MALAYSIAN SOCIETY OF ANAESTHESIOLOGISTS YEARBOOK 2021/2022

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Foreword

The MSA Yearbook 2021/2022 provides comprehensive literature on trauma and its effects on Anaesthesia, Intensive Care, and Pain Medicine. Trauma is one of Malaysia's leading causes of mortality and morbidity. Patients involved with trauma can present to anaesthesiologists and intensivists in many situations. Therefore, we must keep abreast with the knowledge of caring for patients with trauma to improve their outcomes.

The MSA encourages our fraternity to write. Thus, I am delighted to see many new authors who have contributed to this publication. We believe our role in improving Anaesthesia and Intensive care in Malaysia has many façades. A wise word from Martin Luther was, "If you want to change the world, pick a pen and write". I congratulate both the editors, Associate Professor Dr Rufinah Teo and Associate Professor Datin Dr Siti Nidzwani Mohamad Mahdi, for the insightful and informative articles on this issue. I would also like to thank all the authors for taking the time to write their articles. Last but not least, sincere gratitude to all the reviewers for sharing their experience in making this book a success.

I hope all our members enjoy reading this year's publication as much as I do and will benefit from all the updates provided.

Professor Dr Ina Ismiarti Shariffuddin
President
Malaysian Society of Anaesthesiologists

Preface

The first Malaysian National Trauma database was launched in 2006 to determine, evaluate and prepare guidelines for trauma care. It is timely that this year's edition is centred around trauma care, a well-established and continually evolving subspecialty in anaesthesia field. Our collective thanks to all authors and reviewers who were enthusiastic, dedicated and wonderful to work with. Thank you to the readers too, we appreciate your continuing interests. Yearbook articles are frequently cited and downloaded, provides a venue for longer, in-depth explorations of developments within our discipline.

There are eleven articles in this Yearbook, covering trauma management in a series of different scenarios, either pre or intra-hospital care; for a variety subset of the population. Readers will have the first experience of a field hospital and strategies when managing critically ill patients, including COVID-19. There are also article updates related to nutrition and blood management. We hope this year's edition will be both useful and bring genuine clinical and academic insights to all our readers to improve its diversity when dealing with trauma care.

Many thanks for this opportunity.

Associate Professor Datin Dr Siti Nidzwani Mohamad Mahdi
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Transport for Critically Ill Trauma Patient

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INTRODUCTION

Transporting critically ill trauma patients may involve transferring patients from the trauma site to the medical centre, within the hospital facility or interfacility. The movement is deemed necessary for investigations or treatment not available at its location or for an increased level of care. The guidelines for transfer and handing over of a critically ill trauma patient are not standardised. Most of the guidelines are regional or applied locally, mainly due to the unique availability of resources and facilities. The decision for transfer is preferably made by the team leader of the unit, and both the referring and the receiving teams have established communication to ensure continuity of care. Any patient's movement requires good planning and appropriate accompanying personnel. It is a risky procedure that can significantly contribute to additional morbidity or mortality.

TRIAGE OF PATIENTS FOR TRANSPORT

The word triage originates from the French verb *trier*, which means *"to sort"*. In trauma management, it is an important phase to prioritise treatment, especially when resources are limited, lack of information, and the critically ill are involved.[1] The aim of triaging differs during field triage, where priorities are according to the severity of injuries and for immediate life-saving management, while the aim in disaster triage is for doing "the greatest good for the greatest number" of casualties. A four-step trauma field triage decision scheme is often applied to identify casualties requiring transportation directly to a trauma centre (Figure 1).

It is recommended that triage should be based on a combination of physiologic and anatomic parameters, along with the mechanism of injury, comorbidities, and demographics.[2] For example, anatomic triage decisions based on the patient's visible injuries may not be able to rule out severe visceral injuries; on the other hand, a patient may present with stable physiologic parameters but have visible anatomical signs which may be a potential risk of developing later complications.

