Traumatic brain injury in the intensive care unit

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TRAUMATIC BRAIN INJURY IN THE INTENSIVE CARE UNIT

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LIST OF ABBREVIATIONS

TBI- Traumatic Brain Injury

AIS- Abbreviated Injury Scale

GCS- Glasgow coma scale

ACh- Acetylcholine

IL- Interleukin

ICP-Intracranial pressure

APP- Amyloid precursor protein

DAI- Diffuse axonal injury

CT- Computed tomography

MRI- Magnetic resonance imaging

SPECT- Single-photon emission computed tomography

GFAP- Glial fibrillary acidic protein

NSE- Neuron-specific enolase

UCH-L1- Ubiquitin C-terminal hydrolase L1

S100B- Calcium-binding protein B

SIRS- Systemic inflammatory response

ARDS-Acute respiratory distress syndrome

MHC- Major histocompatibility complex

DAMPs- Damage-associated molecular patterns

TNF- Tumor necrosis factor

HMGB-1-High mobility group box 1

TGF ß - Transforming growth factor ß

CPP- Cerebral perfusion pressure

$AVDO_2$- Difference between arterial and arterio-jugular venous oxygen

$PbrO_2$- Brain oxygenation tissue

SjO2-Jugular venous oxygen saturation

FiO_2-Fraction of inspired oxygen

PEEP- Positive end-expiratory pressure

$BtpO_2$- Brain tissue oxygen partial pressure

1. INTRODUCTION

1.1. Traumatic Brain Injury (TBI)

Traumatic Brain Injury (TBI) is defined as damage to the brain resulting from an impact, penetration or rapid movement of the brain within the *cranium* that can lead to mild alterations of consciousness to life-threatening conditions such as coma and possibly death (1).

1.2. Epidemiology and Etiology

TBI is the leading cause of death in people under the age of 40, mainly occurring in young adults and with a high incidence in children under the age of 6, the least for people from the age of 40 to 60. TBI is noticed to occur more frequently in males by 2 times than in females, leading to higher mortality rates in males (2).

The incidence of TBI in Europe is 300 per 100.000 people per year. The rates are comparable throughout industrialized countries (3).

There are various mechanisms of how TBI occurs; the most common cause is falls, followed by motor vehicle accidents, assaults and, sports injuries. Likewise, in Croatia, the most common cause of TBI are falls, in second place motor vehicle accidents (2,3). Other causes of TBI are construction-related, industrial accidents, domestic violence as are firearms and blast injuries among military personnel in war zones (4-7). In children from the age of 2 to 4, the main cause of TBI is falls, while in older children the leading cause of TBI is traffic accidents, followed by bicycling accidents and child abuse (8,9).

1.2.1. Mortality

The mortality rate of TBI is 11.2 per 100.000 people per year, leading to 57 000 TBI related deaths per year in the European Union and 82 500 deaths in the whole of Europe. In Croatia, the mortality rate is 13.1 per 100.000 people per year. TBI should be considered a serious public health problem throughout Europe (3).

1.3. Classification

There are multiple classifications of TBI such as classification by severity, loss of consciousness, alteration of mental state, or location of the injury by structural imaging (10). The Abbreviated Injury Scale (AIS) and Glasgow Coma Scale (GCS) are two commonly used scales, which measure the mental and neurological status of the patient following TBI. Both AIS and GCS have scoring values, which reflect the status of the patient.

The GCS is based on three components: eye-opening, verbal response and motor response (Table 1). This produces a graded score further subdividing into the next categories such as mild injury (GCS 13 to 15), moderate injury (GCS = 9 to 12) and severe injury (GCS = 3 to 8) (11,12).

The AIS is a universal code of injury severity, it is expressed as follows 1 = minor; 2 = moderate; 3 = serious, not life-threatening; 4 = severe and life-threatening, 5 = critical, survival uncertain and 6 = fatal, not survivable (11) (Table 2).

Table 1. Glasgow Coma Scale (13).

	Score
Eye Opening	
Spontaneous	4
To speech	3
To pain	2
No response	1
Verbal response	
Oriented	5
Confused conversation	4
Inappropriate words	3
Incomprehensible sounds	2
No response	1
Motor response	
Obeys commands	6
Localizes pain	5
Withdrawal (normal flexion)	4
Abnormal flexion (decorticate)	3
Extension (decerebrate)	2
No response	1

Table 2. The Abbreviated Injury Scale (14).

AIS Value	Injury Description
0	No injury
1	Minor
2	Moderate
3	Serious, Not life-threatening
4	Severe, Life-threatening
5	Critical, Survival uncertain
6	Fatal, Not survivable

1.4. Neuropathology

Following a TBI, the neuropathology and the neural mechanisms in the brain change, both resulting from mechanical forces and pathophysiological changes, further leading to damages in the axons and eliciting both regenerative and degenerative tissue responses (15).

1.4.1. Biomechanical Mechanisms

Static and dynamic loading are two kinds of mechanical loadings that can produce TBI. Static loading occurs when compressive forces are applied gradually to the head, resulting in a squeezing injury, requiring more than 200 msec. However, the most common type of loading leading to TBI is dynamic loading. In this case, forces acting on the head require less than 20 msec. Dynamic loading can be further subdivided into impulsive and impact. Impulsive loading is described as the head being set in motion and abruptly stopped without it being directly impacted, for instance in a person being violently struck in the face, on the other hand, impact loading occurs when a moving head is impacted, for example against a windshield (16-18).

In addition, acceleration-deceleration can cause TBI and be further subdivided into translational acceleration, in which all brain particles move simultaneously in the same direction. Also divided into rotational acceleration, which leads to shear injury, in other words, diffuse axonal injury (16).

Further on, coup injuries occur when the head is accelerated, causing contusions beneath the site of impact, while countercoup is associated with deceleration, occurring most commonly in frontal and temporal lobes, by definition it is not a lesion that occurs under the point of impact (16,18).

Skull fractures depend on the surface the skull has struck whether it is a hard unyielding surface or soft yielding surface. For a hard unyielding surface, it takes 14-30 kg of energy surface or a fall from 2 meters to produce a fracture. In soft yielding surfaces, if a head strikes or is struck by a deformable object, not all energy possessed by the object or head will deform the skull, the energy will disperse over a considerable area rather than being localized, reducing the possibility of a skull fracture. Therefore, fractures can be further subdivided into linear fractures that are seen in low-velocity impacts with a large area of contact and stellate fractures that happen if the velocity and energy of impact increase. Basilar skull fractures are caused by diffuse impact to the vertex of the skull, hinge fractures are transverse fractures that bisect the base of the skull and ring fractures are circular fractures that surround the foramen magnum (19).

In conclusion, strain is the proximate cause of tissue injury and is divided into compression, tension and, shear. The brain has a low tolerance to tensile and shear strain, therefore they are the most often causes of brain damage (16,18).

1.4.2. Pathophysiology

Following a TBI, which leads to mechanical distortion of the brain and a developing series of cellular abnormalities, such as impairment of axonal transport, further setting off neurochemical and neurometabolic changes (1,20) (Figure 1).

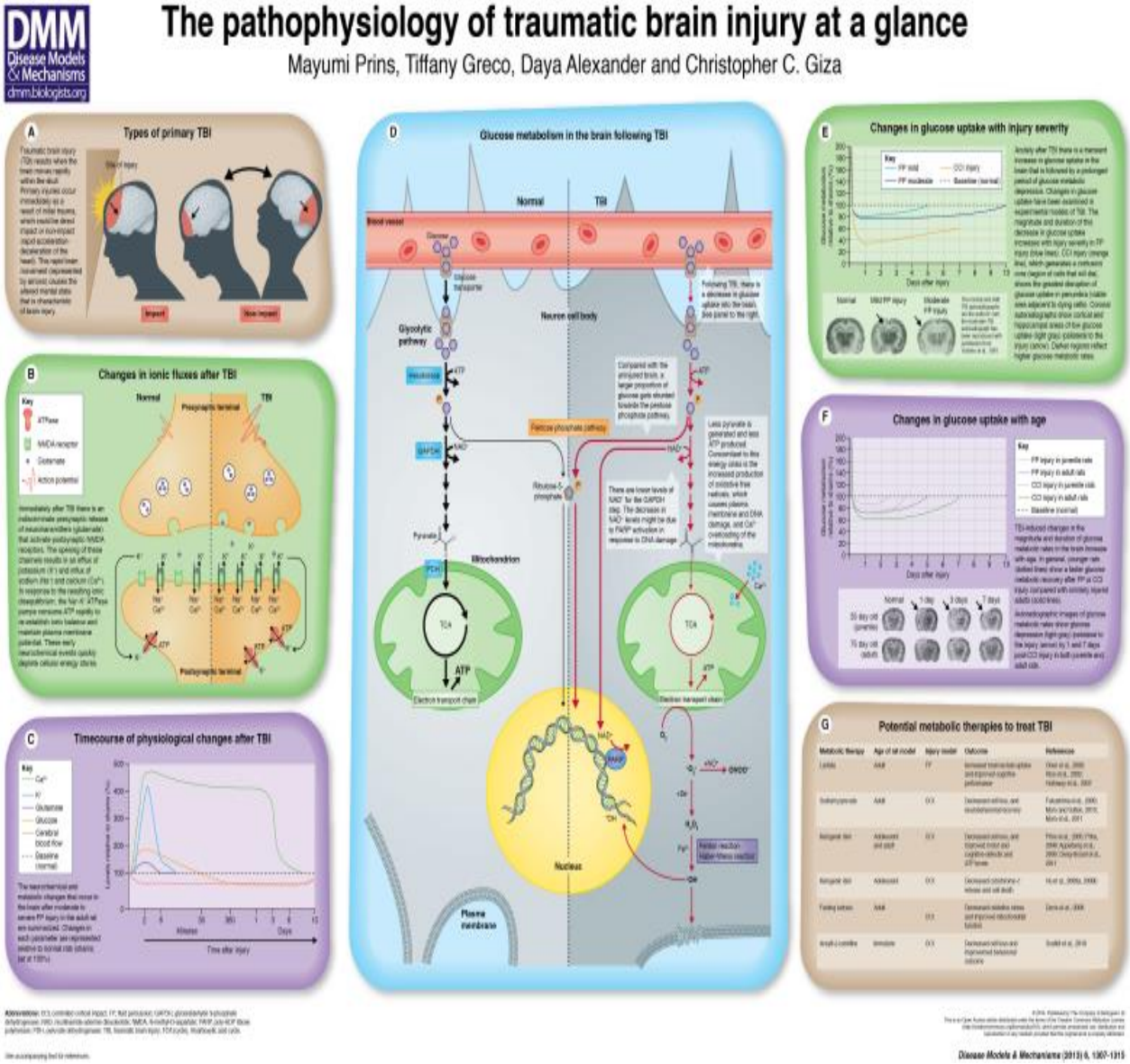

Figure1. The pathophysiology of traumatic brain injury (1).

1.4.2.1. Neurochemical and Neurometabolic changes

The cascade following a TBI permits the release of neurotransmitters leading to massive ion influx (Figure 2). After a TBI, the in the amount of acetylcholine (ACh) in the brain and cerebrospinal fluid increases, but there is decreased binding of ACh at cholinergic receptors, especially in the hippocampus (21).

