Trauma patient management: the role of anesthesiologist

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TRAUMA PATIENT MANAGEMENT: THE ROLE OF ANESTHESIOLOGIST

GRADUATE THESIS

Zagreb, 2023

This graduation paper was recognized at the Department of Anesthesiology, Reanimatology and Intensive Care, University Hospital Centre Zagreb ‘KBC REBRO’ School of Medicine, University of Zagreb, Under the supervision of dr.sc. Vilena Vrbanović Mijatović. And was submitted for evaluation in the academic year of 2022/2023.

Mentor, dr.sc. Vilena Vrbanović Mijatović

Acknowledgments

I would like to acknowledge my mentor, Dr.sc. Vilena Vrbanović Mijatović from the Department of Anesthesiology, Reanimatology, and Intensive Care, University Hospital Centre Zagreb 'KBC REBRO', Zagreb, Croatia for mentoring me on this thesis. I am deeply indebted to her support, corrections, valuable comments, and feedback on this thesis.

I would also like to express my profound gratitude to my parents and friends for providing me with continuous and unlimited support, motivation, and encouragement throughout my years of medical studies. This accomplishment would have never been possible without them.

Abbreviations

ABCDE	Airway, Breathing, Circulation, Disability, Exposure.
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
IV	Intravenous
ECG	Electrocardiogram
TBI	Traumatic Brain Injury
ICU	Intensive Care Unit
NSAIDs	Nonsteroidal Anti-Inflammatory Drugs
PPIs	Proton-Pump Inhibitors
WHO	World Health Organization
COX-2	Cyclooxygenase-2
TBSA	Total Body Surface Area
ICP	Intracranial Pressure
MAP	Mean Arterial Pressure
CPP	Cerebral Perfusion Pressure
MTP	Massive Transfusion Protocol
CICV	Cannot Intubate, Cannot Ventilate
FiO2	Fraction of Oxygen in Inspired Air
LTA	Laryngeal Tube Airway
LMA	Laryngeal Mask Airway
BMV	Bag-Mask Ventilation
ATLS	Advanced Trauma Life Support
AMPLE	Allergies, Medications, Past medical history, Last meal, Events
GCS	Glasgow Coma Scale
FAST	Focused Assessment with Sonography for Trauma
eFAST	Extended Focused Assessment with Sonography in Trauma
SpO2	Oxygen Saturation
C-Collar	Cervical Collar
EMS	Emergency Medical Service
BLS	Basic Life Support

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Abstract

Title: TRAUMA PATIENT MANAGEMENT: THE ROLE OF ANESTHESIOLOGIST

Keywords: Trauma, Airway management, Resuscitation, Bleeding, Pain management, Electrolyte management.

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Trauma is one of the leading causes of morbidity and mortality worldwide. Trauma is caused by external forces that lead to physical injuries. These physical injuries require prompt and comprehensive care to optimize patient outcomes. Trauma care is a medical field that encompasses a range of medical interventions and involves a multidisciplinary approach, with various healthcare providers working together to provide comprehensive treatment, and to address the diverse needs of patients affected by traumatic injuries. Trauma anesthesiology is a specialized field focused on the care and management of patients with traumatic injuries. Trauma anesthesiologists require broad medical knowledge and diverse skills to navigate high-pressure and time-limited environments. They perform various procedures including advanced airway management, vital signs monitoring, pain management, fluid regulation, and resuscitation. Furthermore, they are able to effectively communicate with healthcare team members. Hence, trauma anesthesiology plays a vital role in comprehensive care for patients with traumatic injuries.

Sažetak

Nazlov: ULOGA ANESTEZIOLOGA U ZBRINJAVANJU POLITRAUMATIZIRANOG BOLESNIKA

Ključne riječi: Trauma, Upravljanje dišnim putovima, Reanimacija, Krvarenje, Upravljanje bolovima, Upravljanje elektrolitima.

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Trauma je jedan od vodećih uzroka morbiditeta i mortaliteta u cijelom svijetu. Traumu uzrokuju vanjske sile koje dovode do fizičkih ozljeda. Ove fizičke ozljede zahtijevaju brzu i sveobuhvatnu skrb kako bi se optimizirali ishodi za pacijenta. Skrb za politraumatiziranog bolesnika je područje koje obuhvaća niz medicinskih intervencija i uključuje multidisciplinarni pristup, s različitim pružateljima zdravstvenih usluga koji rade zajedno kako bi pružili sveobuhvatno liječenje i odgovorili na različite potrebe pacijenata pogođenih traumatskim ozljedama. Traumatološka anesteziologija je specijalizirano područje usmjereno na skrb i liječenje pacijenata s traumatskim ozljedama. Traumatološki anesteziolozi zahtijevaju široko medicinsko znanje i različite vještine za snalaženje u napetim situacijama i vremenski ograničenim uvjetima. Oni izvode različite postupke uključujući napredno upravljanje dišnim putovima, praćenje vitalnih znakova, upravljanje bolovima, regulaciju tekućine i reanimaciju. Nadalje, sposobni su učinkovito komunicirati s članovima zdravstvenog tima. Stoga traumatološka anesteziologija igra ključnu ulogu u sveobuhvatnoj skrbi za pacijente s traumatskim ozljedama.

1. Introduction

Trauma anesthesiology is a specialized field within anesthesiology that focuses on the care and management of patients who have experienced traumatic injuries. Anesthesiologists specializing in trauma care should have broad knowledge and acquire a wide range of medical skills, such as treating a patient in a high-pressure and time-limited environment.

This field involves a variety of medical procedures, some of which are: advanced airway management, monitoring of vital signs, pain management, fluid and electrolytes management, and resuscitation. In addition, trauma anesthesiologists should be able to manage complex medication regimens and they should be skillful and experienced in using ultrasound and other advanced imaging technologies.

Trauma anesthesiology is an important component of the overall care provided to patients who have undergone traumatic injuries. Through their specialized training and expertise, trauma anesthesiologists can communicate effectively with other healthcare team members, including surgeons, nurses, and emergency medical personnel. For this reason, they play a vital role in helping to ensure the best possible outcomes for these patients.

2. Trauma

A traumatic injury is a sudden physical injury that usually requires immediate medical attention and may initially be treated in an emergency department. If ongoing treatment or rehabilitation is necessary, the patient may then be referred to a specialist. Severe cases of major trauma can result in disability or even death.

2.1. Epidemiology of trauma

Trauma leads to approximately six million deaths per year, which is more than all deaths due to infectious diseases added together. Also, it is the greatest cause of death in the age group of 5-29 years. There are multiple causes of trauma, the most common cause is road traffic injuries (23%) and others like drowning, burns, and war are less common. Male deaths due to violence and injury are higher than in females, especially in high-income countries. Death due to trauma is three times higher in low and middle-income countries than in high-income countries (1).

2.2. Trauma systems

In the setting of a trauma injury, a systematic approach is essential because it has been proven to improve the outcome of the patients (2). This systematic approach is divided into three main parts:

1. Prevention: injury prevention limits the number of deaths and disabilities caused by trauma and reduces the mortality rate caused by road traffic accidents and motor vehicle crashes. An example of prevention would be the increased awareness needed by the driver and also the use of a safety helmet when riding a bicycle (3).
2. Pre-hospital care and initial hospital care: pre-hospital care is the care given to the patient before reaching the hospital. This step of the treatment is very important since it increases the chance of the patient's survival. Pre-hospital caregivers are trained to be skillful and competent. They should have a broad knowledge of surgery, emergency, and trauma care. In developed countries, pre-hospital care is advanced which is one of the reasons why the mortality rates are lower (4). The initial hospital care takes place in the emergency department where the Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach is used to assess, stabilize and treat the patient. This step of management has to be organized so that there is minimal time loss (5).
3. Secondary care: this step comes after the patient's stabilization in the emergency department. Here it is decided whether the patient is discharged or has to stay in the hospital for observation and further intervention.

