo M, Rue L, Champion HR (2002) A comparison of the abilities of nine scoring algorithms in predicting mortality. J Trauma. 53(4):621–8; discussion 628–9. https://doi.org/10.1097/00005373-200210000-00001
24. Plaisier BR, Punjabi AP, Super DM, Haug RH (2000) The relationship between facial fractures and death from neurologic injury. J Oral Maxillofac Surg 58(7):708–12; discussion 712–3. https://doi.org/10.1053/joms.2000.7250
25. Pappachan B, Alexander M (2006) Correlating facial fractures and cranial injuries. J Oral Maxillofac Surg 64(7):1023–1029. https://doi.org/10.1016/j.joms.2006.03.021
26. Bagheri SC, Dierks EJ, Kademani D, Holmgren E, Bell RB, Hommer L, Potter BE (2006) Application of a facial injury severity scale in craniomaxillofacial trauma. J Oral Maxillofac Surg 64(3):408–414. https://doi.org/10.1016/j.joms.2005.11.013
27. Kanda Y (2013) Investigation of the freely available easy-to-use software "EZR" for medical statistics. Bone Marrow Transplant. 48(3):452–8. https://doi.org/10.1038/bmt.2012.244
28. Petrie A, Sabin C (2005) Medical statistics at a glance: Blackwell Publishing, p 157
29. Domingues Cde A, de Sousa RM, Nogueira Lde S, Poggetti RS, Fontes B, Muñoz D (2011) The role of the New Trauma and Injury Severity Score (NTRISS) for survival prediction. Rev Esc Enferm USP 45(6):1353–1358. https://doi.org/10.1590/s0080-62342011000600011
30. Domingues CA, Coimbra R, Poggetti RS, Nogueira LS, de Sousa RMC (2018) New trauma and injury severity score (TRISS) adjustments for survival prediction. World J Emerg Surg 6(13):12. https://doi.org/10.1186/s13017-018-0171-8
31. Pape HC, Lefering R, Butcher N, Peitzman A, Leenen L, Marzi I, Lichte P, Josten C, Bouillon B, Schmucker U, Stahel P, Giannoudis P, Balogh Z (2014) The definition of polytrauma revisited: an international consensus process and proposal of the new "Berlin definition." J Trauma Acute Care Surg 77(5):780–786. https://doi.org/10.1097/TA.0000000000000453
32. Brucoli M, Boffano P, Broccardo E, Benech A, Corre P, Bertin H, Pechalova P, Pavlov N, Petrov P, Tamme T, Kopchak A, Hresko A, Shuminsky E, Dediol E, Tarle M, Konstantinovic VS, Petrovic M, Holmes S, Karagozoglu KH, Forouzanfar T (2019) The, "European zygomatic fracture" research project: the epidemiological results from a multicenter European collaboration. J Craniomaxillofac Surg 47(4):616–621. https://doi.org/10.1016/j.jcms.2019.01.026
33. Brucoli M, Boffano P, Romeo I, Corio C, Benech A, Ruslin M, Forouzanfar T, Starch-Jensen T, Rodríguez-Santamarta T, de Vicente JC, Snäll J, Thorén H, Tarle M, Dediol E, Pechalova P, Pavlov N, Daskalov H, Doykova I, Kelemith K, Tamme T, Kopchak A, Shumynskyi I, Corre P, Bertin H, Goguet Q, Anquetil M, Louvrier A, Meyer C, Dovšak T, Vozlič D, Birk A, Aničić B, Konstantinovic VS (2020) Management of maxillofacial trauma in the elderly: a European multicenter study. Dent Traumatol 36(3):241–246. https://doi.org/10.1111/edt.12536
34. Haug RH, Savage JD, Likavec MJ, Conforti PJ (1992) A review of 100 closed head injuries associated with facial fractures. J Oral Maxillofac Surg 50(3):218–222. https://doi.org/10.1016/0278-2391(92)90315-q
35. Mica L, Rufibach K, Keel M, Trentz O (2013) The risk of early mortality of polytrauma patients associated to ISS, NISS, APACHE II values and prothrombin time. J Trauma Manag Outcomes 24(7):6. https://doi.org/10.1186/1752-2897-7-6
36. Wong TH, Krishnaswamy G, Nadkarni NV, Nguyen HV, Lim GH, Bautista DC, Chiu MT, Chow KY, Ong ME (2016) Combining the new injury severity score with an anatomical polytrauma injury variable predicts mortality better than the new injury severity score and the injury severity score: a retrospective cohort study. Scand J Trauma Resusc Emerg Med 8(24):25. https://doi.org/10.1186/s13049-016-0215-6
37. Huang CY, Rau CS, Chuang JF, Kuo PJ, Hsu SY, Chen YC, Hsieh HY, Hsieh CH (2016) Characteristics and outcomes of patients injured in road traffic crashes and transported by emergency medical services. Int J Environ Res Public Health 13(2):236. https://doi.org/10.3390/ijerph13020236
38. Bocchialini G, Castellani A (2019) Facial trauma: a retrospective study of 1262 patients. Ann Maxillofac Surg. 9(1):135–139. https://doi.org/10.4103/ams.ams_51_19