In addition, alteration of resting cell membrane potential occurs, mediated by glutamate-dependent gates, causing depolarization, hyperglycolysis and, increased lactate levels, further on increasing the concentration of calcium, potassium and lowering the concentration of sodium and eventually leading to severe cell swelling, formation of calpain and excitotoxic

death, all leading to axonal death (22,23). While there is an intracellular increase in calcium, a compensatory alteration in magnesium within cells occurs, resulting in a decline (23,24).

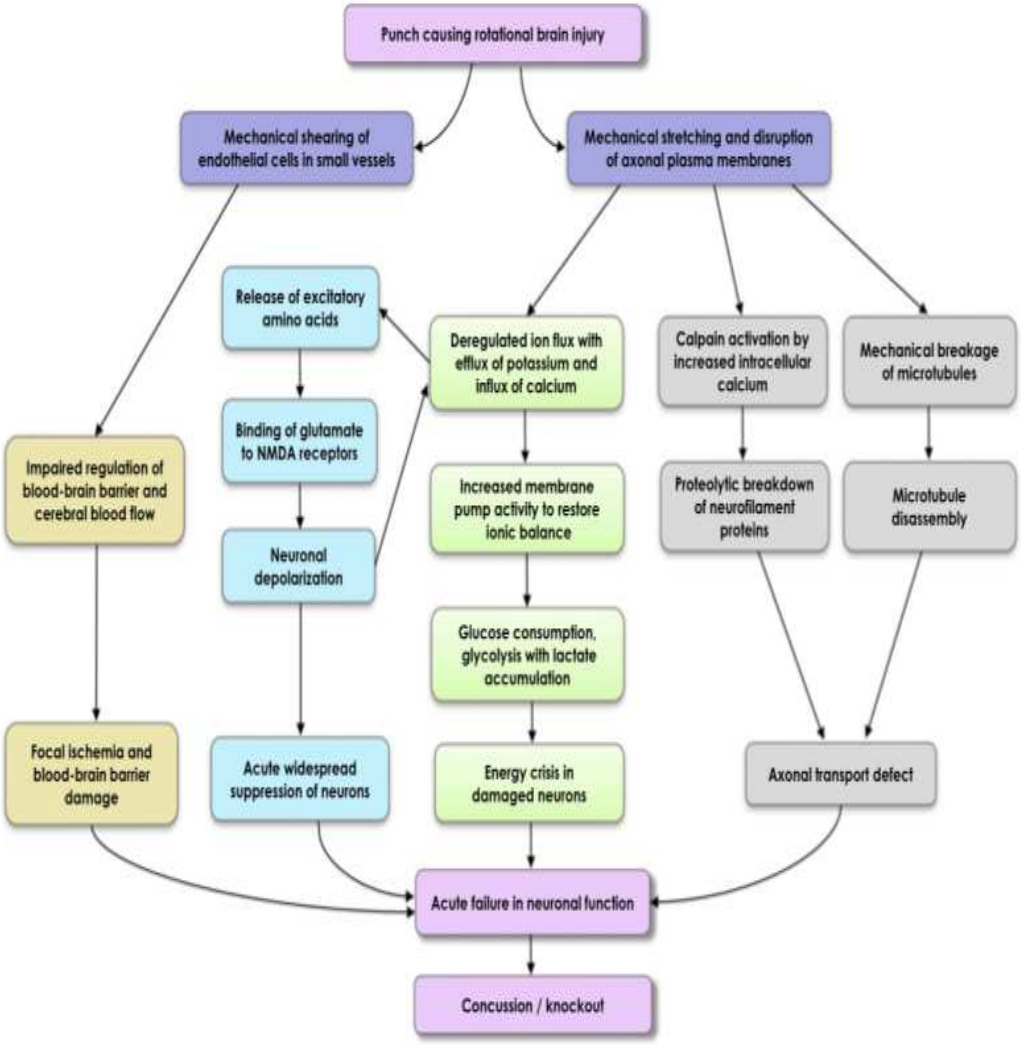

Figure 2. Molecular Pathophysiology of Concussion (15).

1.4.2.2. Free radicals, Inflammatory Changes and Apoptosis

The glutamate release and ionic influxes activate genes, oxygen radicals and the arachnoid acid cascade, which results in apoptosis and damage to neurovascular structures, having in mind the central nervous system is highly vulnerable to oxidative stress (23).

Within 24 hours, the activation of cellular mediators starts, including proinflammatory cytokines, prostaglandins and, the complement system. Tissue is infiltrated with macrophages and polymorphonuclear leukocytes, further on, proinflammatory enzymes such as tumor necrosis factor, interleukin (IL) 1-b and interleukin-6 are upregulated. The further release of

prostaglandins and lack of nitric oxide causes vasoconstriction, edema formation and, reduced tissue perfusion (25).

1.4.2.3. Secondary Injury

The main task in the Intensive Care Unit is to prevent and minimize secondary injuries. Secondary injuries are indirect results of the injury and if not treated they can lead to severe damage and death. Most often, edema of the brain, herniation, ischemia and elevated intracranial pressure (ICP) occur (26). Edema occurs in association with head injuries, it may be localized or generalized and it is thought to occur due to the increase in intracranial pressure (ICP), blood flow and water content. Three types of brain swellings can be differentiated, swelling adjacent to contusions, diffuse swelling of one cerebral hemisphere and diffuse swelling of both hemispheres. Herniation occurs when hematomas continue to enlarge, or focal swelling of the brain tissue increases, the brain is shifted away and may be displaced. When herniation occurs the brain can shift across structures as the *falx cerebri, tentorium cerebelli and, foramen magnum*. Herniations can be classified as supratentorial and infratentorial herniations. Further on, supratentorial herniation can be classified as uncal, central, cingulate, transcalvarial and tectal, while infratentorial herniation can be classified with upward and tonsillar. The herniation can result in pupil and gaze abnormalities and can even cause cardiorespiratory arrest. ICP is the pressure within the skull, brain and, cerebrospinal fluid, it is normally 7-15 mmHg, the upper value being 20 mmHg. In patients with TBI, the ICP is increased (above 20-25 mmHg) and at this point, it is called intracranial hypertension (16). The pathophysiology of the injuries is previously described.

1.4.2.4. Late Neurodegenerative Changes

Survivors of TBI develop late neurodegenerative disorders. TBI is a risk factor for developing Alzheimer's, although the exact mechanism is not known, there is an increased deposition of the amyloid beta-peptide after TBI and an increased expression of amyloid precursor protein (APP), leading to decreased cholinergic binding, particularly in the hippocampus (Figure 3). In addition, the presence of apolipoprotein E4 allele, with a history of TBI increases the risk of Alzheimer's like neurodegeneration. Neurofibrillary tangles also have an impact in forming Alzheimer's like neurodegeneration, with the tau tangles causing disassembly of microtubules and leading to axonal degeneration (15,18,27).

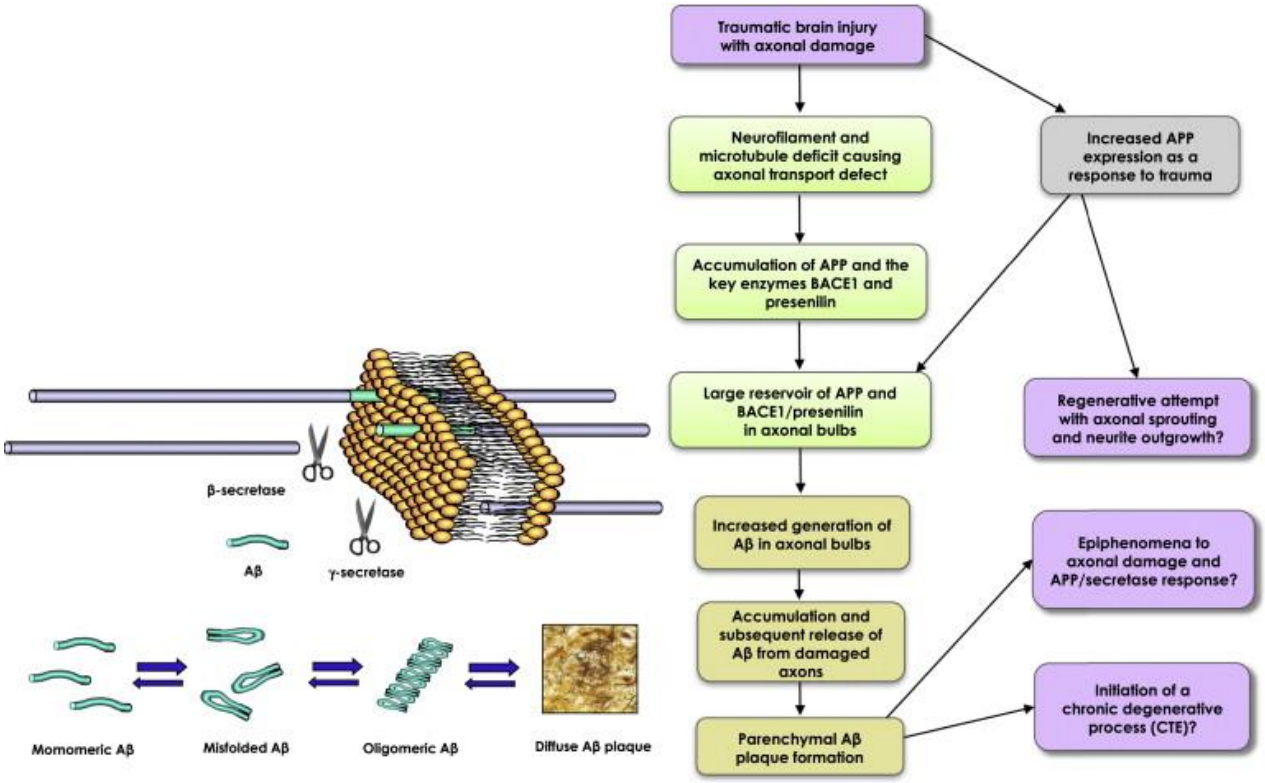

Figure 3. Neurochemical Pathophysiology of APP an amyloid beta peptide in TBI (15).

1.5. Types of Injuries

Classification of injury processes that occur in TBI, in other ways, known as primary injuries, are the results of mechanical forces producing tissue deformation at the time of the injury (16).

1.5.1. Skull Fracture

Many patients with a skull fracture will not have any brain injury, they are more likely to develop subarachnoid, subdural or epidural hemorrhage. In the case of basal skull fracture, rhinorrhea or otorrhea are likely to occur. Formerly mentioned basal skull fractures can be divided into linear and depressed skull fractures. Linear fracture having fewer complications and being much easier to treat, while depressed skull fracture causing downward displacement on bone and can often have complications, such as lacerations and hemorrhages (16,18,28).

1.5.2. Focal Brain Damage

Focal brain injuries are contusions, which occur at locations by contact of brain tissue and irregular bony protuberance, most often being the frontal and temporal lobe. Contusion results from damage to small blood vessels that produce small hemorrhages, which may extend into *gyri* and white matter causing degeneration and scarring. In addition to contusions, focal injuries include lacerations, which are physical disruptions of the brain parenchyma and may occur in combination with a contusion (16,18).