2.3. Polytrauma

Polytrauma refers to a condition in which an individual has two or more traumatic injuries resulting from a single event. At least one of these injuries is life-threatening and requires immediate medical intervention. Just like traumatic injuries, polytrauma can be caused by a variety of similar causes such as car accidents, falls, explosions, warfare, and combat injuries. The injuries may range from mild to severe and can involve multiple body systems, including respiratory, neurological, cardiovascular, and musculoskeletal systems.

The treatment of a polytraumatic patient is quite complicated and involves a multidisciplinary approach, specialists from different medical fields cooperate and work together to address and diagnose the different injuries and to provide the patient with a comprehensive care and treatment plan. The main goal of the first steps of the treatment is to stabilize the patient, be in control of the situation, prevent any further injuries, and avoid any life-threatening complications. Once the patient is saved then the long-term goals of the treatment may include rehabilitation and physical therapy to help the patient regain function and improve quality of life (6,7).

2.4. Mechanisms of injury

Mechanisms of injury refer to the various ways in which the body can be harmed or damaged. Understanding the mechanism of injury is important in determining the appropriate management and treatment of the injury, and it can also be useful in developing strategies to prevent similar injuries in the future(8).

These mechanisms can be categorized into five types:

Blunt injury

Is an injury that occurs as a result of an impact or collision between the body and a blunt object, such as a vehicle, wall, or floor. The impact may cause damage to various body tissues and organs, including skin, muscles, bones, and internal organs(9).

Common causes of blunt force trauma are motor vehicle crashes, physical assaults, sports injuries, and falls. Force and location of the impact as well as the health condition and age of the injured person are the factors that determine the severity of the injury(9).

The symptoms of this type of injury may vary depending on the location and severity of the injury but may include pain, swelling, and bruising in mild severity and if the injury is severe it can lead to fractures, internal bleeding, and organ damage(10).

The treatment of blunt force trauma also depends on the severity and location of the injury. Mild injuries may only require bed rest, ice, and pain relief medication, while more severe injuries may require surgery or other medical interventions(11).

Examples of the prevention of blunt force trauma may include wearing appropriate gear during sports activities, following safety guidelines while driving, and using caution while walking or moving around in a potentially dangerous environment(12).

Penetrating injury

Is an injury caused by a foreign object piercing the skin, which damages the underlying tissues and results in an open wound(13). The most common causes of such trauma are gunshots and stab wounds. Damage might also happen to the adjacent structures to the path of the foreign object, this is caused by cavitation of the path and the generation of shockwaves, which cause alternating compression and collapse of the structures lying within the region of the shockwave(14).

The clinical picture differs depending on the injured parts of the body, shape, and size of the penetrating object. Diagnosis is established based on history and imaging studies, such as computed tomography (CT) and magnetic resonance imaging (MRI). Management usually involves supportive measures (hemostasis, blood transfusion, respiratory support), and surgical intervention in order to repair the damaged structures and/or to remove the foreign object(15).

Handling sharp objects safely, avoiding dangerous environments, following gun safety guidelines, and wearing bulletproof protective gear are important steps in the prevention of penetrating trauma because they reduce the risk of accidents and injuries(16).

Thermal injury

Is a type of injury that occurs when the body's tissues are exposed to heat, cold, chemicals, and radiation(17). This type of injury can cause damage to the skin, muscles, and internal organs and can range in severity from minor burns to life-threatening injuries like hypothermia or shock(18). Hot liquids, fire, cold temperatures, and chemical agents are examples of causes of thermal injury. The symptoms of the thermal injury vary depending on the severity, mild injuries may cause pain, swelling, redness, and blisters, while in more severe cases the injury might lead to shock, and infection and can be fatal(19). Treatment for minor cases may only require cleaning and bandaging, while more severe cases may require further medical interventions to repair the damaged tissues, prevent infection, or manage further complications(20).

Burns are injuries to tissue caused by heat, chemicals, and/or radiation. The two factors that influence the severity of a burn are its depth and the surface area involved(21). Accordingly, burns are classified into four grades based on the depth of tissue involvement:

1^{st}-degree burn (superficial burn), the affected tissue layers include the superficial layers of the epidermis. The burn looks like a sunburn, featuring localized erythema and swelling with no blistering. It heals with no scarring within 3-6 days(22).

2^{nd}-degree burn: this type of burn can be divided into two groups(23), 2a (superficial partial thickness burn) where the epidermis and upper layers of the dermis (papillary dermis) are the affected tissue layers, and 2b (deep partial thickness burn), where the affected layers are the epidermis and the whole dermis including papillary and reticular dermis. In addition to tissue swelling and erythema, vesicles, and bullae might develop. And healing occurs within 1-3 weeks without causing any scar tissue.

A 3rd-degree burn is a full-thickness burn, affecting the epidermis, dermis, and subcutaneous tissue. Tissue necrosis and eschar formation are seen, and the burn does not heal by itself(24).

4th-degree burn is a deeper injury burn that damages the epidermis, dermis, subcutaneous tissue, and deeper structures like muscles, fat, fascia, and bones(25). This burn causes tissue death and requires surgical intervention to be treated.

In the case of massive tissue necrosis sepsis, shock, and sequential organ failure might happen. Patients should be intubated, given supplemental oxygen, and resuscitated with intravenous fluids(26). Different formulas exist to calculate initial fluid requirement, but fluids should be adjusted to maintain clinical stability and appropriate urine output(27). Pulse oximetry, blood gas analysis, and measurement of electrolytes and creatinine levels are important diagnostic procedures for patients with severe burns. Peripheral pulses and capillary refill can be used to detect tissue perfusion.

First and second-degree burns can be treated with antiseptic ointment and dressings, while treatment of third and fourth-degree burns involves debridement of necrotic tissue followed by a skin graft or tissue transfer via flap(28).

Blast injury

Blast injury is a complex type of physical injury that results from direct or indirect exposure to an explosion. Explosions are physical phenomena that lead to a sudden release of energy, which causes a quick compression of the surrounding medium and an increase in pressure above the atmospheric pressure resulting in a blast wave (overpressure wave) that propagates outward from the explosion at a very high speed(29).

Blast waves that occur within or near solid hard surfaces can be amplified two to nine times because of the shock wave reflection. Hence, they have an increase in their destructive potential. For example, people located between a blast and a building will often suffer more extensive injuries than when a blast occurs in an open area(30).

Blast injuries range from minor injuries to severe injuries. Internal organ damage, including lung and traumatic brain injury (TBI), tympanic membrane rupture, middle ear damage, hearing and vision injuries, abdominal hemorrhage, and perforation are all examples of blast injuries(31).

Environmental injury

Is an injury caused by exposure to environmental factors such as extreme temperature, rapid changes in ambient pressure, electricity, wildlife (e.g., dog bites, snake bites, spider bites, and zoonotic diseases.) environmental and occupational toxins and irritants (e.g., carbon monoxide toxicity, carcinogen exposure, and metal toxicity)(32).

Electrical injuries occur when an electrical current enters the body, passes through tissues, and exits the body(33). Thermal injuries might occur due to the conversion of the electrical current to heat. They also typically manifest with burns, cardiac dysrhythmias, and/or traumatic injuries(34).

Lightning injury is a type of electrical injury caused by lightning and is characterized by cutaneous manifestations (e.g., burns, Lichtenberg figure, and metalization)(35). Cardiac arrhythmias like ventricular fibrillation and asystole as well as fixed dilated pupils may also be seen(36).

Individuals with an electrical injury require a thorough assessment for burns, cardiac complications, and traumatic injuries. Management may include Advanced trauma life support (ATLS), advanced cardiac life support, cardiac monitoring, and treatment of complications(37).