Step 1: Physiological Criteria Glasgow Coma Scale, vital signs
Step 2: Anatomical Criteria Penetrating injuries i.e. to the head and neck, body and limbs Thorax, Long-bone, Spine/spinal cord, Pelvic *fractures, crushed, degloved, pulseless extremity, amputation
Step 3: Mechanism of Injury Criteria Falls, road traffic trauma, burns, explosion, natural disaster
Step 4: Special Consideration Criteria Elderly, Paediatrics, Pregnancy > 20 weeks high risk for rapid deterioration *based on EMS provider judgment

Figure 1: Four-step triaging for transport of trauma patients.
[2]Adapted from Practice management guidelines for the appropriate triage of the victim of trauma. Eastern Association for the Surgery of Trauma, 2010;1-34

Beate I.L et al. concluded that there is no sufficient evidence that evaluates whether the pre-hospital triage systems are effective or if there are any superior systems which are more effective than others, or whether it is effective to use the same triage system in different settings of an Emergency Management System (EMS).[3] This lack of validated efficacy was related to various aspects of care including patient safety and satisfaction, user-friendliness of the source use, achievement of targeted goals, and the quality of the information between the different settings of the EMS.

MODE OF TRANSPORT

Critical care regionalisation is becoming more common, necessitating the transport of these critically ill patients to a tertiary care centre aiming to improve outcomes (Figure 2). In our local setting, most of the interfacility transport is via land transport using an ambulance. Although not often, air transport or transport using waterways is carried out in certain regions. The different modes may post different risks and special considerations should be taken. Air transport may impose an added risk to the patient's physiological instabilities. Regardless of the mode of transport, it must be equipped with all the necessary medication, equipment, and personnel required for resuscitation and ongoing treatment.

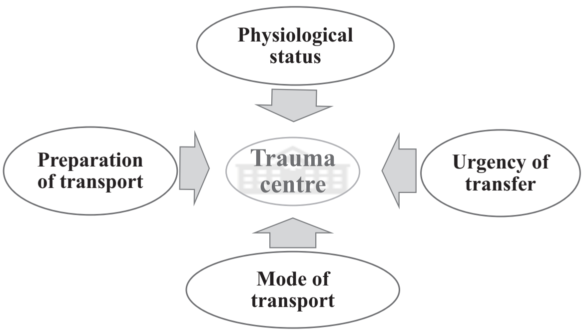

Figure 2: Preparing for transporting of ill trauma patients

A written and informed consent along with the reason to transfer must be documented. In some centres a dedicated team is established to coordinate and ensure a smooth process of the transfer. Prior to the transport, direct communication between the transferring and receiving centre should be agreed and early sharing of information on the patient's condition, treatment and resuscitation given, reasons and mode of transfer, and the timeline of the transfer, should be in formal documentation. The date/time for arrival to the destination should be also agreed on before departure.

PATIENTS TRANSPORT

Patients' and providers' safety, as well as the benefits and cost-effectiveness of the mode of transport, are key considerations when assessing whether a transport should proceed. There is evidence showing that implementing the use of a checklist for the transport process can improve the quality and compliance to the safety guidelines (Figure 3 and 4).[5] It is almost a routine procedure in an intensive care area to transport trauma patient within the hospital area i.e. for diagnostic imaging, for surgical procedures in the operating theatre, or to another high dependency care area. These patients often have reduced or exhausted physiological reserves and are in life-threatening conditions.[4] Transporting such patients exposes them to additional risk and the service requires highly trained and skilled personnel.[5,6] It is important to have a prior assessment, optimisation, and appropriate planning for the patient to ensure safe transport. In addition, having essential equipment and effective liaison between referring, transporting, and receiving staff at the senior level is as important.[1] Adverse events that may happen during transport can be minimised with appropriate in advance communication and planning.[5,7]