Hematomas and hemorrhages occur frequently, resulting from blood vessel tears. They can produce deteriorating levels of consciousness if occurring fast and may produce a life-threatening situation. Epidural hematoma is most common in the temporal region with eighty-five percent of the cases demonstrating a concurrent skull fracture (16,18). Subdural hematomas are induced by a rupture of the bridging veins, also known in having higher mortality because blood spreads throughout the subdural space covering the entire hemisphere. Subarachnoid hemorrhage is the most common type of vascular injury following head trauma, usually followed by ischemic symptoms.

Intraventricular hemorrhages occur within the ventricles, while intraparenchymal hemorrhages occur by rupture of internal blood vessels within the brain, most commonly in the frontal and temporal lobes, commonly seen 48 h until after the injury (18,29).

1.5.3. Diffuse Brain Damage

Diffuse Axonal Injury (DAI) occurs with acceleration-deceleration injuries and is characterized by focal lesions in the *corpus callosum*, rostral brainstem, hematomas in the basal ganglia and microscopic damage to axons. Further on, ischemic brain injury occurs very soon after TBI, the pathogenesis can be of varying reasons, hypoxic episodes, reduced perfusion, high ICP, arterial spasm, loss of autoregulation and much more. Lastly, brain edema occurs to be localized or generalized and results in a combination of increased water content and blood volume. Brain edema may occur adjacent to contusion, in one cerebral hemisphere or both hemispheres (29).

1.6. Diagnostics

Computed tomography (CT) remains the primary method for evaluating closed-head injuries and is used in acute settings. CT provides images of soft tissues, as well as the bony *calvaria*. Indications for CT in patients who sustained head trauma are: GCS less than 15, a penetrating injury, clinical signs of basilar of depressed skull fracture, anisocoria or fixed dilated pupils, cranial nerve deficit, neurological deficit, abnormal Babinski sign, known bleeding disorder, loss of consciousness for more than 5 minutes and anterograde amnesia. Patients can be further separated into three categories, those with normal intracranial structures, those with focal intra-axial or extra-axial hematomas and those with a diffuse pattern of injury (18,23) (Figure 4).

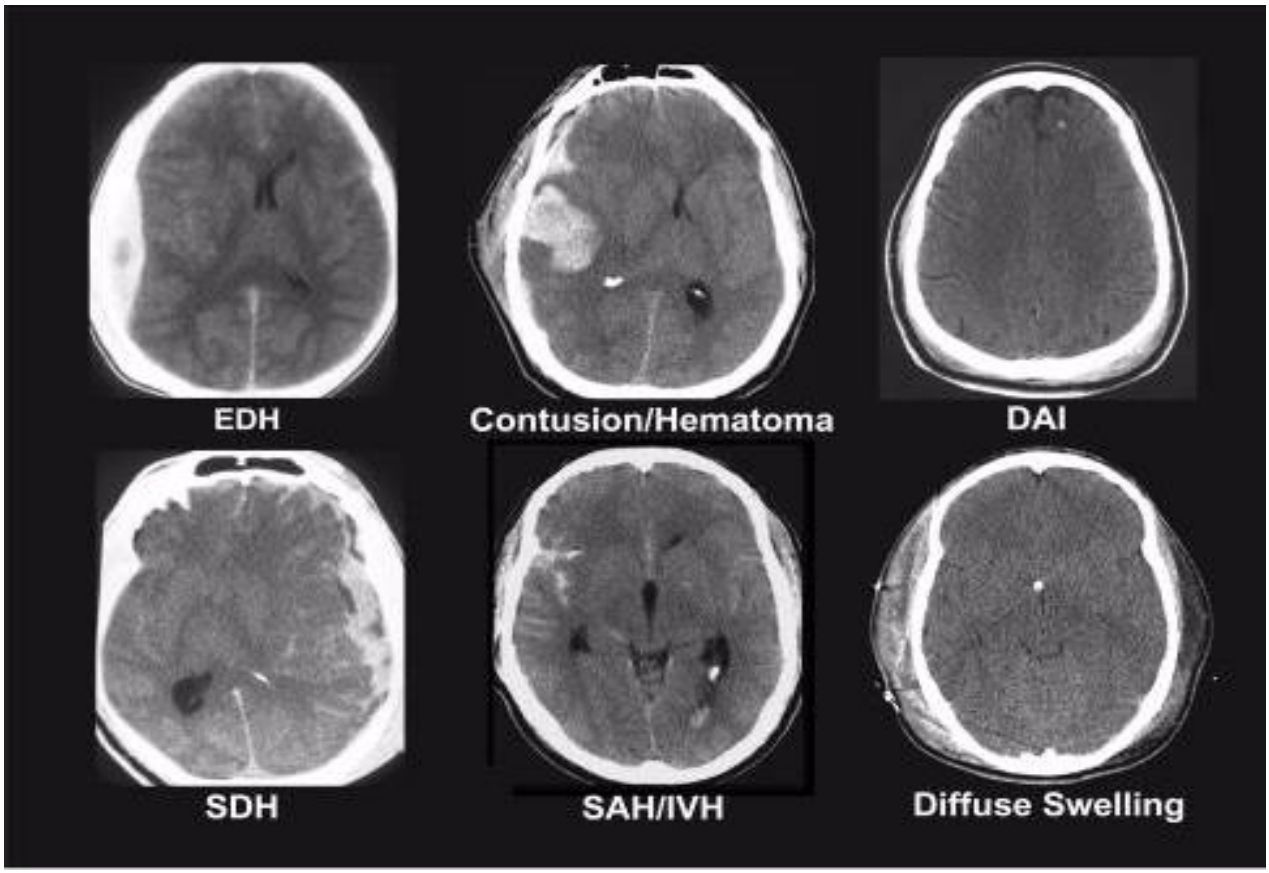

Figure 4. Heterogeneity of severe traumatic brain injury. CT scans represent patients with epidural hematomas (EDH), contusions and parenchymal hematomas (Contusion/Hematoma), diffuse axonal injury (DAI), subdural hematoma (SDH), subarachnoid hemorrhage and intraventricular hemorrhage (SAH/IVH), and diffuse brain swelling (Diffuse Swelling) (30)

In general, the diagnosis of TBI relies on a clinician to interpret the patient's signs and symptoms of the injury, GCS is one of the most important entry criterion assessment tools for the injury magnitude.

Further evaluation, but less so, can be done with magnetic resonance imaging (MRI) and its newer techniques such as functional magnetic resonance, magnetic resonance spectroscopy, T2 flair, electroencephalography, CT, single-photon emission computed tomography (SPECT), positron emission tomography (PET) and a combination of PET/MRI. Biomarker identification could provide an objective tool in the future to measure the injury magnitude, it has not been established yet for TBI in routine clinical practice. A number of proteins have been proposed as potential TBI biomarker candidates such as calcium-binding protein B (S100B), glial fibrillary acidic protein (GFAP), hyperphosphorylated neurofilament, (ubiquitin C-terminal hydrolase L1) UCH-L1 and neuron-specific enolase (NSE), which are all found to be increased in TBI and found in serum or cerebrospinal fluid (31,32).

1.7. Complications of TBI

Eighty-five percent of patients with TBI can exhibit organ dysfunction (Figure 5); cardiorespiratory complications are common, resulting from a high ICP, which stimulates trigger zones such as the nuclei of the solitary tract, increasing catecholamine excess, causing autonomic dysfunction and inflammatory response. Seventy-five percent of patients will have transient electrocardiography changes such as sinus tachycardia, electrocardiographic signs of ischemia and repolarization abnormalities such as pathological T waves, QT prolongation and, U waves. By lowering the ICP, cardiac dysfunction will be resolved.

Respiratory complications following TBI may occur, such as apnea and respiratory failure that can occur from neurogenic pulmonary edema, aspiration pneumonitis, lower respiratory tract infections, systemic inflammatory response (SIRS)/sepsis with acute respiratory distress syndrome (ARDS). However, only twenty percent of patients will develop neurogenic pulmonary edema. There are four mechanisms in developing neurogenic pulmonary edema, the first one being neurocardiac, resulting in a catecholamine excess, myocyte ischemia, cardiac dysfunction and, an elevated pulmonary artery occlusion pressure leading to cardiogenic pulmonary edema. The second mechanism being neuro-hemodynamic, resulting in increased hydrostatic pressure, reduced aortic compliance, increased sympathetic outflow and left ventricular failure.

Immunological complications are very complex, glial cells alter major histocompatibility complex (MHC) gene expression and T-cell response, further on activating cytokines, chemokines, damage-associated molecular patterns (DAMPs) and alter the extracellular potassium and calcium concentrations. This leads to the release of proinflammatory cytokines IL-1B, IL-6 and tumor necrosis factor (TNF-α).They exert their effects locally through phagocytosis, leukocyte activation, glutamate and proteolytic enzyme release disrupting of the blood-brain barrier. Expression of the counter-inflammatory mediators, such as IL-4, IL-10 and transforming growth factor ß (TGF-ß) leads to susceptibility to nosocomial infections. DAMPs such as heat shock protein and high mobility group (HMGB-1) alter adaptive and innate immunity.

Hematological complications are divided into a hypocoagulable state caused by astrocytes releasing tissue factor, depleting the procoagulant factors, further leading to a hypocoagulable state and in extreme cases to disseminated intravascular coagulation. In addition, endothelial activation and activated protein C play a role in fibrinolysis and anticoagulation. Following their activation, a hypercoagulable state occurs and is related to SIRS, clot propagation/termination imbalance and increased platelet activity.

Hypothalamic-pituitary-adrenal dysfunction can occur due to primary or secondary injuries. Most commonly there is a decrease in the thyroid-stimulating hormone, total triiodothyronine, free tetraiodothyronine, cortisol, growth hormone and, gonadotropin hormone. One of the most significant endocrine disorders following TBI is the syndrome of inappropriate antidiuretic hormone secretion, including cranial diabetes insipidus and cerebral salt wasting.

Another complication that develops is gastric ulceration, it is related to an increase in the vagal tone and an increased catabolic state occurring because of the stress response in the body following TBI. Seventeen percent of ulcers will develop significant bleeding and are associated with increased mortality (33).