High-altitude illnesses result from inadequate acclimatization to the low partial pressure of inspired oxygen found at elevations higher than 2500 meters. Manifestations include acute mountain sickness, high-altitude pulmonary edema, and high-altitude cerebral edema. Management involves descending to a lower elevation, supplemental oxygen, and possible pharmacotherapy. Preventative measures include ascending in stages and prophylactic medications(38).

Diving-related illnesses are caused by rapid changes in ambient pressure. Decompression illness is caused by the presence of gas bubbles in the blood or tissue and manifests as musculoskeletal pain, altered mental status, and/or circulatory collapse. Treatment involves 100% oxygen and hyperbaric oxygen therapy(39).

Barotrauma is caused by a large pressure difference between the ambient environment and air-filled structures such as the sinuses, middle ear, and lungs. Treatment is usually conservative but life-threatening complications such as pneumothorax may occur(40).

3. Advanced trauma life support (ATLS)

ATLS is a framework for the systematic evaluation of trauma patients to improve outcomes and reduce missed injuries. It describes management sequences (e.g., ABCDE algorithm) that prioritize the most immediately life-threatening injuries first.

It also aims to standardize trauma care across centers with varying resources and experience with trauma management both in prehospital and hospital settings(41).

3.1. Prehospital trauma care

Prehospital trauma care is situation-dependent and centered on field stabilization of the patient by performing life-saving interventions and basic life support (BLS) in the field by emergency medical services (EMS) and providing rapid transportation to the nearest appropriate hospital(42).

The bystanders play an important role in the prehospital management of a trauma patient. They should assess the safety of the scene before assisting, shout for help and/or call emergency services, remove the patient from dangerous situations, initiate BLS, and perform life-saving interventions such as airway opening maneuvers, hemorrhage control, and spinal immobilization(43).

The EMS typically performs an abbreviated version of the primary survey and ABCDE approach. They aim for airway management for respiratory distress or altered mental status, hemorrhage control with the use of tourniquets or pressure bandages, hemodynamic support via IV fluids, prevent further injury by spinal immobilization with cervical collar placement and backboard, fracture stabilization, provide analgesia, transport of the patient to the nearest hospital while also notifying the receiving hospital, and sign-out of the patient to the trauma team upon arrival with delivering information about the situation and the vital signs of the patient(44).

3.2. Primary survey

The ABCDE algorithm in ATLS provides a sequence to treat the most life-threatening injuries first. In clinical practice, the trauma team members evaluate and treat these simultaneously, continually reassessing the severity of each injury throughout the resuscitation.

Airway and cervical spine stabilization

In this step, the airway obstruction must be identified and treated. The causes of obstruction might be due to various reasons, like blood, direct injury, edema, and/or because of altered mental status or coma.

The initial step is assessing the airway. The ability of the patient to talk and answer questions typically correlates with a patent airway. Examine the airway for foreign bodies or injury (e.g., facial fractures, burns) and evaluate for signs of airway compromise, which are signs and symptoms that suggest impending or total loss of airway patency. These include partial airway obstruction (e.g., stridor, hypoxia, signs of increased work of breathing) and complete airway obstruction (e.g., paradoxical chest/abdomen movement, inability to speak) as well as features of conditions associated with an anticipated loss of airway protection (e.g., reduced level of consciousness, inability to swallow secretions). The evaluation of signs of respiratory distress is also important, these signs include tachypnea, use of accessory muscles of respiration, nasal flaring, grunting, cyanosis, and an inability to lie flat caused by increased work of breathing to meet oxygen demands(45).

The second step is to perform initial interventions such as suction of oropharyngeal secretions and/or blood, performing airway opening maneuvers (e.g., head-tilt/chin-lift maneuver) and, insertion of basic airway adjuncts (oropharyngeal airway/nasopharyngeal airway)(45).

Intubation is performed on patients with airway obstruction and/or respiratory failure, which is a condition that occurs when the respiratory system is unable to adequately oxygenate the body and/or eliminate carbon dioxide(46). Patients with depressed mental status and patients with severe shock and/or cardiac arrest are also to be intubated.

Cervical spine injury is presumed in any trauma patient complaining of neck pain, or with any significant head injury, neurological signs or symptoms suggestive of cervical spine injury, or intoxication or loss of consciousness. The application of a cervical collar (C-collar) to protect the cervical spinal cord will limit the degree of cervical extension that is ordinarily expected for direct laryngoscopy and tracheal intubation. The front portion of the C-collar can be removed to facilitate tracheal intubation as long as the head and neck are maintained in a neutral position by an assistant maintaining manual stabilization(47).

Breathing

The goal of this step is to identify and treat chest injuries (e.g., tension pneumothorax, open pneumothorax, massive hemothorax, flail chest, and tracheobronchial injuries). The trauma team should maintain suspicion of pulmonary injury in a trauma patient, because pulmonary injuries may evolve into a tension pneumothorax once mechanical ventilation is started(41).

Oxygen saturation (SpO_2) must be evaluated and titrated to $SpO_2 > 95\%$, and continuous pulse oximetry should be started to assess oxygenation. Monitoring of rate and quality of respirations, inspection for jugular venous distention and tracheal deviation, lung auscultation, and inspection for chest wall injuries (e.g., penetrating wounds, subcutaneous emphysema, and absent breath sounds) are all important steps in the assessment of ventilation. Extended Focused Assessment with Sonography in Trauma (eFAST) should be considered to help identify pneumothorax at the bedside(48).

The initial intervention is supplying oxygen via mask ventilation or mechanical ventilation in the case of respiratory failure. If the patient has a sucking chest wound it should be treated with a 3-sided dressing. If a traumatic pneumothorax is suspected in a patient requiring positive pressure ventilation, tube thoracostomy should be performed, which is done by inserting a flexible tube into the thoracic cavity at the 4^{th}-5^{th} intercostal space between the anterior and midaxillary line (safe triangle)(49). Chest X-ray is used to evaluate the lungs if required but only once the patient is stabilized.

Circulation

Circulation is the third part of the primary survey. The main goal is to provide immediate hemodynamic support and hemostatic methods to control and stop the bleeding while identifying sources of bleeding. These methods include applying external pressure, interrupting blood flow with a tourniquet, vessel suturing or ligation, angiographic embolization, and using pharmacological hemostatic drugs such as tranexamic acid(41).

Monitoring of the vitals and continuous cardiac telemetry, evaluating central and peripheral pulses, capillary refill time, and level of consciousness, are needed in the assessment of the hemodynamic status. As well as evaluating the overall appearance of the patient and his color (e.g., pink, pale, cyanotic) which helps with the diagnosis of bleeding and adequacy of the blood perfusion(50).

Localizing the hemorrhage, identifying obvious pelvic or long bone deformity, and identifying indications for immediate surgery (e.g., exploratory laparotomy) should be done rapidly.

Focused Assessment with Sonography for Trauma (FAST) test is performed to quickly identify hemopericardium, intrathoracic, intraabdominal, and/or intrapelvic bleeding in unstable patients(51).

The initial interventions are placing two large-bore IVs and administration of 1 liter of warmed isotonic crystalloid bolus(52). In case the patient does not respond to IV fluid, the trauma team should proceed to blood transfusion(52). If peripheral IV cannot be obtained, intraosseous access should be considered(53).

Disability

Once the A, B, and C are covered, the next thing that should be assessed is the disability and neurological status of the patient. The level of consciousness is assessed with the Glasgow Coma Scale (GCS). The pupillary function is examined with the pupillary light reflex and helps in the assessment of the brain stem function. Looking for extremity movement and sensation of the four limbs in order to make sure that there is no evidence of any focal neurologic deficit that could suggest a problem with the brain or spinal cord. If the patient is altered in any way, it is important to check the glucose levels and to check for other signs of comorbidities that might have contributed to the current trauma event(41).