It is recommended to have minimum standards of monitoring during the transport which include appropriate trained and skilled health personnel, oxygen pulse saturation (SpO2) and end-tidal carbon dioxide in ventilated patients, electrocardiograph (ECG), and non-invasive blood pressure, and temperature monitoring.[6,7] All the monitoring, medications and equipment need to be established before the transfer. The person in charge should ensure all medication including resuscitation drugs, inotropes, vasopressors, muscle relaxants, sedatives, and analgesics are in adequate supplies. Some of these drugs need to be prepared earlier in pre-filled syringes, ready for use. It is also important to ensure all electrical equipment is functioning with adequate battery power. When ventilation is required, a portable ventilator adequate with the appropriate mode of ventilation, respiratory rate, inspiratory: expiratory ratio, display of tidal volume, inspired oxygen fraction and airway pressure with alarms should be prepared.

Most transport of critically ill is to have at least two skilled personnel with sufficient training in airway management, advanced cardiac life support and critical care. The standard care required during the transport will depend on the patient's status. When a doctor is not available for the transfer of an unstable patient, a concerned physician should be available at all times for contact by the transport team.

The route for transport should be identified, where lifts and corridors, and accessibility of the facility are secured as necessary prior to transfer. All activities of patient's management during the transport should be documented, preferably using standardised format. It is a legal document that must include reason to transfer, name and designation of referring and receiving clinician, details and status of vital signs before the transfer, clinical events during the transfer and the treatment given. The handing over at the receiving centre should be done formally, between the transferring and receiving team including both doctors and nurses. All related investigations and diagnostic reports should be included. These documents should be audited regularly for quality assurance purposes.

ANTICIPATION OF PROBLEMS AND COMPLICATIONS

The benefits of transport must outweigh the risks, in order to optimise or improve care. Complications and problems may arise from multifactorial causes including the existing injuries which may be exacerbated during the transport, factors related to the clinical management, facilities during the

AIRWAY
Prior Cormack Lehane (CL) grade if known : ETT size : ETT depth:
ETT taped/ device checked and secured
Cervical spine cleared T-L spine cleared? If no→ logroll for transfers
Tracheostomy tube cuffed and secured (if present) Tracheostomy tube size:
BREATHING
Ventilator settings: Mode: RR: TV: IP/PEEP: FIO2: ETCO2:
Oxygen tank correct size and full
HME filter connected
Equipments present: ETT tube laryngoscope bag valve mask appropriate size mask suctioning device
CIRCULATION
Access iv line sufficient, secured, flushed and working
Monitorings on and alarm set Monitorings displayed on monitor: BP HR SPO2 ETCO2 NIBP IABP ECG
Emergency medications available: (Atropine, Adrenaline, Ephedrine)
Sufficient IV Medications: sedations inotropes antibiotics other Sufficient IV fluids / blood products
DISABILITY/OTHER
Lines, drains and tubes untangled and secured
Patient's notes and consent available
Coordinate with department of transfer before departing
UPON RETURN TO ICU
Observations during transport documented
Patient's condition handed over to ICU Nurse and Doctors in charge
Nil adverse event Adverse event present: Specify: ___________________

Figure 3: An example of transport checklist during preparation for transport

OBSERVATIONS DURING TRANSPORT:

Time / Vital Signs	Pre-Transport	20 Mins	40 Mins	60 Mins	Post Transport
HR/Rhythm					
BP					
SPO_2					
RR					
Vent MODE					
FiO_2					
PEEP/PS					
GCS					
PUPILS L/R					

**To fill only the clinical parameters recorded in ICU*

ADVERSE EVENTS DOCUMENTATION IF PRESENT:

ADVERSE EVENTS	YES (√)	Remark
Physiological alterations		
Variation in HR ≥ 20 BPM		
Hypertension		
Hypotension		
Variation in RR ≥ 10 RPM		
Agitation		
Saturation drop < 90%		
Hypoglycaemia		
Bleeding		
Vomiting		
Equipment failures		
End of O_2 cylinder		
End of the CIP battery		
Team failures		
Interrupted ventilation for 1 minute		
Medication CIP interrupted		
Loss of venous access		
O_2 tank accidentally closed		
Moved to the wrong location		
Lack of communication between shifts		
Medication error (wrong patient)		
Secretion in the orotracheal tube		
Delays		
Delayed attendance		
Obstacle on the transport path		
Lift delay		
Transported in bed not compatible with the lift		
Team disagreement about medication		
Door of the destination room locked		