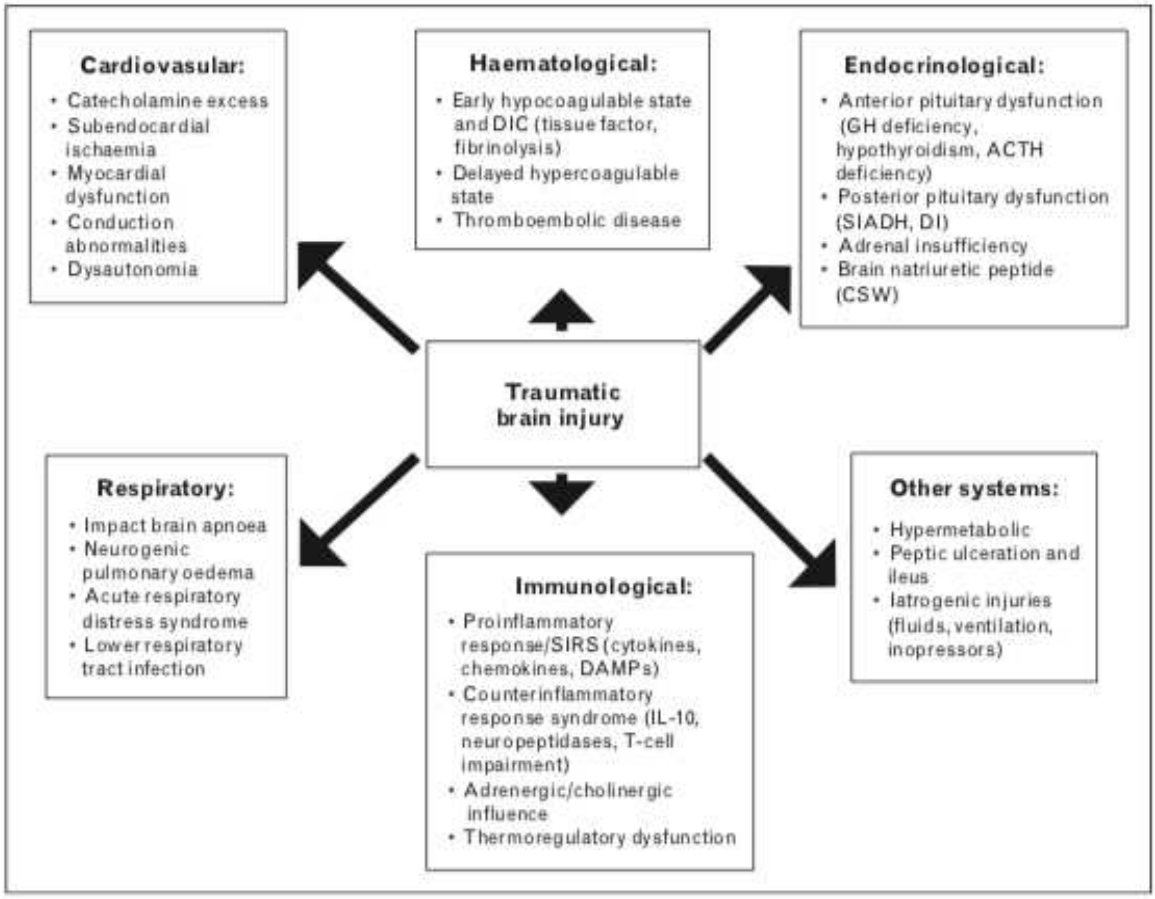

Figure 5. Systemic complications of traumatic brain injury (31)

Short-term complications can develop such as cognitive disabilities, memory loss being the most common, post-traumatic amnesia, post-traumatic seizures, hydrocephalus, vascular or cranial nerve injuries and communication problems such as aphasia and dysarthria.

Psychiatric complications can occur following a TBI, such as depression, bipolar disorder, generalized anxiety disorder, obsessive-compulsive disorder, posttraumatic stress disorder, substance abuse, schizophrenia, mania and, dysthymia (34).

Finally, but importantly, long term complications can occur following a TBI such as Alzheimer's, Parkinson's disease, posttraumatic epilepsy and, dementia pugilistica also know as chronic traumatic encephalopathy, all previously described (18,28).

1.8. Monitoring and Thresholds

The primary goal of monitoring is to prevent secondary brain injury, such as ischemia, which usually has a poor outcome. By measuring the ICP, which is the cornerstone in monitoring TBI, and cerebral perfusion pressure (CPP), patients show lower in-hospital mortality rates. The CPP is defined as the difference between mean arterial pressure and the ICP. It represents the pressure gradient driving the cerebral blood flow and hence oxygen and metabolite delivery. Following TBI, the brain becomes susceptible to changes in blood pressure.

Advanced cerebral monitoring includes: transcranial Doppler, the difference between arterial and arterio-jugular venous oxygen ($AVDO_2$) and measurements of local tissue oxygen, additional monitoring includes microdialysis measuring the brains metabolism and electroencephalography.

The threshold for maintaining ICP levels is 22 mmHg; above this level, a high mortality rate is noticed. The preferred threshold for systolic blood pressure is 110 mmHg for patients 15 to 49 and over 70 years old, while for patient's 50 to 69 years old the threshold is 100 mmHg**.** The CPP threshold is 70 mmHg; under this, level a high incidence in hypoxia is noticed, and above this level high, levels of ARDS were noticed, mortality increased as well. Brain oxygenation tissue ($PbrO_2$) threshold is 29-50 mmHg, anything lower is associated with higher mortality. The jugular venous oxygen saturation (SjO_2) threshold is 50-75% (35-37).

1.9. Treatment

The treatment for TBI varies extensively based on the severity of the injury, it usually consists of surgical therapy and conservative intensive medical care. Guidelines have been set for optimal management of TBI. The current guidelines can be found on the internet, easily accessible and are from 2016. They can be found under "Guidelines for the Management of Severe Traumatic Brain Injury, 4 edition" by the Brain Trauma Foundation.

The current guidelines used suggest head elevation, brief periods of hyperventilation and hyperosmolar treatment, which all lower ICP. Ventilation in patients with TBI aims to maintain a normal range of $PaCO_2$ within a range of 34-38 mmHg, hypoventilation should be avoided because it may lead to cerebral hyperemia and high ICP, while hyperventilation can lead to tissue hypoxia.

A brief period of hyperventilation is still acceptable according to the Brain Trauma Foundation guidelines. The fraction of inspired oxygen (FiO_2) on the ventilator should be adjusted to ~90 mmHg, higher levels should be avoided considering the risk of hyperoxic cerebral vasoconstriction and lung injury. Tidal volume in current practice is set to be around 6 - 8ml/kg and the positive end-expiratory pressure (PEEP) of 5-10 cm H_2O should be administered to prevent atelectasis. The assisted ventilator rate should be 12 breaths per minute, a breath for every 5 seconds. Early tracheostomy is associated with a reduction in the ventilation days; late tracheostomy is performed after respiratory complications after extubation (38).

Hyperosmolar therapy such as hypertonic saline and mannitol are important for lowering ICP. Mannitol 0.25-1 g/kg is effective and hypotension should be avoided. Hypertonic saline is preferred, in doses of 3-5 cc/kg because ICP reduction was significantly higher compared to those treated with mannitol.

Further on, early seizures are classified when they occur within 7 days of the injury, while late seizures occur after 7 days of the injury. Early seizure prophylaxis with phenytoin and levetiracetam help to prevent early seizures. Phenobarbital, valproate and, carbamazepine previously used, show to have a lot of adverse effects, making phenytoin the desired drug. The newer drug levetiracetam can be used as an alternative to phenytoin. The dose of phenytoin is 17 mg/kg intravenously, followed by a maintenance dose of 100 mg three times a day. While a dose of levetiracetam is 20 mg/kg intravenously with a maintenance dose of 1000 mg every 12 h. Unfortunately, late seizures can not be prevented with the same treatment mentioned (39).

In some cases, the patient is put in the state of so-called "induced" or barbiturate coma. A barbiturate coma decreases the metabolic need of the brain by decreasing cerebral blood flow, ICP and, even mortality. Lower doses of barbiturates are used for sedation, while higher doses >2g/24h are used for barbiturate coma. Thiopental, midazolam, propofol, barbiturates and, narcotics such as fentanyl and morphine can be used for sedation of patients. Propofol has been associated with serious adverse effects leading to propofol related infusion syndrome. This condition is characterized by the development of lactic acidosis, acute renal failure, hyperkalemia, rhabdomyolysis, bradyarrhythmia and acute cardiac failure hence leading to death. Barbiturates may cause hemodynamic instability by causing myocardial depression, peripheral venous pooling with decreased venous return, left ventricular diastolic filling and decreased stroke volume and a decrease in the sympathetic nervous system (37,40-42).

With hypothermia, there is a decrease in ICP and oxidative injury, but a higher risk of complications exists such as alterations in coagulation and platelet factors, pulmonary complications and higher mortality; therefore, it is not recommended.

If fluids are needed, saline is the most common crystalloid used, with Ringer's lactate being an alternative. To reduce the edema hypertonic saline has been preferred over mannitol, as already mentioned. Hypertonic saline acts faster, has anti-inflammatory effects, decreases neuronal damage and improves tissue oxygenation. In contrast, isotonic fluids in trauma require high volume, which can lead to raised ICP, requiring careful dosing (37,43).

Steroid treatment has not shown a favorable impact on mortality or the outcome. Early feeding is recommended, it decreases the complication rates such as glucose misbalance and pneumonia. In addition, glucose should be closely monitored, as TBI leads to hyperglycemia due to the cortisol and catecholamine surge.

Infection prophylaxis decreases the infection rates, pneumonia development and, further complications, while deep venous thrombosis prophylaxis decreases developing thromboembolism but carries a higher risk in developing hemorrhage. Pharmacological thromboprophylaxis is usually initiated 48-72 hours after neurosurgical interventions and in absence of other contraindications, mechanical prophylaxis can be included, or a combination of both.

Additional care such as peptic ulcer prophylaxis, physiotherapy and, full hygienic care is extremely important in TBI patients.

Ventricular drainage coupled to an ICP monitor is the external ventricular drainage and is the gold standard of measuring ICP in patients with TBI. When the drainage system is placed it allows monitoring of the ICP and in the same manner, drainage of the excess CSF. There are two types of drainage systems, the open external ventricular drains with continuous drainage of cerebrospinal fluid and a closed external ventricular drain with intermittent drainage. The open external ventricular drain seems to have lower mortality rates. The advantage of a closed external ventricular drain is the real-time measurement of ICP, while the advantage of an open external ventricular drainage approach carries the advantage of tighter ICP control (37,44).

Apart from so-called conservative intensive medical care, the most common type of treatment in TBI patients is surgical intervention. The procedures that can be done are trepanning and placement of the ICP monitors and drains, craniotomy and decompressive craniectomy. Trepanning is a surgical intervention in which a burr hole is drilled into the skull and placement of ICP monitor and drains follows. A craniotomy is a procedure in which a

bone flap is temporarily removed and the hematoma is drained, the bone flap is then replaced after the surgery has been completed. In decompressive craniectomy a large section of the skull is removed allowing the edematous brain to expand, thus reducing ICP. The increased size of a craniectomy shows better neurological outcomes and lower mortality (37,45).

2. OBJECTIVES

Hypothesis:

1. High mortality can be observed in TBI, due to the complexity of the injury.
2. The GCS on admittance is an important prognostic factor of recovery, as low GCS will result high mortality.
3. Due to the nature of the injury, TBI leads to increased length of stay in the Department and long duration of mechanical ventilation is expected.

The purpose of the study is to compare the following parameters in TBI:

- Distribution throughout genders
- Mechanism of TBI
- Admittance and discharge from the Department of Anesthesiology and Intensive Care
- Admittance and discharge from the Department of Neurosurgery
- The GCS at admittance and discharge
- Duration of mechanical ventilation
- Types of TBI
- Treatment of TBI
- The mortality of TBI amongst patients

3. MATERIALS AND METHODS

3.1. Study Design

The study was conducted as a retrospective study.