It is crucial to identify life-threatening TBI, consult a neurosurgeon, and begin with neuroprotective measures to limit secondary brain injury, which are the maintenance of normoxia, normocapnia, normotension, and euglycemia(54).

The initial management for patients that show signs of significant neurologic impairment or patients that are significantly comatose or have GCS ≤ 8 is airway support and intubation(55). If the patient is stable, then emergent cranial imaging with non-contrast CT should be obtained. The treatment should then proceed depending on the imaging results.

Exposure

Lastly, after A, B, C, and D are covered and the patient is stabilized, the managing team must think about exposing and undressing the patient completely. Examining the entire patient from head to toe is important since some injuries could be hidden and not diagnosed. The team must keep in mind that undressing the patient can cause hypothermia, which can cause coagulopathy and exacerbate bleeding and trauma. So once the physical examination is done, the team should make sure that hypothermia is avoided and the patient is rewarmed(41).

3.3. Secondary survey

The secondary survey is an important component of the ATLS algorithm and is performed once the primary survey has been completed and any life-threatening injuries have been addressed. The purpose of the secondary survey is to conduct a more detailed assessment of the patient's injuries and to determine the most appropriate treatment plan.

The secondary survey is divided into three components:

1. Head-to-toe physical examination: This includes a comprehensive examination of the patient's head, neck, chest, abdomen, pelvis, extremities, and back. The examiner should look for any signs of injury such as bruises, ecchymosis, lacerations, or deformities, and assess for any tenderness, swelling, or crepitus. They should also check for any signs of neurological deficits(56).
2. Vital signs: The patient's vital signs should be monitored and recorded, including their heart rate, blood pressure, respiratory rate, and oxygen saturation. Any abnormalities should be noted and addressed.
3. Laboratory and imaging studies: Blood tests, such as a complete blood count and basic metabolic panel, should be ordered to assess for any signs of bleeding or organ dysfunction. Imaging studies, such as X-rays, computed tomography (CT) scans, or ultrasounds, should be ordered as needed to further evaluate any suspected injuries.

Allergies, Medications, Past medical history, Last meal, Events and environment related to the injury (AMPLE) history is a recommended focused history approach done in the rapid evaluation of patients with trauma.

The secondary survey is critical in identifying any injuries that may not have been immediately apparent during the primary survey, as well as in monitoring the patient's condition over time. Effective implementation of the ATLS protocol, including the secondary survey, can help improve outcomes for trauma patients.

3.4. Tertiary survey

During the last few years, the medical teams in trauma centers noticed that there was an increase in undiagnosed injuries in trauma patients (57). Hence more attention is being paid to the tertiary survey. It is performed 24 hours after the patient has been admitted and after the primary and secondary surveys have been completed and any life-threatening injuries have been addressed. The purpose of the tertiary survey is to identify any injuries that may have been missed during the primary and secondary surveys, particularly those that are less urgent but still require medical attention(58).

The tertiary survey involves a thorough head-to-toe examination of the patient, including a detailed assessment of all body systems. It also includes a review of the patient's medical history and any imaging studies that have been performed.

It also includes a review of the patient's vital signs, including heart rate, respiratory rate, blood pressure, body temperature, and oxygen saturation. The healthcare provider will also monitor the patient's urine output and assess their fluid and electrolyte status. Overall, the tertiary survey is a critical component of the ATLS protocol, as it helps to ensure that all injuries are identified and treated appropriately. By performing a thorough assessment of the patient, healthcare providers can help to prevent long-term complications and improve the patient's overall outcome(59).

4. Trauma anesthesiology

As mentioned earlier, the management of a trauma patient requires a multidisciplinary approach involving different medical specialties. Trauma anesthesiologists are trained to care for patients with any form and severity of injury. While the trauma surgeon focuses on treating the patient's injury, the anesthesiologists are in charge of the patient's vital life functions: breathing, blood pressure, and establishing an adequate blood supply and oxygen to the heart, brain, and other organs. Anesthesiologists also provide effective airway management and resuscitation with IV fluids, blood transfusions, and potent medication. They also administer anesthetics to put the patient into a deep unconscious state like a medically induced coma and take away the patient's pain.

4.1. Airway management

Airway management involves a variety of medical procedures and devices that are used to restore or maintain an effective, safe pathway for oxygenation and ventilation. These procedures are indicated for patients who have symptoms and signs of airway obstruction and respiratory failure (e.g., noisy breathing, stridor, hoarse voice, hypoxia, and/or hypercarbia), or in patients that need airway protection (e.g., for general anesthesia)(60).

Basic airway maneuvers are the initial steps performed to treat airway compromise in patients that do not have any serious complications. They are used to relieve airway obstruction in an obtunded but spontaneously breathing patient. The main goals of these maneuvers are specific positioning strategies (head-tilt/chin-lift, jaw thrust), oxygenation, and/or ventilation of the patient. They can also be used as a temporary bridge before the placement of a definitive airway in apneic patients, or in patients with intense respiratory failure. All patients require monitoring with pulse oximetry(61).

Head-tilt/chin-lift is a maneuver done to reposition the head and neck to open the airway. The patient's head should be tilted posteriorly to 15-30° of atlantooccipital extension, then the chin should be lifted with the fingers to pull the tongue and oropharyngeal soft tissues anteriorly. This position must be maintained to align the oral, pharyngeal, and laryngeal axes. This maneuver should not be done to a patient with a suspected cervical spine injury(62).

Jaw-thrust maneuver may be used with head-tilt/chin-lift maneuver, or alone in a patient with cervical spine injury. The fingers are placed behind the angles of the lower jaw, then the mandible and tongue are displaced anteriorly to open the airway.

Bag-mask ventilation (BMV) is used to ventilate a patient with positive pressure. A mask is held in place over the face, and breath is delivered by squeezing a self-inflated bag that is attached to the mask. The goal is to deliver 500-600 ml tidal volume at 10-12 breaths/minute(63).

The jaw is lifted towards the mask using the 3^{rd}, 4^{th}, and 5^{th} fingers of one hand, forming an E-shape and the mask is held firmly to the face with the thumb and index finger of the same hand, forming a C-shape. The oxygen is then delivered by compressing the bag with the other hand. To confirm the adequacy of the BMV, bilateral chest rise should be seen, air leaks around the mask should not be heard, and air entry on auscultation should be confirmed in both lungs(64).

Basic airway adjuncts are devices that may be used in combination with airway opening maneuvers to improve airway patency. Oropharyngeal airway is a rigid curved device that is placed in the mouth to prevent the tongue from occluding the airway. It is typically used as a bridge to intubation, but it can be attached to an unconscious patient with airway obstruction. The size of the device should be equal to the distance between the corner of the mouth to the earlobe. The device should be inserted with the concave side up or lateral until it passes the tongue and then it should be rotated until the concave is down. It should be ensured that the device has bypassed the tongue and it is not pushing it down(65).

Nasopharyngeal airway is a soft flexible tube that is inserted through the nostrils to the nasopharynx to prevent the tongue from occluding the airway. It is indicated in oropharyngeal obstruction, and it is contraindicated in facial fractures, and basilar skull fractures, hence it can pass through a fractured cribriform plate directly into the brain, and in coagulopathy (severe epistaxis caused by the tube may worsen airway compromise).

The insertion starts by lubricating the tube, topical decongestant to decrease the epistaxis should be considered. The tube is then gently inserted into the nostril posteriorly and not superiorly, then it is twisted back and forth to ease the passage until the tip of the tube sits at the opening of the oropharynx and the flange of the tube sits comfortably on the nostril(66).