*CIP= Continuous infusion pump

Figure 4: An example of transport checklist during preparation for transport

transport and associated environmental factors which make it difficult to predict risk profile. Complications may include loss of airway, oxygen desaturation, haemodynamic instability and importantly interruption of treatment.[8]

When there are potential respiratory or airway difficulties, a special attention to airway stabilisation and devices related to airway adjuncts should be readily available i.e. in cervical spine injuries. Spinal and brain injury are among the most critical problems necessitating special attention. Even minor manipulation may result in propagation of injury.[9,10] Orthopaedic traction or splinting devices may not completely immobilise fractures which may result in secondary injury. In patients with higher brain injury severity scores showed a greater risk of secondary insults.[8,9] Although most of transports are scheduled and planned, complications e.g. oxygen desaturation, bronchospasm, ventilator asynchrony, intracranial hypertension, and arrhythmias may still happen.[11-14] Maintaining ongoing resuscitation is challenging; correction of acid-base derangement, glycaemic control, haemodynamic stability and appropriate analgesia and sedation is also as important.

CONCLUSION

Critically ill trauma patients should only be transported when the benefits outweigh the risks. When needed, it should be appropriately planned, organised, scheduled and, include all necessary equipment and trained personnel.

References

1. Debacker M, Hubloue I, Dhondt E, Rockenschaub G, Rüter A, Codreanu T, et al. Utstein-style template for uniform data reporting of acute medical response in disasters. *PLoS Curr* 2012;**4**:1-40

2. Barraco RD, Chiu WC, Bard MR, Dieter M, Iii TZH, Hoff WS. Practice management guidelines for the appropriate triage of the victim of trauma. Eastern Association for the Surgery of Trauma 2010;1-34

3. Beate I.L., Hilde H.H. and Gunn E. Triage systems for pre-hospital emergency medical services - a systematic review. *Scand J Trauma Resusc Emerg Med* 2013;**21**:28. doi: 10.1186/1757-7241-21-28

4. Guideline for Transport of Critically ill patients. 2015.. 2nd Edition. Australasian College of Emergency Medicine., Australian and New Zealand College of Anaesthetists. & College of intensive Care Medicine of Australia and New Zealand

5. Williams, P., Karuppiah, S., Greentree, K. & Darvall, J. 2020. A checklist for intrahospital transport of critically ill patients improves compliance with transportation safety guidelines. Australian Critical Care 33(1):20-24

6. Whiteley, S., Macartney, I., Mark, J., Barratt, H. & Binks, R. 2011. Guidelines for the transport of the critically ill adult. 3rd ed. Intensive Care Society

7. Lightenberg, J.J., Arnold, L.G., Stienstra, Y., Van der Werf, T.S., Meertens, J.H., Tulleken, J.E. & Zijlstra, J.G. 2005. Quality of interhospital transport of critically ill patients: A prospective audit. Critical Care 9(4):446-451

8. Knight PH, Maheshwari N, Hussain J, Scholl M, Hughes M, Papadimos TJ, Guo WA, Cipolla J, Stawicki SP, Latchana N. Complications during intrahospital transport of critically ill patients: Focus on risk identification and prevention. *Int J Crit Illn Inj Sci* 2015 Oct-Dec;**5**(4):256-64. doi: 10.4103/2229-5151.170840. PMID: 26807395; PMCID: PMC4705572

9. Joosse P, Saltzherr TP, van Lieshout WA, van Exter P, Ponsen KJ, Vandertop WP, et al. Impact of secondary transfer on patients with severe traumatic brain injury. *J Trauma Acute Care Surg* 2012;**72**:487-90