3.2. Study Population

In this study 131 TBI patients were included, they were treated in the Department of Anesthesiology and Intensive Care and in the Department of Neurosurgery, University Hospital Split, during the 2-year period from January 2017 to end of December 2018. During the 2-year period, there were 670 neurosurgical patients admitted to the Department of Anesthesiology and Intensive Care.

Inclusion criteria:

1. Patients being above 18 years' old
2. Specifically, TBI.

Exclusion criteria:

1. Patients under the age of 18 years' old
2. Patients with stroke and, spontaneous hemorrhages.

3.3. Methods of Collecting and Analyzing Data

The study material was collected at the Department of Anesthesiology and Intensive Care and the Department of Neurosurgery, location Firule.

Gathering the materials from both of the departments' computer databases and archives the patients and the medical histories were reviewed and inserted in the Microsoft Excel program.

3.3.1. Primary Outcomes

The primary outcomes were the mortality of TBI amongst patients, the GCS on admittance and discharge, the duration of stay at Departments and, duration of ventilation.

3.3.2. Secondary Outcomes

The secondary outcomes were mechanisms, types of TBI and treatments.

3.4. Statistical Analysis

By using the medical history and discharge papers of the patients, the parameters needed were analyzed and shown in figures and tables. Microsoft Excel and Microsoft Word were used to make the tables and figures.

4. RESULTS

In 2017 out of 60 patients, TBI occurred in 44 male patients (73.3%) and 16 female patients (26.7%). During 2018, TBI occurred in 71 patients, out of them, 51 male patients (71.8%) and 20 female patients (28.2%).

In the two years followed there was a total of 131 patients, 95 of the patients were males (72.5%) and 36 of them were females (27.5%) (Table 3).

Table 3. Distribution of TBI in genders in the University Hospital Split

	Males (%)	**Females (%)**	**Total (%)**
2017	44 (73.3)	16 (26.7)	60 (45.8)
2018	51 (71.8)	20 (28.2)	71 (54.2)
Total	95 (72.5)	36 (27.5)	131 (100)

The most common event leading to TBI is falls. In 74 patients (57%), the causes of falls were work-related, alcohol intoxication and instability within elderly people. The second most common reason for TBI was car and motorcycle accidents with 29 patients (22%).

Other causes were pedestrian accidents (8%), being struck against an object or by an object (5%), bicycle accidents (2%), suicide attempts (2%) and other transportation accidents (1%). In some patients we did not know the exact cause, they were found lying on the ground (2%) (Figure 6).

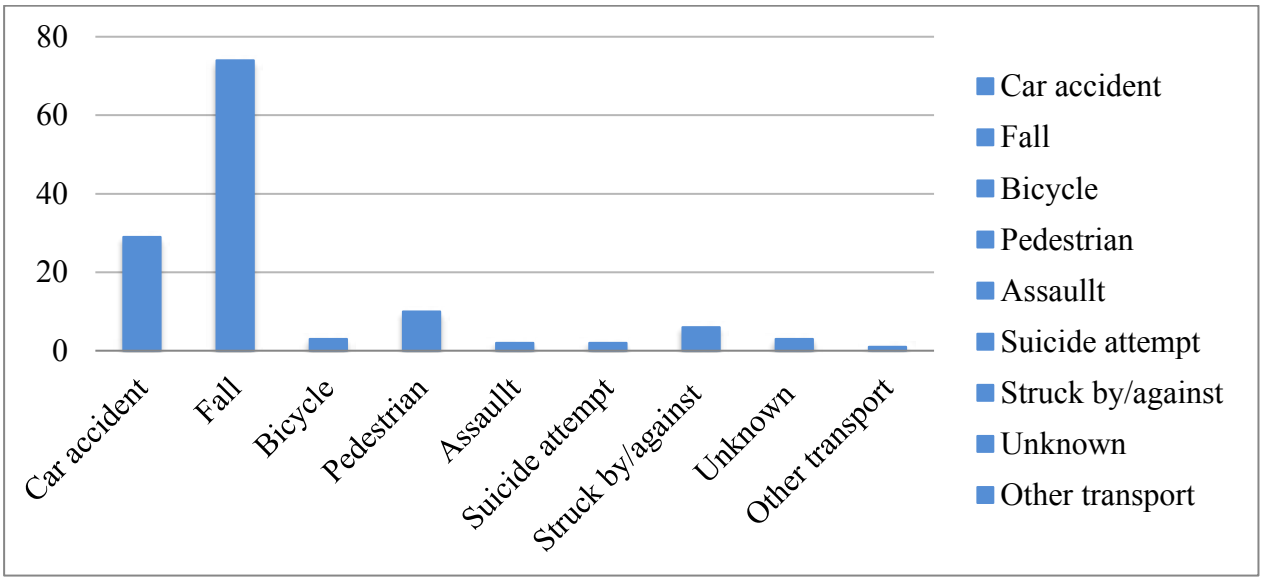

Figure 6. Distribution of causes leading to TBI in the Department of Anesthesiology and Intensive Care and the Department of Neurosurgery in University Hospital Split 2017 and 2018

The admittance and discharge from the Department of Anesthesiology and Intensive Care were measured as the length of stay in the Department, it was followed for 2017 and 2018.

More than half of the patients from 2017 and 2018 spent from 1 to 10 days in the Department of Anesthesiology and Intensive Care, which being 74 patients (56.5%) (Figure 7).

The Department had 60 TBI patients during 2017, in 2018 the department had 71 TBI patients, the median duration of stay was 9 days for both years (Table 4).

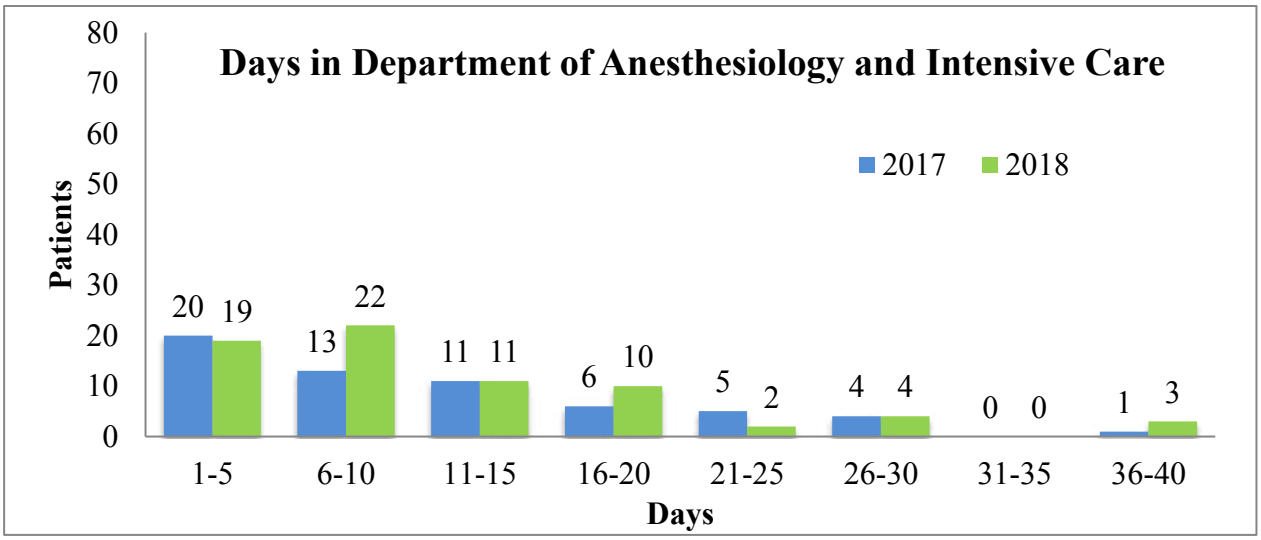

Figure 7. The admittance and discharge from the Department of Anesthesiology and Intensive Care in University Hospital Split 2017 and 2018

Table 4. Statistics for admittance and discharge at the Department of Anesthesiology and Intensive Care

	2017	**2018**	**Total**
Median	9	9	9
No. of patients	60	71	131

Some patients from the Department of Anesthesiology and Intensive care were transferred to the Department of Neurosurgery and followed from there.

The Department of Neurosurgery had 49 TBI patients in 2017, in 2018 47 TBI patients. More than half of the patients, 79 patients (82.3%) spent from 1 to 30 days at the Department of Neurosurgery (Figure 8). The median duration of stay was 18 days, for both years (Table 5).

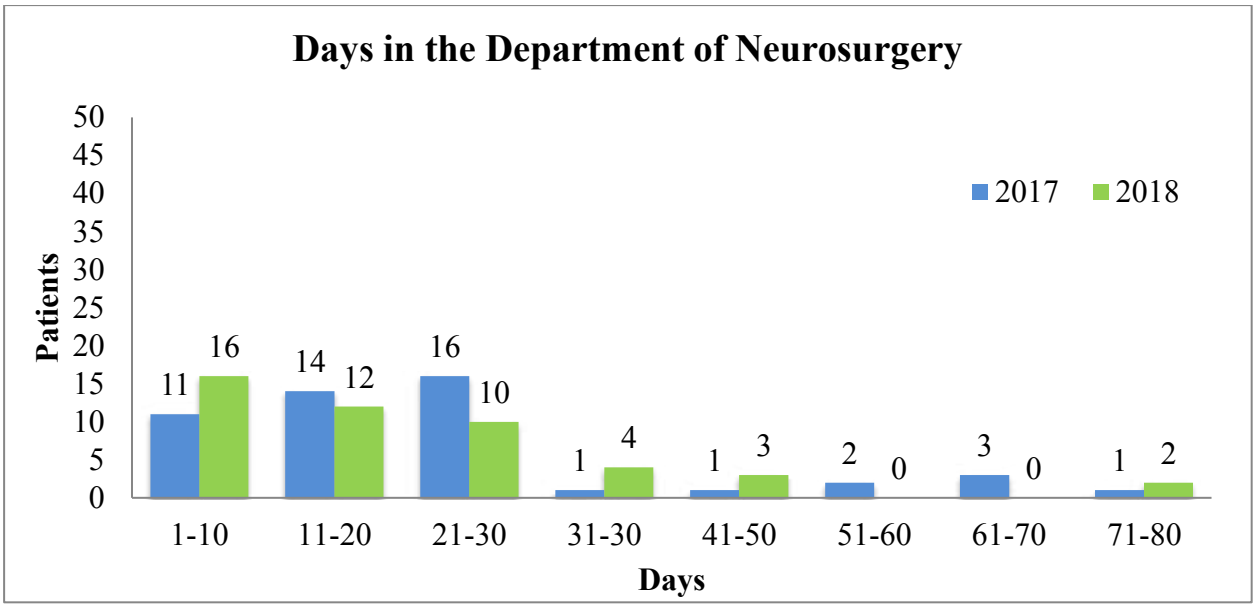

Figure 8. The admittance and discharge from the Department of Neurosurgery in University Hospital Split 2017 and 2018

Table 5. Statistics for admittance and discharge at the Department of Neurosurgery

	2017	**2018**	**Total**
Median	20	16	18
No. of patients	49	47	96

From both years, 87 patient GCS scores on admission were collected. On admission 21 patients (24.1%) presented with a GCS score of 3, while sharing second place, 10 patients (11.5%) presented with a GCS score of 6 and 10 patients (11.5%) presented with a GCS score of 15 (Figure 9).