Supraglottic airway devices are advanced airway devices that occlude the distal oropharynx to facilitate positive pressure ventilation when an endotracheal tube is not available(67). Many devices are used in medical practice, some of which are laryngeal mask airway (LMA), I-gel, and laryngeal tube airway (LTA). LMA contains an inflatable mask that is attached to the end of a tube, second-generation LMAs have some safety adaptations (e.g., bite blocks, gastroesophageal drain ports), while intubating LMAs have adaptations that allow passage of an endotracheal tube through the device. I-gel is similar to LMA, but the mask is anatomically molded, noninflatable, and made of a soft gel-like material. LTA is a device consisting of a tube with two inflatable cuffs and ventilation holes between them. The smaller distal cuff occludes the esophagus, and the larger proximal cuff occludes the laryngeal inlet. Intubating LTA features additional adaptations in order to allow for the passage of an endotracheal tube(68).

There are three recommended sizes of the devices, for LMA and I-gel the recommendation is based on the weight of the patient, while for LTA the recommendation is based on the height. Size 3 for small adults, size 4 for medium adults, and size 5 for large adults(68).

After choosing the size of the device appropriate to the patient, the devices are lubricated at their tip (careful not to block ventilatory openings), the patient is placed in the sniffing position with his mouth opened widely, then the device is held firmly and inserted. LMA and I-gel are inserted smoothly along the hard palate and downwards with the outlet facing caudally until the devices pass the base of the tongue and resistance is felt. LTA is inserted until the connector reaches the teeth with the tube rotated at 45-90° from the midline (concave lateral) until it passes the base of the tongue, then it should be rotated back to the midline (concave up)(69).

After insertion is done, the correct placement of the device must be confirmed by hearing air movement in both lungs on auscultation, visible chest rise, and fall, and monitoring oxygenation (stable or improving).

Endotracheal intubation is a complex procedure that requires extensive training and expertise. It is typically performed in emergencies or during surgeries by healthcare professionals with specialized training, such as anesthesiologists, emergency doctors, or critical care specialists, to ensure adequate oxygenation and ventilation of the patient. In endotracheal intubation, a tube is inserted into the trachea through the mouth (or nose) in order to allow for gas exchange via mechanical ventilation and to protect the airway from aspiration.

The endotracheal tube is a hollow flexible tube that is designed to enter the trachea and is placed distal to the vocal cords(70). The procedure is commonly preceded by preoxygenation of the patient with 100% oxygen to replace alveolar nitrogen with oxygen and to increase the safe-apnea time by applying high-flow oxygen (10-12L/min) through a nonrebreather mask(71). It is important to assess the patient prior to the procedure and identify any red flags for a difficult airway by looking for features associated with a difficult airway, evaluating the mouth and larynx position, assessment of oral accessibility (Mallampati score), looking for obesity and evaluating the neck mobility (LEMON assessment)(72).

Sedation and paralysis of the patient using induction agents and neuromuscular blocking drugs are typically performed before the start of intubation. Induction agents sedate the patient, and as a result, the airway reflexes are diminished, which facilitates intubation. The induction agent is chosen based on the experience of the physician and the characteristics of the patient. Propofol (2-2.5 mg/kg IV once)(73), etomidate (0.3 mg/kg IV once)(74), and ketamine (1-2 mg/kg IV once)(75) are three commonly used induction agents. Neuromuscular junction blockers are used in order to paralyze the patient, administering them before intubation decreases the risk of injuring the airway and provides better visualization of the glottic opening by relaxing the muscles of the head and neck(76). Succinylcholine is a depolarizing neuromuscular junction blocker that is commonly used due to its rapid-acting characteristic (0.6 mg/kg IV once)(77). It may cause severe hyperkalemia; thus, it is contraindicated in patients that have hyperkalemia, renal impairment, severe burns, rhabdomyolysis, and neuromuscular diseases (e.g., multiple sclerosis)(78). Rocuronium is an example of a nondepolarizing neuromuscular blocker that can be used in all patients (1.0 +/-- 0.2 mg/kg IV once)(79), or in patients who have contraindications to succinylcholine(80). It has a long duration of action (30-50 minutes), which is why it is avoided in patients with difficult airways due to the risk of deterioration.

Intubation procedure can be done by direct laryngoscopy (the traditional approach), or by the routinely performed videolaryngoscopy. After the assessment of the patient, induction of anesthesia, and preoxygenation, the patient is positioned in the sniffing position (head elevated to a height of 10 cm, neck flexed at the lower cervical vertebrae and extended at the atlantooccipital joint), the mouth of the patient should be gently opened, the laryngoscope is inserted, and the tongue is moved to the side by sweeping with the groove. Once the tip of the laryngoscope is at the epiglottic vallecula and the epiglottis is visible, the laryngoscope is lifted gently forward and upward to elevate the epiglottis and reveal the vocal cords and arytenoid cartilages. Next, the styleted endotracheal tube is inserted, the stylet is removed when the tip of the tube reaches the glottis, and the tube is further inserted until the cuff of the tube passes the vocal cords. The cuff is inflated in order to protect the airway from any secretions, blood, or gastric contents(81). Confirmation of correct endotracheal tube placement is done via carbon dioxide detection through capnometry or capnography (gold standard), by imaging (chest X-ray), or by auscultation of bilateral breath sounds. Early complications of intubation may include hypoxia, bradycardia, pulmonary aspiration, laryngospasm, or bronchospasm. Long-term intubation may lead to vocal cord injury and damage (e.g., vocal cord granuloma), irritation and scarring of the trachea may also occur, which might cause laryngotracheal stenosis (narrowing of the larynx and/or trachea) which commonly manifests with hypoxia, respiratory distress, and stridor(82–84).

Intubation is also routinely performed via videolaryngoscopy, with a laryngoscope that allows indirect fiberoptic visualization of the glottic opening. A camera delivers a video from the distal end of the blade to an external video screen. Videolaryngoscopy is used in a previously known or suspected difficult airway. The procedure is similar to direct laryngoscopy, except that the patient does not have to be always put in the sniffing position, and the confirmation of the tube passing the vocal cords is confirmed immediately on the screen(85).

Sometimes intubation can lead to further complications in a critically ill patient that suffers from a traumatic injury, so some modifications should be made to the standard intubation procedure. For example, if the patient is hemodynamically unstable, further hypotension must be avoided. IV fluid bolus before the sedation of the patient should be considered. Etomidate or ketamine should be used as induction agents (because propofol causes hypotension). Bolus-dose vasopressors (e.g., phenylephrine), which are vasopressor medications that are used as an immediate temporizing measure in patients with very low blood pressure to prevent hemodynamic collapse, are given as an IV bolus(86).

Patients with conditions such as head injury, hypoxia, or brain hypoperfusion present with agitation as a result of their primary condition, which makes it hard to intubate them. In this case, the use of an induction agent (e.g., ketamine) is used to facilitate preoxygenation before intubation (delayed-sequence intubation)(87).

Extubation is the process of removing the endotracheal tube. The reason and timing of extubation depends on the reason for intubation (general anesthesia or respiratory failure), and it also depends on the respiratory status of the patient and the risk of complications after the extubation is done (e.g., aspiration, excessive secretions, hypoventilation, and upper airway obstruction). To extubate, some criteria need to be met, the patient's vitals must be acceptable, the neuromuscular blockade must be adequately reversed, the patient must have adequate spontaneous minute ventilation, inhalation anesthesia drugs used to maintain sedation (e.g., sevoflurane) are stopped, swallowing and cough reflexes are seen, and the patient is awake and clinically stable. The patient must be oxygenated with 100% fraction of oxygen in inspired air (FiO_2), suction of the airway is performed to minimize the risk of aspiration, the endotracheal tube is removed as the patient exhales, the cuff is deflated, and the securing mechanism is removed(88).

In some cases, intubation is hard to be performed due to a difficult airway that is caused by upper airway distortion, excessive oral bleeding/secretions, limited neck mobility, or limited mouth opening. The inability to intubate the patient, in addition to the inability to ventilate and/or maintain arterial oxygen saturation with either BMV or a supraglottic device, is referred to as a cannot intubate, cannot ventilate scenario (CICV). In most CICV cases, surgical airway management (e.g., surgical cricothyrotomy, needle cricothyrotomy, and emergency tracheostomy) is indicated(89).