10. H. Conrad BP, Rossi GD, Horodyski MB, Prasarn ML, Alemi Y, Rechtine GR. Eliminating log rolling as a spine trauma order. *Surg Neurol Int* 2012;**3**(Suppl 3):S188-97

11. A. Parmentier-Decrucq E, Poissy J, Favory R, Nseir S, Onimus T, Guerry MJ, et al. Adverse events during intrahospital transport of critically ill patients: Incidence and risk factors. *Ann Intensive Care* 2013;**3**:10

12. B. de Lassence A, Timsit JF, Tafflet M, Azoulay E, Jamali S, Vincent F, et al. Pneumothorax in the intensive care unit: Incidence, risk factors, and outcome. *Anesthesiology* 2006;**104**:5-13

13. C. Mazza BF, Amaral JL, Rosseti H, Carvalho RB, Senna AP, Guimarães HP, et al. Safety in intrahospital transportation: Evaluation of respiratory and hemodynamic parameters. A prospective cohort study. *Sao Paulo Med J* 2008;**126**:319-22

14. E. Damm C, Vandelet P, Petit J, Richard JC, Veber B, Bonmarchand G, et al. Complications during the intrahospital transport in critically ill patients. *Ann Fr Anesth Reanim* 2005;**24**:24-30

The Traumatic Parturient

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INTRODUCTION

Trauma is one of the leading causes of non-obstetric maternal mortality worldwide and is estimated to complicate approximately 1 in 12 pregnancies.[1] Pregnant women are 1.6 times more likely to die of trauma than non-pregnant women with similar traumatic injuries.[2] Domestic violence (DV) or intimate partner violence (IPV) and motor vehicle accidents (MVA) were found to be the two predominant mechanisms of trauma in this group of patients, followed by falls, toxic exposure, penetrating trauma, homicide and suicide.[3] Assessment and management of traumatic parturient impose unique challenges as it involves two lives, the mother and the foetus. Trauma management requires consideration of several aspects specific to pregnancy, such as altered maternal physiology and anatomy, exposure to radiation or potential teratogens, and the need to assess foetal well-being in addition to the usual management of trauma-related injuries. A multidisciplinary approach is essential to ensure optimum care and, hence, a favourable outcome for both the mother and the foetus. In this article, we will be highlighting obstetric trauma from the aspect of assessment, management and preventative measures, as well as an anaesthetic role in managing trauma in pregnancy.

PHYSIOLOGICAL CHANGES DURING PREGNANCY

Pregnancy is associated with significant changes in every organ system. To recognise abnormal vital signs and injuries in a pregnant patient, it is necessary to understand anatomical and physiological changes during pregnancy.

Cardiovascular changes

- Cardiac output (CO) increases by 35-50%.
- Maternal heart rate increases by 15 to 20 beats per minute.
- Diastolic blood pressure reduces by 15 to 20% in the first half of the pregnancy and returns to baseline during the third trimester.

These physiological changes may mask signs of hypovolaemic state, thus leading to a potentially delayed recognition of shock. They may have sustained significant blood loss of up to 30% of their circulating volume before showing notable changes in their vital signs.[4,5] Foetal distress is a sign of uterine hypoperfusion and can precede maternal evidence of haemodynamic compromise.[6]

Respiratory changes

- Oxygen consumption increases by up to 20% at term.
- Respiratory rate and tidal volume increase leading to an increase in minute ventilation by 45-50%, thus lower partial pressure of carbon dioxide of 30mmHg.
- Elevated diaphragm as a result of growing uterus reduces functional residual capacity by 20%.
- Airway oedema and vascular engorgement.

These changes may lead to difficult airway access, and ventilation followed by rapid desaturation during induction of anaesthesia and increased risk of bleeding during airway instrumentation.[4,5]

Haematological changes

- Plasma volume rises by 50% at term.
- Red cell mass increases by 25-33% at term.
- Elevated clotting factors (importantly factor VII and fibrinogen).
- Mild thrombocytopaenia (100-150 x 10^9/L) is a normal finding.