Out of the collected GCS scores, 27 patients died (31%). Of those 27 patients that died, half (48.2%) presented with a GCS score of 3 (Figure 10).

From the 21 patients with a GCS score of 3 more than half died (61.9%).

The GCS score on discharge from both years was collected from 74 patients, with 19 of the patients (25.7%) having a GCS of 3 while the second most common GCS score was 15 with 18 patients (24.3%) (Figure 11).

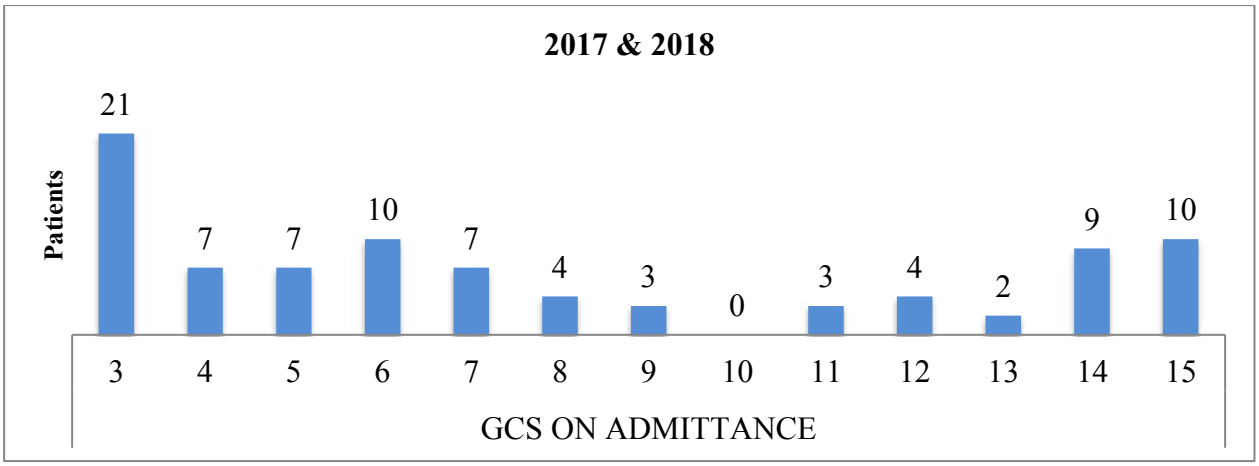

Figure 9. GCS on admittance in University Hospital Split 2017 and 2018

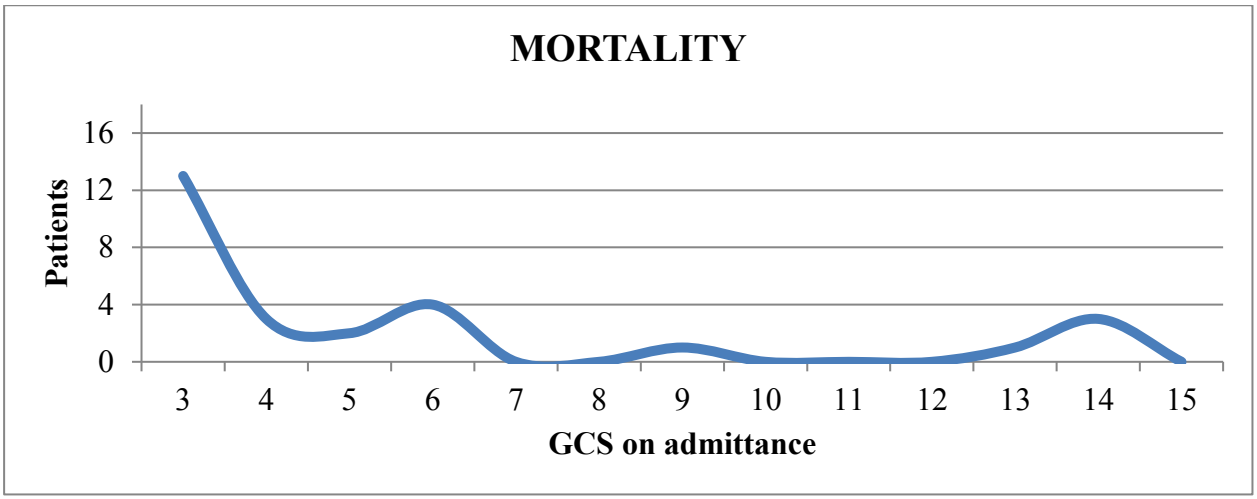

Figure 10. Mortality according to GCS scores on admittance in University Hospital Split 2017 and 2018

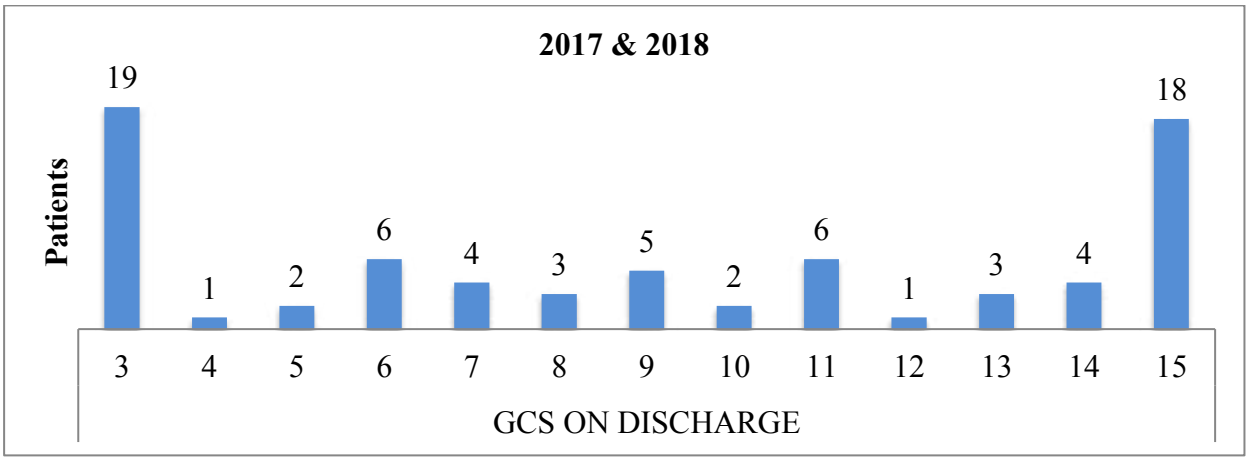

Figure 11. GCS on discharge in University Hospital Split 2017 and 2018

Mechanical ventilation following TBI was required at some point throughout the course of treatment for 130 patients (99.2%), with one patient not requiring it (0.8%).

The median of mechanical ventilation was 7 days, for both the years 2017 and 2018 (Table 6).

In total 51 patients (38.9%) were on mechanical ventilation from 1 to 5 days (Figure 12).

Table 6. Statistics regarding the duration of mechanical ventilation (days)

	2017	**2018**	**Total**
Median	7	8	7
No. of patients	59	71	130

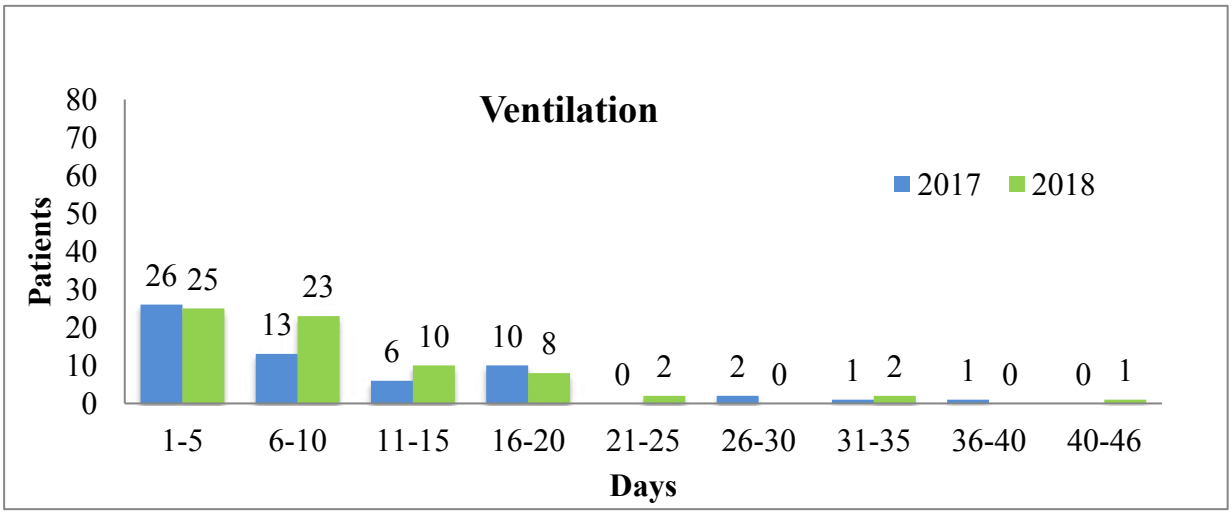

Figure 12. Duration of mechanical ventilation during the stay at the Department of Anesthesiology and Intensive Care and Neurosurgery in University Hospital Split 2017 and 2018.

The most common brain injury within TBI patients was subarachnoid hemorrhage with 93 patients (71%) out of a total of 131 patients from both years. In the second place, subdural hemorrhage with 77 patients (58.8%). From the total amount of patients half of the patients presented with neurocranial fractures (50.4%) (Table 7). Some patients had multiple focal brain injuries.

On admission 34 patients (26%) presented with edema (Table 8).

Out of the total amount of patients 38 patients (29%) did not require surgery and were treated by conservative management, 93 patients (71%) required surgical treatment (Table 9).

Table 7. Distribution of focal injury in patients

Focal brain injury	N. of patients in 2017 (%)	N. of patients in 2018 (%)	Total N. of patients in 2017 & 2018 (%)
Subarachnoid hemorrhage	40 (66.7)	53 (74.7)	93 (71)
Subdural hemorrhage	36 (60)	41 (57.8)	77 (58.8)
Epidural hemorrhage	15 (25)	15 (21.1)	30 (22.9)
Intracerebral hemorrhage	13 (21.7)	7 (9.8)	20 (15.3)
Intraventricular hemorrhage	8 (13.3)	4 (5.6)	12 (9.2)
Intrapontine/intracerebellar hemorrhage	1 (1.7)	1 (1.4)	2 (1.5)
Contusion	18 (30)	39 (55)	57 (43.5)
Concussion	1 (1.7)	3 (4.2)	4 (3.1)
Neurocranial fracture	29 (48.3)	37 (52.1)	66 (50.4)
Total	60	71	131

Table 8. Distribution of diffuse brain injury in patients

Diffuse brain injury	N. of patients in 2017 (%)	N. of patients in 2018 (%)	N. of patients in 2017 & 2018
Diffuse axonal injury	6 (10)	4 (5.6)	10 (7.6)
Edema	13 (21.7)	21 (29.6)	34 (26)
Total	60	71	131

Table 9. Treatments in patients

Type of treatment	N. of patients in 2017 (%)	N. of patients in 2018 (%)	N. of patients in 2017 & 2018 (%)
Craniotomy	28 (46.7)	33 (46.5)	61 (46.6)
Craniectomy	6 (10)	4 (56.3)	10 (7.6)
Other operation	6 (10)	16 (22.5)	22 (16.8)
Total operated	40 (66.7)	53 (74.7)	93 (71)
Nonoperated	20 (33.3)	18 (25.4)	38 (29)
Total	60	71	131

In total 131 patients suffered a TBI, out of which 39 patients (29.8%) died.