Surgical cricothyrotomy allows for the passage of a tube into the trachea through an incision in the skin, cervical fascia, and cricothyroid membrane. A 1.5 cm wide transverse incision is made through the skin, subcutaneous tissue, and cricothyroid membrane. Then a tapering cylindrical instrument (bougie) is inserted and directed toward the feet of the patient. The tube is then placed over the bougie and inserted into the trachea, the cuff is then inflated and the bougie is removed(90). Correct placement is confirmed via positive partial pressure of carbon dioxide present at the end of expiration.

Needle cricothyrotomy is done through the passage of a large bore cannula through the cricothyroid membrane into the trachea. It is commonly used with jet ventilation, which is a type of ventilation in which oxygen is delivered at high pressure to the trachea. Although needle cricothyrotomy supports oxygenation, the ability to ventilate is limited and exhalation is passive and might be insufficient, which may cause gas trapping, progressive hypercapnia, and respiratory acidosis(91,92).

Emergency tracheostomy is performed by a trained practitioner. An opening (stoma) is created in the cervical trachea below the cricoid cartilage(93). Tracheostomy is not performed as much as cricothyrotomy because it might take more time to be done, and it is associated with more bleeding. As it is already known, there is no surgical procedure that is free of risk. Bleeding, pneumothorax. laceration of the posterior tracheal wall and damage to surrounding structures are all examples of complications that might arise during surgical airway procedures(94).

4.2. Bleeding and resuscitation

The team providing help and rescue to a bleeding patient must be familiar with medical terms such as hemorrhage classifications, damage control surgery, and damage control resuscitation.

Hemorrhage is classified into four classes (I, II, III, IV)(95). Class I hemorrhage is the loss of blood that does not affect the hemodynamic status of the patient (heart rate and blood pressure are not affected by the blood loss). Usually, the amount of blood lost is less than 15% of the circulating blood volume. Class II hemorrhage is when the volume of blood lost stimulates sympathetic responses (increase in heart rate) so that organ perfusion is maintained. Usually, the percentage of blood lost is 15-30% of circulating blood volume. IV fluids are usually indicated for class II hemorrhage. And if bleeding continues, then blood transfusions may be required. In class III hemorrhage, 30-40% of blood is lost. Vasoconstriction and tachycardia are not sufficient to maintain blood perfusion to the organs, and metabolic acidosis is seen in arterial blood gas analysis(96). Blood transfusions are needed to restore tissue perfusion and tissue oxygenation. Class IV hemorrhage is a life-threatening hemorrhage. If more than 40% of blood is lost, the patient will be unresponsive and extremely hypotensive. The patient will require massive blood transfusion and rapid bleeding control interventions to decrease the probability of a lethal outcome. These patients often develop trauma-induced coagulopathy and experience a high likelihood of death(97).

Trauma-induced coagulopathy is a complex and multifactorial condition that manifests as abnormal blood clotting and impaired hemostasis, leading to severe bleeding, compromised wound healing, and increased mortality among trauma patients(98). Several factors contribute to the development of this condition(99). Hypoperfusion and tissue damage trigger the release of procoagulant substances, disrupting the normal clotting process. The trauma response activates clotting factors, platelets, and endothelial cells, which can result in the depletion of clotting factors and platelets(100). Inflammatory mediators released after trauma further disrupt the balance between procoagulant and anticoagulant factors(101). Additionally, large-volume fluid resuscitation dilutes clotting factors and platelets, exacerbating coagulation abnormalities(102). Clinical signs include prolonged bleeding, uncontrolled hemorrhage, and poor response to traditional resuscitation methods. Laboratory tests may show abnormalities in standard coagulation parameters. Managing trauma-induced coagulopathy involves controlling bleeding, balanced resuscitation with blood products, administration of clotting factors and antifibrinolytics, and temperature control to prevent the worsening of the coagulopathy(103).

Damage control surgery is an expedited surgical approach aimed at addressing immediate life-threatening conditions and stabilizing the patient's overall condition. The goal is to prevent further injury and provide a window of time for more definitive treatment. After surgery, the patient is transferred to the intensive care unit (ICU) for further monitoring and resuscitation. Subsequent surgeries or procedures may be performed once the patient's stability has been regained to complete necessary repairs or address additional injuries(104).

Damage control resuscitation is a comprehensive approach to managing severely injured patients, particularly hemodynamically unstable patients. It involves a combination of techniques aimed at rapidly controlling bleeding, maintaining tissue perfusion, and optimizing the patient's physiological status to improve survival outcomes and avoid deterioration and death(105). Administering blood products (red blood cell: fresh frozen plasma: platelets) at equal ratios (1:1:1) is a common intervention used in damage control resuscitation that has become an accepted approach and technique in trauma patient management(106). The red blood cells will improve oxygen delivery to ischemic, hypoperfused tissues. Fresh frozen plasma will improve clotting by providing clotting factors V, VIII, and fibrinogen. Platelet transfusions are necessary and beneficial for prolonged resuscitation, as it is in most cases of major trauma injury. Severely hemorrhaging patients require a universal donor blood components transfusion (uncrossmatched blood type O negative) in the early phase of the resuscitation(107). Then the administration of blood products progresses to type-specific, and then to crossmatched transfusion.

It is important not to forget about the potential blood-borne infections such as hepatitis B and C, as well as noninfectious complications (like transfusion-related acute lung injury) when administering blood transfusions to patients(108,109). While there is a risk of transfusion-related reactions, it is important to remember that this risk is minimal compared to the much higher probability of death resulting from severe bleeding.

A massive transfusion protocol (MTP) is an established set of guidelines and procedures implemented in hospitals to facilitate the rapid and efficient administration of blood products to patients who are experiencing or at risk of severe bleeding and require a large volume of blood transfusion(110). It is typically activated in situations where significant blood loss is expected. Specific triggers or criteria are defined to activate the MTP. These criteria may include the estimated blood loss, signs of hemodynamic instability, laboratory values (e.g., hemoglobin level), or clinical decision by the healthcare team. MTP aims to maintain adequate oxygen-carrying capacity, correct coagulopathy, and prevent dilutional coagulopathy, most commonly by administering 1:1:1 blood products(111). These products are typically stocked near the resuscitation area for quick access. The MTP emphasizes the need for timely laboratory testing, including complete blood count, coagulation studies (e.g., prothrombin time, activated partial thromboplastin time), and other relevant tests such as fibrinogen levels or viscoelastic. It also recognizes the importance of continuous reassessment of the patient's condition, laboratory values, and response to transfusion. Adjustments to the blood product ratios or other interventions may be made based on the evolving clinical situation. Lastly, MTP involves clear communication and coordination among members of the healthcare team involved in the transfusion process, including emergency physicians, surgeons, nurses, blood bank personnel, and laboratory staff. It may include designated roles and responsibilities for each team member during the massive transfusion.

During the anesthetic management of a bleeding trauma patient, a key issue that faces the anesthesiologist is the need to avoid sedation agents that cause hypotension, vasopressors, and minimize crystalloid infusions until the bleeding is controlled(112).

4.3. Anesthetic considerations in TBI management

TBIs are categorized as either primary (subdural hematoma, epidural hematoma, intraparenchymal injury, and diffuse neuronal injury) or secondary brain injuries(113). The focus of TBI management is to maintain adequate cerebral perfusion and arterial oxygenation and treating elevated intracranial pressure (ICP)(114). Cerebral perfusion pressure (CPP) is the difference between mean arterial pressure (MAP) and ICP. CPP is considered normal when it is between 60- and 80 mm Hg(115). ICP is normally 7-15 mm Hg(116). If there is an increased risk for elevated ICP (20-25 mm Hg), or if examinations and medical tests show neurological impairment, then an ICP monitor should be placed(117).