A disproportionate rise in plasma volume compared to red cell mass results in dilutional anaemia during pregnancy, which may render pregnant patients more vulnerable to acute haemorrhage. Elevated levels of clotting factors predispose them to develop thromboembolism. Because it is expected to have elevated fibrinogen levels at term, a normal fibrinogen level may indicate disseminated intravascular coagulation.[4,5]

Gastrointestinal changes

- Lower oesophageal sphincter tone is reduced.
- Gastric acid secretion and residual volume of gastric content are increased.
- Gastric motility is reduced, precipitated by labour, pain, anxiety and administration of opioids.

All the above changes increase the risk of regurgitation and aspiration in pregnancy.[4,5]

Uterine changes

- In the first trimester, the uterus is relatively protected from external injury by the bony pelvis and its thick-walled anatomy. Further uterine enlargement into the abdomen after 12 weeks of pregnancy makes it more exposed to injury.
- Uterine blood flow increases by more than 10-fold (600-1000 ml/min) at term and is not autoregulated.
- The pelvic vasculature is dilated in pregnancy.

The peritoneum stretches markedly with the growing uterus and, by the third trimester, becomes less sensitive to peritoneal irritation. These physiological uterine changes predispose pregnant women to an increased risk of massive blood loss and rapid exsanguination from uterine or pelvic injuries.[4-6]

ASSESSMENT AND MANAGEMENT OF OBSTETRIC TRAUMA

The initial focus of trauma management during pregnancy should be geared towards maternal stabilisation, as foetal outcomes are directly related to early maternal resuscitation. A multidisciplinary approach to managing such cases should begin early to achieve optimal results for the injured gravida and the foetus. Upon trauma notification, vital information should be obtained from the notifier using the MIST mnemonic, an acronym widely used by first aiders when handing over casualty to the next level of emergency care.[7]

Four parts of MIST are:

- Mechanism of injury.
- Injuries found or suspected.
- Signs: respiratory rate, pulse, blood pressure, peripheral oxygen saturation (SpO2), Glasgow Coma Score (GCS) or AVPU (Alert, response to Voice, response to Pain, Unresponsive).
- Treatment given.

Quick estimation of gestational age should be done early as it will determine the direction of subsequent management. Fundal height will give a rough estimation of gestation, (Figure 1a). Enlargement of the uterus beyond 18 to 20 weeks is associated with compression to the aorta and inferior vena cava (Figure 1b). Hence women with estimated gestation beyond 20 weeks should be nursed in a left uterine displacement (LUD) of 15 to 30 degrees tilt (Figure 1c) to reduce the likelihood of supine hypotension and decreased uterine perfusion.

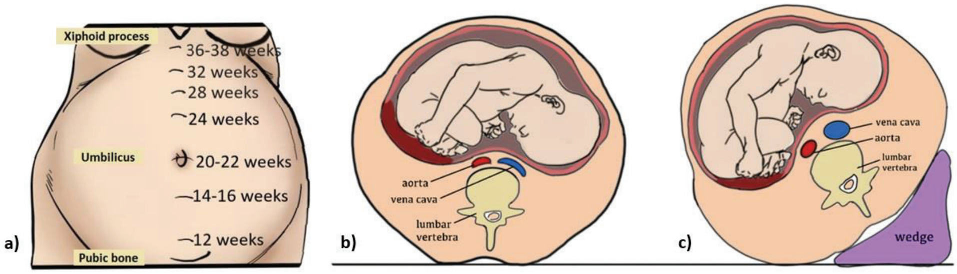


Figure 1: a) Estimated gestational age from fundal height, b) Aortocaval compression by the gravid uterus, c) Relief of aortocaval compression by left uterine displacement

Rapid and efficient assessment and management of life-threatening conditions should be consistent with the advanced trauma life support protocols (ABCDE survey: airway, breathing, circulation, disability, and exposure).[7]