The mortality rate was lower in 2017 with 16 patients (26.7%) that died out of overall 60 patients admitted to the hospital for TBI. While in 2018 out of 71 patients, 23 died (32.4%), having in mind that 2018 had more patients (Table 10).

The mortality in both years was higher in male gender (71.8%), while it is much lower in women (28.2%) (Table 11).

Table 10. Mortality in TBI patients

	N. of patients in 2017 (%)	**N. of patients in 2018 (%)**	**N. of patients in 2017 & 2018 (%)**
Mortality (%)	16 (26.7)	23 (32.4)	39 (29.8)
Total	60	71	131

Table 11. Mortality of TBI regarding genders

	Mortality in 2017 (%)	**Mortality in 2018 (%)**	**Mortality in 2017 & 2018**
Males	11 (68.8)	17 (74)	28 (71.8)
Females	5 (29.4)	6 (26.1)	11 (28.2)
Total N. of deaths	16 (41)	23 (57.5)	39 (100)

5. DISCUSSION

In this study, we examined the incidence of TBI in the University Hospital Split regarding gender, mechanism of injury, length of stay and treatment of TBI. The result of the study shows high mortality following TBI. More commonly TBI occurs in male patients and the most common cause is falls. The prevailing injury in TBI is subarachnoid hemorrhage and the majority of the patients were treated surgically, mainly by craniotomies.

The incidence of TBI amongst genders was much higher in males (72.5%) than in females (27.5%) in this study. In comparison to a study done by Munivenkatappa and associates, the incidence of male gender was higher as well, TBI being 4.5 times more frequent in males, coinciding with our study (46). In a study done in Europe by Majdan M and associates, there was a predominance in male gender (61%), again, matching our results. The reasons for such high male incidence are work-related accidents as falling from heights, males being more common road users and being predominately affected in road traffic injuries and disputes (3). From our study, it was noticed that the most common cause of TBI is falls (57%) mainly work-related to construction sites, during intoxication with alcohol and within elderly people the main cause being instability. In second place were road traffic accidents (22%) including cars or motorcycles.

TBI is a major international health problem and cause of death and disability in the world. Knowing the severity of TBI, it can lead to complications, life-threating conditions and eventually death. The injury itself or secondary injuries could be the cause of death amongst patients (2). The study done by Majdan M and associates, which included 25 countries, amongst them Croatia, described and compared the mortality rates. In Europe, the mortality rate was 37% while in Croatia it was 27% (3). In our study the mortality was 29.8%, indicating the severity of TBI. From the number of patients that died males prevailed (71.8%) over females (28.2%). The mortality was followed for patients treated at the Department of Anesthesiology and Intensive Care and Neurosurgery. There was no information on patient mortality once patients were discharged to another facility or home care.

All the patients from our study required treatment in the Department of Anesthesiology and Intensive Care. Since the Intensive Care Unit is highly equipped with the needed technology and equipment, the management of TBI aims to minimize the effects of secondary brain injury and other complications. Therefore, we measured the length of stay of patients in our study, half of our patients (56.5%) resided from 1 to 10 days in the ICU, the median duration is 9 days. In comparison, a study done in Canada by Tardif PA and associates shows that the median was 11.4 days, while a study done by Böhmer and associates from Germany shows a median of 5 days, both of the studies had a higher number of patients

than our study. Concluding from our study, the length of stay in the ICU is dependent on multiple factors such as the patient age, the severity of the injury, the need for mechanical ventilation, the GCS and complications such as sepsis, coagulopathies and, other comorbidities (47,48). Almost all patients (n=96) were transferred from the Department of Anesthesiology and Intensive Care to the Department of Neurosurgery. The rest of the patients were transferred to other departments, facilities or died at the departments. The patients transferred to the Department of Neurosurgery were followed. A majority of the patients (82.3%) spent from 1 to 30 days at the Department of Neurosurgery requiring further neurosurgical care. We can assume that the stay at the Department of Anesthesiology and Intensive Care was during the most critical period of the patients' health. Having the equipment, technology and certain treatments needed to be provided at the Department. Further on, we can assume that the transfer to the Department of Neurosurgery was done once patients were stabilized, showed signs of recovery and did not require mechanical ventilation. When comparing the length of stay in the Department of Neurosurgery to the Department of Anesthesiology and Intensive Care, patients at the Department of Anesthesiology and Intensive Care resided from 1 to 10 days, while the patients at the Department of Neurosurgery had much longer stays from 1 to 30 days. We can assume that the patients at the Department of Neurosurgery had longer stay due to complications such as infections and a need for a long recovery and rehabilitation needed following TBI. While at the Department of Anesthesiology and Intensive Care the main focus could've been exclusively on maintaining the patients' stability and preventing secondary injury to the brain such as edema, herniation, hypoxic and vascular injuries.

Patients with TBI require definitive airway protection because they are at risk of compromised respiratory drive and pulmonary aspiration. When patients with TBI receive mechanical ventilation, $PaCO_2$ has to be tightly regulated, it should be within a range of 34-38 mmHg. Low $PaCO_2$ will result in low CBF and cerebral ischemia, while a high $PaCO_2$ will result in cerebral hyperemia and high ICP. According to the current Brain Trauma Foundation guidelines, some patients may require hyperventilation to treat high ICP values, but it should be avoided during the first 24 hours when CBF is critical.

If patients are being hyperventilated, SjO2 or brain tissue oxygen partial pressure ($BtpO_2$) measurements are recommended to monitor oxygen delivery. In addition to $PaCo_2$ being regulated, other modalities should be adjusted as well, such as FiO_2~90 mmHg, tidal volume 6-8 ml/kg, PEEP to 5-10 cm H_2O and respiratory rate with 12 breaths per minute. A study done by Asehnoune and associates shows successful extubation from patients with a GCS

score of 8 and higher. In addition, performing an early tracheostomy shows to decrease the incidence of pneumonia, days of ventilation and the length of stay. Tracheostomies in the ICU were noticeably done in situations after unsuccessful extubations (37,38,49). In our study, almost all patients (99.2%) required mechanical ventilation, the time on mechanical ventilation for a majority of the patients (38.9%) was from 1 to 5 days. The need for ventilation is during the most critical period following the injury. The respiratory management of patients with TBI is complex, assuming that patients requiring mechanical ventilation for longer periods will have a higher risk of developing hospital-acquired pneumonia. Also, the management of mechanically ventilated patients is quite challenging, as lung injuries can happen if not ventilated properly.

We looked into the incidence of GCS at admittance and discharge, we were able to collect 87 patients GCS scores on admittance and 74 GCS scores on discharge. On admittance the most common GCS score was 3 (24.1%), in second place GCS scores of 6 and 15 shared places, each having the same amount of patients (11.5%). From mentioned above, we can conclude that accidents leading to TBI are of such great force, structurally damaging neurocranial components and leading to life-threatening damages, therefore explaining low GCS scores on admittance.

In our study, of the collected GCS scores there was high mortality (31%). Of the aforementioned patients that died, half (48.2%) had a GCS score of 3 on admittance. In comparison, a study done by Chamoun and associates shows that half of the patients (49.2%) with GCS score of 3 on admission died, concluding that a GCS score of 3 is a bad prognostic factor (50). A GCS score of 3 is considered a deep coma or death, patients having no meaningful response or voluntary activities. To consider brain death, we must first exclude any condition that might cofound brainstem functions like hypothermia, shock and, drugs such as anesthetics and neuroparalytics. Then we determine brain death by the absence of all brainstem reflexes, the most relevant being pupillary, corneal, cough, gag reflex, oculocephalic and oculovestibular responses. Brain death is defined as a deep comatose state with irreversible brain damage and a GCS score of 3 with at least 3 or more absent brainstem reflexes causing the end of independent respiration. Brain death is diagnosed after the absence of all brainstem reflexes and after an electroencephalogram and apnea test. The electroencephalogram will show no brain activity and the apnea test is considered positive if there are no respiratory movements and PCO_2 is 60 mmHg or increases >20 mmHg over the baseline. The apnea test is performed by discontinuing mechanical ventilation and deliver 100% O_2 into the trachea. Additional confirmatory tests may be done such as chemical,

giving 1 mg of atropine, in a brain-dead patient it does not cause an increase in the heart rate. In addition, several other tests that measure cerebral blood flow can be done such as MRI, CT, radionuclide angiography, transcranial Doppler ultrasound and, SPECT (51). After a patient is declared brain dead they can be a candidate for organ donation. For certain organs, there are age restrictions and protocols. Usual contraindications for organ donation are infectious diseases and neoplastic conditions. Three of our patients were explanted for organ donation (52).

Out of the discharge GCS scores collected from the Department of Anesthesiology and Intensive Care, the most common score was 3 (25.7%), followed by a GCS score of 15 (24.3%). All of the patients with a GCS score of 15 on discharge were transferred to other departments or facilities for further care needed for complete recovery, while all patients with a GCS score of 3 died.

We looked into the number of patients presenting with focal and diffuse brain injury. In our study, most of the patients that presented with focal brain injury had subarachnoid hemorrhage (71%), followed by subdural hemorrhage (58.8%). According to Bullock's handbook of Neurology, the most common type of injury following a TBI is subarachnoid hemorrhage (29). A lot of the patients from our study had neurocranial fractures (50.4%), this being mentioned, we can conclude there is a correlation between fractures and subarachnoid, subdural hemorrhages, caused by bone fractures damaging the blood vessels, stretching and tearing them, therefore leading to hemorrhage.

On admission there was a moderate amount of patients (26%) with edema, the number of patients most likely increased in the hospital due to secondary injuries. A minority of patients (7.6%) had DAI, we can assume that there is a low percentage of DAI diagnosed because of its difficulty to be detected on neuroimaging techniques like CT or MRI, as much of the damage is microscopic. For diffuse brain injury, such as DAI, certain MRI techniques are used, such as T2-weighted imaging (53). This may be a limitation in this study because CT was exclusively used in acute settings, while conventional MRI was used to follow up patients. The main focus was on life-threatening situations such as focal brain damages rather than DAI, which has less relevance in acute settings.