Hyperventilation is one way for the treatment of elevated ICP. Cerebral blood perfusion is related to arterial carbon dioxide concentration (decreasing arterial CO_2 causes cerebral vasoconstriction, thus reducing ICP)(118). However, hyperventilation should be avoided in the early stages of the treatment of a hypotensive patient with TBI, because it increases the risk of neurological ischemia(119).

Osmotic diuretic therapy with mannitol is another used method of reducing elevated ICP. Mannitol increases plasma osmotic pressure, which draws extravascular fluid into the vascular system, which will decrease ICP and brain edema(120). The diuretic effect of mannitol should alert the anesthesiologist to monitor the plasma osmolarity and electrolytes (especially potassium)(121).

Barbiturate coma therapy is a treatment approach used in certain cases of refractory intracranial hypertension and elevated ICP. It involves the administration of barbiturate medications, typically thiopental or pentobarbital, to induce a deep coma-like state in the patient(122). Barbiturates decrease cerebral metabolic demand, reduce brain swelling, and lower intracranial pressure by suppressing cerebral metabolism and neuronal activity, which leads to decreased oxygen and glucose consumption by the brain. This reduction in metabolic demand can help protect brain tissue, mitigate secondary brain injury, and potentially improve neurological outcomes.

4.4. Anesthetic considerations in burn management

All patients with severe burns share the inability to regulate their body temperature, making it crucial to maintain a resuscitation environment close to body temperature.

This can be achieved using radiant warming, forced air warming devices, and fluid warming devices(123).

Major burns induce a unique hemodynamic response termed burn shock (a state of normovolemic hypoperfusion). Cardiac output decreases by up to 50% within half an hour of the injury (due to massive vasoconstriction), and a decline in plasma volume and urine output is noted(124).

Intravenous fluid therapy and fast restoration of circulating volume are the key factors improving the survival rates of patients that suffer from major burns. crystalloid fluids (particularly lactated Ringer's solution) are used in the resuscitation of burn injuries. Fluid administration should be maintained throughout the initial 24-hour period of resuscitation(125). The Parkland and modified Brooke are two formulas that require an understanding of the rule of nines (used to estimate burned surface area as a percentage of total body surface area (TBSA)) and are used as a guide to fluid resuscitation in burn injury(125). According to the Parkland protocol, it is recommended to administer a fluid volume of 4 mL/kg/% TBSA within the initial 24-hour period. Half of the calculated volume should be administered within the first 8 hours, while the remaining amount is given over the subsequent 16 hours(126,127). The modified Brooke protocol recommends 2 mL/kg/% TBSA, half of which is administered in the first 8 hours, and the rest is administered during the following 16 hours(128). Both formulas use urine output as a marker for assessing fluid resuscitation. 0.5-1.0 mL/kg/h urine production is an indicator of adequate circulating volume.

Sometimes, the amount of the needed fluid for resuscitation is miscalculated. For example, if the patient is sedated with drugs that cause hypotension, he should be treated with vasopressors and not extra fluid. Another example is when first-degree burns are mistakenly added to the TBSA value, which leads to wrong calculations. If the intravenous fluid therapy volumes increase beyond the intended calculations, a phenomenon called fluid creep might occur. This phenomenon is associated with complications related to fluid therapy, such as abdominal compartment syndrome, and pulmonary complications (e.g., pulmonary edema, pneumonia)(129,130).

Unconsciousness or decreased levels of consciousness in patients with burn injuries can be a sign of carbon monoxide poisoning, which requires mechanical ventilation with a high concentration of inspired oxygen therapy, or, if severe, endotracheal intubation.

Carboxyhemoglobin can be measured via arterial blood gas analysis. Intubation and mechanical ventilation are indicated when carboxyhemoglobin is 20% (80%

hemoglobin oxygen saturation). Death from carbon monoxide poisoning occurs when carboxyhemoglobin levels exceed 60%(131,132).

4.5. Pain management

Pain is an unpleasant sensation that is caused by injury or illness. The distinction between acute and chronic pain is a common method to differentiate pain. Acute pain can be a sign of acute injury and tissue damage. Chronic pain is long-lasting pain that lasts beyond the normal recovery and healing time(133,134). Standardized pain intensity scales (e.g., numerical rating scales, visual analog scales, categorical scales) are used to assess the severity of pain in a clinical setting(135). Pain can be managed in various ways, like painkiller drugs, physical therapy, behavioral therapy, and interventional and surgical methods. There are many categories of analgesic drugs used, like nonsteroidal anti-inflammatory drugs (NSAIDs) and cyclooxygenase-2 (COX-2) inhibitors, paracetamol, and opioids(136).

The management of acute and chronic pain is done according to the World Health Organization (WHO) analgesic ladder, which is a 3-step algorithm that recommends giving nonopioid analgesics (i.e., NSAIDs) for mild pain, a combination of nonopioid analgesics and weak opioids (i.e., tramadol, codeine) for moderate pain, and nonopioid analgesics, weak opioids, and strong opioids (i.e., morphine, fentanyl) for severe pain(137).

Analgesic drugs are given at a minimal effective dose and shortest time so that side effects are minimized. Some analgesics are given orally, like acetaminophen, ibuprofen, and tramadol, while some other analgesics are given parenterally like ketorolac, fentanyl citrate, and morphine sulfate. Peptic ulcers are a common side effect of prolonged use of NSAIDs. Thus proton-pump inhibitors (PPIs) must be considered in patients taking NSAIDs(138). Laxatives and antiemetics are also used to manage other side effects, like constipation, which is commonly noted when using opioids(139). In some cases, outside of the operating room, sedation and analgesia might be required for some procedures (procedural sedation and analgesia), like abscess drainage, electrical cardioversion, and closed reduction of fractures(140). The sedatives and analgesics are used in lower doses than the doses applied in general anesthesia. The goal is to achieve anxiolysis, amnesia, analgesia, and mild to moderate sedation while maintaining airway reflexes and function. Some of the sedative agents used are midazolam, dexmedetomidine, ketamine, etomidate, and propofol. Fentanyl and alfentanil are analgesic agents that are commonly used in procedural sedation and analgesia. These sedative and analgesic drugs may be combined into different regimens. For example, propofol or etomidate plus an opioid (fentanyl or alfentanil), midazolam plus fentanyl, ketamine and midazolam, and some other combinations(141).

Although complications from procedural sedation and analgesia are not very common. However, patients must be closely monitored and not discharged unless their vitals are normal, and they can communicate clearly. Some complications might include oversedation and respiratory depression, aspiration, hypoxia, hypotension, hypoventilation, allergic reaction, nausea, and vomiting(142). That is why procedural sedation must be done by an experienced doctor with advanced skills.

Many patients in the ICU are not capable of communication due to their unique condition. Assessment of pain in such patients requires different approaches than in normal patients. The behavioral pain scale is one method to assess pain in critically ill patients with mechanical ventilation. Facial expressions, mechanical ventilation compliance, and movement of the upper limbs are the evaluated components. A score of 5 or higher is an indicator of significant pain(143). Another method to assess pain in critically ill patients is the critical care pain observation tool. This method evaluates facial expressions, body movements, muscle tension, vocalization in patients that are not intubated, and ventilator compliance in intubated patients. Significant pain is indicated by a score of 3 or higher(144).

The type and severity of pain are the factors that determine the kind of painkillers used in the treatment. In severe cases, IV opioids are the first-line analgesics used in combination with adjuvant NSAIDs(145). In cases of neuropathic pain, gabapentin or carbamazepine can be used(146). It is important to be careful of the side effects of opioids (e.g., central nervous system depression, tolerance, and delirium).