PRIMARY SURVEY

Airway

Airway assessment with cervical spine protection should be undertaken to avoid catastrophic consequences given a potential cervical spine fracture. Pregnant women desaturate more rapidly and are prone to hypoxic injury. Early intubation should be considered when SpO_2 falls below 94% or a GCS of less than 9. Difficult airway equipment should be made available, and the presence of experts in managing the airway cannot be understated. This is owing to the fact that the obstetric population has a four times higher risk of difficult/failed intubation than the non-obstetric population. Trauma makes the airway even more challenging due to potential airway distortion, the presence of debris such as blood or vomitus and oedema from inhalation or head injury.[7-9]

Breathing

High-flow oxygen is advisable to maintain SpO_2 of more than 95% as maternal hypoxia is associated with poor foetal outcomes. Life-threatening injuries such as tension pneumothorax should be excluded. If a chest tube is indicated, the insertion point is recommended to be at least one or two intercostal spaces above the usual landmark of the fifth intercostal space due to the elevation of the diaphragm during pregnancy.[3,7,10]

Circulation

Two large-bore cannulas, preferably 14 G or 16 G, should be inserted to facilitate initial rapid fluid infusion and eventual blood transfusion if necessary. According to the standard trauma protocols, fluid and blood products should be administered during resuscitation to maintain a haematocrit at 25 to 30% and urine output of more than 0.5 ml/kg/hour. Initial resuscitation of up to 1 to 2 litres (20 ml/kg) can be done using a crystalloid solution. If minimal response to fluid resuscitation is observed, packed red blood cells transfusion is advised. In a dire emergency, Group O Rhesus-negative blood should be used while waiting for crossmatched blood.[11]

Disability

Evaluation of conscious level can be done using the GCS or AVPU assessment. Metabolic causes leading to impairment of consciousness should be excluded.

Exposure/Environment

The patient must be fully exposed to assess for injury. Hypothermia should be prevented by keeping the patient in a warm environment and by warming the intravenous fluid to maintain the patient's body temperature above 36.5 degrees Celcius.[7]

SECONDARY SURVEY

Once the primary survey and interventions for life-threatening injuries have been carried out, a secondary survey should commence. A comprehensive head-to-toe examination should take place, focusing on signs of injury around the pelvis, which include tenderness over the uterus, uterine contractions, vaginal bleeding, or ruptured membranes.[11]

Blunt abdominal trauma is associated with poor pregnancy outcomes, such as intraperitoneal or retroperitoneal haemorrhage. It can also cause intrauterine foetal demise mainly due to abruptio placenta or other types of placental injury, direct foetal injury, uterine rupture, or as a result of maternal shock or death.[12] Abruptio placenta, either concealed or revealed, may lead to massive haemorrhage and coagulopathy.

In cases of penetrating trauma, complete undressing of the victim is paramount to ensure vigilant inspection of all entrance and exit wounds can be performed. The impact of high-velocity bullet trauma is often unpredictable, and multiple injuries may co-occur. The decision to perform a surgical exploration depends on the injury site, gestational age, and maternal and foetal vital signs. Due to the postulated cephalad displacement of the bowel by the gravid uterus during pregnancy, penetrating trauma to the upper abdomen can lead to a more complex bowel injury.[13] Awwad et. al. looked into the value of selective laparotomy in penetrating abdominal trauma. The retrospective survey reviewed cases of pregnant women with penetrating abdominal injuries during the Lebanese civil war and found that visceral injuries were present when the missile entry point was in the upper abdomen or the back. In contrast, visceral injuries were absent when the entry point was below the uterine fundus anteriorly. Hence, in the case of penetrating trauma to the upper abdomen, surgical exploration is generally the best approach, whereby a more conservative approach remains an option in a case of a lower abdominal injury, provided a reassuring foetal-maternal status is established.[14]

IMAGING DURING OBSTETRIC TRAUMA

Diagnostic imaging should be performed if clinically indicated and should not be withheld because of concerns of harmful radiation effects on the foetus.[3] Foetal shielding decreases radiation exposure and should be used whenever possible.[7]