In our study, we looked into treatments done in the Department of Neurosurgery and the Department of Anesthesiology and Intensive Care. A majority of the patients (71%) underwent surgery, the rest of the patients did not require surgery and were treated with conservative medical treatment. After ICP targeted medical therapies fail, craniectomy is a secondary procedure that is done. Craniectomy is a surgical procedure used for

decompression in cases of high ICP and edema, removing a piece of the *cranium* to allow the edematous brain to expand. According to the Guidelines for the Management of Severe Traumatic Brain Injury larger sized craniectomies show to have lower mortality rates than smaller size craniectomies. It is thought that the large craniectomy diminishes the amount of axonal stretch or venous congestion of the herniated brain, in this way decreasing the mortality rates (37,54,55). Only a minor number of patients (7.6%) underwent craniectomy, on the contrast, a lot of patients underwent craniotomies (46.6%), assuming that the hematomas were too large to be managed by conservative treatment further risking development of complications such as edema or herniation. We can assume that craniotomies were more commonly performed in the University Hospital Split because it is a well-known surgical procedure, with known complications and benefits. While on the other hand craniectomy is a surgical procedure still under research to this day. The other surgical procedures such as trepanation, placement of ICP monitors and external ventricular drains were done in a minority of patients (16.8%). The patients that did not require surgical procedures (29%) were managed by conservative medical therapy including mechanical ventilation, hyperosmolar therapy, sedative drugs, antiseizure drugs and placement in medically induced comas. In conclusion, we can assume that patients with mild TBI can be managed successfully by conservative medical therapy, while severe TBI will require surgical procedures such as craniotomy, craniectomy or other surgical procedures.

A limitation of this study is that, some patients were transferred to other departments, facilities, other hospitals and foreigners to their countries of residence, by this way, some of the information might have not been reported throughout the study, such as mortality, length of stay and ventilation and by this way restricting information to the study. Also not all patient GCS scores were collected, some not mentioned. Furthermore, as this was a retrospective study, there was no way to gather any information missing.

6. CONCLUSIONS

1. TBI is a very common cause of admittance in the Department of Anesthesiology and Intensive Care. In our study during the two years, there have been 131 TBI patients out of 670 neurosurgical patients admitted patients to the Department of Anesthesiology and Intensive Care.
2. TBI is defined as an intracranial injury and occurs from damage to the brain resulting from an impact, penetration or rapid movement of the brain within the *cranium*. It can be divided into focal, diffuse brain injury and skull fractures.
3. In our study, TBI in the University Hospital of Split is more common in male gender than in females, the occurrence of TBI in males is 72.5%.
4. The most common cause of TBI in our study is falls 57%, in second place traffic accident 22%.
5. TBI leads to increased mortality; the mortality seen in the patients from our study is 29.8%. The mortality is higher in males, being 71.8%.
6. The median stay amongst patients in the Department of Anesthesiology and Intensive Care was 9 days. The median stay at the Department of Neurosurgery was 18 days; TBI leads to long recovery and complications, adding to a long stay in the Department of Neurosurgery.
7. Out of all the patients, 99.2% required mechanical ventilation. The median duration for mechanical ventilation was 7 days.
8. The most common GCS score on admission for 24.1% of patients was 3, in second place GCS 6 and 15 shared places with 11.5% of patients each.
9. Of the collected GCS scores there was a total of 31% patient mortality. Of the aforementioned patients that died, 48.2% had a GCS score of 3 on admittance. This statistic indicates that a GCS score of 3 is a prognostic factor for a poor outcome.
10. The most common focal brain injury in our study was subarachnoid hemorrhage with 71% of patients, followed by subdural hemorrhage with 58.8% of patients. Diffuse brain injuries were common at admission, with 26% of patients presenting with edema and 7.6% presenting with DAI.
11. Seventy-one percent of patients required surgical intervention, specifying the severity of injury resulting from a TBI. The most common surgical procedure done was craniotomy 46.6%. A minority of the patients required conservative treatment, 29% of them.

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8. SUMMARY

OBJECTIVES: The aim of the paper was to find out the prevalence of TBI regarding gender, the incidence of focal brain injury, length of stay in the Department of Anesthesiology and Intensive Care and the Department of Neurosurgery, the duration of mechanical ventilation, GCS scores on admission and discharge, type of treatments and the mortality of TBI.

MATERIALS AND METHODS: The study is a retrospective study including 131 patients with a diagnosis of TBI. The data were collected from the Department of Anesthesiology and Intensive Care and the Department of Neurosurgery in the University Hospital of Split. The information gathered dated from January 2017. to the end of December 2018. The medical records were collected from the computer database and archives. The medical data were reviewed and the statistical analyses were made using Microsoft Excel and Word.

RESULTS: In this study, we followed TBI patients in the Department of Anesthesiology and Intensive Care and the Department of Neurosurgery. Most of the patients in the study were males (72.5%), the most common event leading to TBI are falls (57%). The duration of stay at the Department of Anesthesiology and Intensive Care was from 1 to 10 days for half of the patients (56.5%), while at the Department of Neurosurgery it was from 1 to 30 days for more than half of the patients (82.3%). On average the stay at the Department of Neurosurgery was 18 days. Almost all patients with TBI required mechanical ventilation (99.2%), except for one patient, the majority required mechanical ventilation from 1 to 5 days (38.9%). The most common GCS score on admittance for patients was 3 (24.1%). Of the collected GCS scores high mortality was noticed (31%), of the aforementioned patients that died, (48.2%) had GCS scores of 3 on admittance. A majority of the patients had a focal brain injury, the most common being subarachnoid hemorrhage (71%) followed by subdural hemorrhage (58.8%). Some patients presented with multiple focal brain injuries with or without diffuse brain injury. The most common diffuse brain injury was edema (26%). Twenty-nine percent of patients did not require surgery and were treated by conservative therapy, while a majority of the patients (71%) underwent surgery, craniotomy is the most common type of surgical procedure (46.6%) and craniectomy being less common (7.6%). The mortality in our study was quite high for a small number of patients (29.8%). Out of patients that died more than half were males (71.8%).

CONCLUSION: TBI is a complex intracranial injury occurring when an external force injures the brain, it is more commonly seen in males. The mortality of TBI is high, indicating the severity of TBI. Due to the complexity of the injury and the multitude of cascades of pathological cellular pathways, TBI does lead to a long recovery and thus a long stay in the hospital. The average length of stay in the Department of Anesthesiology and Intensive Care was 9 days, while in the Department of Neurosurgery it 18 days. Furthermore, knowing the severity of TBI, the most common GCS score on admission and discharge was 3. The patients that presented with a GCS score of 3 on admission had high mortality and more than half died due to its severity. The injured brain, nonetheless, induces respiratory system changes, with the patients requiring assisted ventilation, on average being ventilated 7 days. Furthermore, due to the shearing and damage produced to blood vessels, the most common focal brain injury occurring following a TBI is subarachnoid hemorrhage, with more than half of the patients requiring the need for surgical treatment, with craniotomy being the most common type of surgical procedure.

9. CROATIAN SUMMARY

NASLOV: Traumatska ozljeda mozga u jedinici intenzivne njege

CILJEVI: Ciljevi ovog istraživanja su bili, utvrditi rasprostranjenost traumatske ozljede mozga među spolovima, učestalost fokalne ozljede mozga, odrediti dužinu boravka na Klinici za anesteziologiju, reanimatologiju i intenzivno liječenje te na Zavodu za Neurokirurgiju, odrediti dužinu mehaničke ventilacije, GKS ljestvicu tijekom prijema i otpusta, način liječenja te stopu smrtnosti traumatske ozljede mozga.

MATERIJALI I METODE: Obuhvaća retrospektivni studiju u koju je uključeno 131 bolesnik s dijagnozom traumatske ozljede mozga. Podatci su prikupljeni s Klinike za anesteziologiju, reanimatologiju i intenzivno liječenje te sa Zavoda za Neurokirurgiju u Kliničkoj bolnici Split, u razdoblju od siječnja 2017. do kraja prosinca 2018. Pregledani su protokoli liječenja i povijesti bolesti iz baze podataka s računala i iz arhiva navedenih odjela. U programskim paketima Microsoft Excel i Word obrađeni su podatci te su analizirani.

REZULTATI: Ovo istraživanje bavilo se praćenjem bolesnika s traumatskom ozljedom mozga na Klinici za anesteziologiju, reanimatologiju i intenzivno liječenje te sa Zavoda za Neurokirurgiju. Istraživanje je obuhvatilo ukupno 131 bolesnika. Govoreći o spolnoj distribuciji, većina bolesnika bilo je muškog spola (72.5%). Najčešći razlog traumatske ozljede mozga bili su padovi (57%). Najčešći boravak na Klinici za anesteziologiju, reanimatologiju i intenzivno liječenje za pola bolesnika (56.5%) iznosio je od 1 do 10 dana, a na Zavodu za Neurokirurgiju od 1 do 30 dana za više od pola bolesnika (82.3%). U prosjeku su bolesnici boravili na Zavodu za Neurokirurgiju 18 dana. Gotovo svi bolesnici s traumatskom ozljedom mozga (99.2%), osim jednog, bili su na mehaničkoj ventilaciji, većina ih je bilo mehanički ventilirano od 1 do 5 dana (38.9%). Najčešći GKS rezultat tijekom prijema za bolesnike bio je 3 (24.1%). Od umrlih bolesnika njih 48.2% imalo je GKS 3 kod prijema. Tijekom otpusta najčešći GKS bio je 3 (25.7%), a na drugom mjestu GKS 15 (24.3%). Većina bolesnika prezentirala je s fokalnom ozljedom mozga među kojim je subarahnoidalno krvarenje (71%) bilo najčešće, a na drugom mjestu je subduralno krvarenje (58.8%). Neki bolesnici su imali višestruke fokalne ozljede s ili bez difuzne ozljede; najčešća difuzna ozljeda mozga bio je moždani edem (26%).Veliki broj bolesnika bio je podvrgnut kirurškom zahvatu (71%), kraniotomija je bio najčešći izvođeni kirurški zahvat (46.6%), dok se kraniektomiju najmanje izvodilo (7.6%). Veliki dio bolesnika liječen je konzervativno, bez

operacije (29%). U istraživanju je primijećena visoka stopa smrtnosti (29.8%), više od pola bolesnika koji su umrli bili su muškarci (71.8%).

ZAKLJUČCI: Traumatska ozljeda mozga je kompleksna ozljeda, koja se događa se kada mehanička sila uzrokuje ozljedu i promjene u funkciji mozga. Smrtnost je prilično visoka što ukazuje na ozbiljnost ozljede. Češće se zapaža kod muškaraca. Zbog složenosti ozljede i patofiziologije, traumatska ozljeda mozga zahtjeva dugotrajni oporavak. Duljina boravka na Klinici za anesteziologiju, reanimatologiju i intenzivno liječenje u prosjeku bila je 9 dana, dok na Zavodu za Neurokirurgiju je bila 18 dana. Znajući ozbiljnost ozljede najčešći GKS rezultat tijekom prijema i otpusta bio je 3. Bolesnici s GKS rezultatom 3 na prijemu su imali veliku stopu smrtnosti i manje od pola bolesnika je preživjelo. Traumatska ozljeda mozak izaziva promjene dišnog sustava. Ovi bolesnici se moraju mehanički ventilirati, u prosjeku su bili ventiliran 7 dana. Nadalje, zbog oštećenja krvnih žila, najčešća fokalna ozljeda mozga koja nastaje nakon traumatske ozljede mozga je subarahnoidalno krvarenje, pri čemu su više od polovice bolesnika bili podvrgnuti kirurškim zahvatom, od kojih je kraniotomija bila najčešća.

10. CURRICULUM VITAE

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