4.6. Management of electrolyte disturbances

Electrolyte imbalances and disturbances like hyponatremia, hypokalemia, hypocalcemia, hypomagnesemia, and hypophosphatemia are commonly seen in the ICU and critically ill patients. Renal and hepatic functions should be tested and taken into consideration when planning a repletion of an electrolyte. It is important to identify and treat the underlying cause of the electrolyte disturbance. The repletion depends on the severity of the patient and the serum level of the electrolyte(147).

Hyponatremia is commonly seen in patients who experienced TBI, in dehydrated patients, or in patients who increased amounts of water intake (i.e., polydipsia)(148). Hyponatremia can be mild (serum sodium levels of 130-135 mEq/L), moderate (125-129 mEq/L), or severe (<125 mEq/L). Mild to moderate hyponatremia can be asymptomatic or cause nonspecific symptoms like headache, fatigue, and dizziness. Severe hyponatremia can cause ataxia, confusion, seizures, respiratory failure, and coma(149).

The correction of sodium in severely symptomatic patients or acute hyponatremia (onset in less than 48 hours) aims for the rapid increase in serum sodium levels with IV hypertonic saline bolus (3% sodium chloride 100 mL bolus over 10 minutes) to avoid neurological damage (e.g., cerebral edema and brain herniation). If the patient has acute hyponatremia without severe symptoms, then an IV hypertonic saline infusion is given (3% sodium chloride 0.5-2 mL/kg/hour). Serum sodium levels are monitored every 2-4 hours after the target levels have been achieved. Urine output must be closely monitored (every hour). Because excessive diuresis might be a sign of overcorrection.

Rapid correction of sodium can be dangerous and cause serious side effects like osmotic demyelination syndrome, and intracranial hemorrhage (due to the shearing forces resulting from water shifts, which can lead to rupturing of the vessels)(150).

Mild and moderate hypovolemic hyponatremia is treated with isotonic saline infusion (0.9% sodium chloride). Euvolemic and hypervolemic hyponatremia is mainly treated with fluid restriction. Loop diuretics (i.e., furosemide 20 mg IV) can be used in hypervolemic hyponatremia(151).

Potassium is repleted via a peripheral IV line, orally, or through central line administration of potassium chloride (in severe cases). The target serum potassium level should be close to 4.0 mEq/L It is always important to check for magnesium levels before potassium repletion (low magnesium levels can increase kidney potassium excretion)(152). If serum potassium levels are less than 2.5 mEq/L, potassium chloride is administered via central line at a rate of 10-40 mEq/hour with hourly monitoring of serum potassium, vitals, and serial electrocardiogram (ECG). If the serum potassium level is 2.5-2.9 mEq/L, oral potassium chloride, if tolerated by the patient, is given (40 mEq orally) every 2-4 hours, or via peripheral line (10 mEq/hour) until target levels are reached (serum potassium levels are monitored at least once daily). In cases of higher serum potassium levels (3.0-3.9mEq/L), potassium chloride is given orally (10-40 mEq) once, or until target levels are reached with daily monitoring of the serum potassium levels)(153,154).

Cautions should be taken while repleting potassium since it can cause dangerous adverse side effects like hyperkalemia, and cardiac arrhythmias. That is why potassium should always be administered slowly.

During magnesium repletion, the target levels of serum magnesium are 1.5-2.4 mg/dL. The oral route of repletion is the preferred method of repletion (if possible); because IV magnesium is slowly distributed into tissues and can be quickly excreted by the kidneys. If the patient's serum magnesium is less than 1 mEq/dL, magnesium sulfate is given intravenously 4-8 g over 12-24 hours, the maximum rate of administering is 1 g/hour. And in the case of hemodynamic instability, 2 g IV bolus is given over 5-10 minutes, then 4-8 g IV (1 g of IV magnesium sulfate has approximately 8 mEq of elemental magnesium). Continuous telemetry and monitoring of serum magnesium 6-12 hours after every administration should be considered in patients receiving magnesium. If the serum levels are 1.0-1.5 mEq/dL, IV magnesium sulfate (1-4 g IV once), or magnesium gluconate 500 mg orally every 8-24 hours, can be given. Repletion of magnesium is often not necessary in patients who have serum magnesium levels of 1.6 mEq/dL or higher, but it can be considered in patients who are at risk (e.g., hypomagnesemia, cardiac arrest). Some adverse effects of magnesium are diarrhea, nausea, vomiting, low blood pressure, and cardiac arrest (hypermagnesemia can cause cardiac arrest)(155–157).

The measuring of ionized calcium levels is one common and efficient way to measure physiologically active calcium. It is important to measure and correct the albumin levels when testing serum calcium levels because a decrease in albumin (hypoalbuminemia) will decrease serum calcium levels. When there is an attempt to correct hypocalcemia, repletion will target serum calcium levels to about 8.5 mg/dL. IV calcium gluconate (1-2 g IV bolus administered over 10-20 minutes, then 5.4-21.5 mg/kg/hour IV infusion) is given when corrected serum calcium is equal to or less than 7.5 mg/dL. Serum calcium levels are monitored every 4-8 hours with continuous telemetry and vital signs monitoring. If corrected serum calcium levels are between 7.6 mg/dL and 8.4 mg/dL, then repletion via oral route is preferred. Calcium carbonate/citrate (1500 mg) is given orally daily(158,159). Adverse effects of calcium repletion may include local irritation, soft tissue calcifications, hypotension, and bradycardia.

Hypophosphatemia is commonly seen in critically ill patients due to the increased metabolism and high phosphate excretion in the kidneys. The serum phosphorus levels should normally be higher than 3 mg/dL. IV phosphate (0.48-1.00 mmol/kg body weight over 4-6 hours) is given to patients with serum phosphorus levels less than 1.6 mg/dL. Continuous telemetry and serum phosphorus monitoring (6 hours after infusion) should be considered in all critically ill patients receiving phosphate. If serum phosphorus levels are 1.6-2.2 mg/dL, phosphate is administered IV (0.32-0.64 mmol/kg over 4-6 hours). And if serum phosphorus levels are 2.2-3.0 mg/dL, then a lower dose of IV phosphate is administered (0.16-0.32 mmol/kg). It is important to test the potassium levels while considering phosphate repletion. If potassium levels are less than 4.0 mg/dL, then phosphate should be administered as potassium phosphate (careful with hyperkalemia). And if serum potassium levels are equal to or higher than 4.0 mg/dL, phosphate is then administered as sodium phosphate. Some adverse effects of phosphate repletion include confusion, arrhythmias, sore throat, precipitation with calcium, and renal damage(160–162).

5. Conclusion

Trauma remains one of the leading causes of morbidity and mortality in all age groups and is the primary cause of death in the young. A coordinated and comprehensive approach is crucial for maximizing the chances of survival and full recovery in trauma patients. This approach encompasses various stages, including initial scene care, transportation, resuscitation, surgery, intensive care, and rehabilitation.

Trauma anesthesiologists contribute to caring for the trauma patient by performing a wide range of medical procedures, including advanced airway management, vital signs monitoring, pain management, fluid and electrolytes regulation, and resuscitation.

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7. Biography

Kareem Younis, born on the 8th of January 1998, is a highly motivated and ambitious individual and a reliable medical student. Once he completed his primary and secondary education in Israel, he learned the German language in Munich, Germany. He then moved to Zagreb, Croatia to begin his medical studies in English at the University of Zagreb in September 2017. During his medical studies, he volunteered in various departments in different hospitals in the city of Zagreb and his homeland, which made him gain experience and further improved his personality and character. Being able to speak five different languages fluently and having vital work experience with both medical practitioners and patients, he possesses all the qualities, aptitude, and enthusiasm to make a positive contribution to the medical field. After graduating, he will be looking forward to honing and enhancing his current skill set and applying it to his future career in medicine.