Ultrasonography is a rapid and non-invasive tool that can provide obstetrical information such as gestational age, placental localisation, foetal well-being and viability. Its portability does not require the patient to be transported out from the trauma unit for the scan. Although it is a valuable tool for assessment in trauma settings, it is unreliable in predicting adverse outcomes as it may miss 50 to 80% of traumatic abruptions. Therefore, ultrasound should only be used to complement electronic foetal monitoring (EFM).[3,10]

Focused Assessment with Sonography for Trauma (FAST scan) should be considered if equipment and personnel trained in its use are available. Although this point-of-care examination has a reasonable specificity (≥90%) for detecting intraperitoneal free fluid (positive FAST scan), a negative FAST scan does not preclude a bleed which may eventually become significant. A repeated examination should be considered in highly suspected cases.[10,15]

Focused Assessment with Sonography for Obstetrics (FASO) is a modified version of FAST which focuses on the placenta and uterine cavity, bilateral hypochondria and the pouch of Douglas. A combination of clinical evaluation and FASO may facilitate the decision-making process in managing traumatic parturients.[16]

Computed tomography (CT) scan allows for the assessment of multiple organ systems in a stable patient and offers more accurate information, such as intracranial bleed or abruptio placenta in a negative FAST scan. CT studies of the abdomen, pelvis and lumbar spine should be ordered prudently and only when their use is expected to benefit the patient as these may subject the foetus to 3.5 rad (radiation absorbed dose). The American College of Obstetricians and Gynecologists (ACOG) has specifically reviewed the issues of concern regarding radiation exposure to the developing foetus and highlighted that foetal exposure to radiation dose <5 rad is not associated with an increased risk of foetal loss, congenital disabilities, or growth restriction.[15] Therefore, if these techniques are necessary to answer a relevant clinical question, especially when maternal benefit outweighs the potential foetal risk, their use should not be withheld during pregnancy.

Foetal monitoring

In cases of severe maternal trauma, abruptio placenta complicates nearly 50% of cases, compared to a 1 to 5% incidence in minor or trivial trauma cases. The shear injury resulting from the shear force between the myometrium and placenta is the hypothetical mechanism for the abruptio placenta due to trauma. Since abruption usually becomes apparent soon after the injury, foetal monitoring should be initiated once the mother is stabilised. The EFM may predict abruptio placenta in trauma victims beyond 20 weeks of gestation. The ideal duration for post-trauma monitoring has not been ascertained, with recommendations ranging from 4 to 48 hours.[3] The ACOG recommends a minimum of 2 to 6 hours of monitoring post-trauma.[13] In traumatic parturient with adverse factors such as uterine contraction, a non-reassuring foetal heart rate pattern, vaginal bleeding, significant uterine tenderness or irritability, severe maternal injury, or a ruptured amniotic membrane should be admitted for observation and further assessments.[13]

Foetal-maternal haemorrhage (FMH)

Foetal-maternal bleeding occurs in 10 to 30% of trauma victims and can lead to foetal demise, foetal cardiac arrhythmias, abrupt foetal anaemia, and cardiac failure. Abdominal trauma is a potential sensitising event, and the presence of as little as 0.01 ml of foetal blood can induce alloimmunisation in Rh-negative mothers. In most cases of traumatic maternal-foetal haemorrhage, the estimated volume of foetal blood in the maternal circulation is less than 15 ml. Therefore, administration of 300 mcg (1 vial) of anti-D immunoglobulin within 72 hours of injury may protect against alloimmunisation in the vast majority of Rh-negative mothers.[10,11,17]

Kleihauer-Betke (KB) test has been used to quantify the amount of foetal blood cells in the maternal circulation. Despite being used in many institutions as a standard component of trauma evaluation, it has a high incidence of false-positive results, especially in Rh-positive women. Flow cytometry, a simpler and more accurate technique for detecting FMH, has also been proposed as a valuable adjunct to differentiate the true positive KB test from the false positive.[11]

Cardiopulmonary resuscitation (CPR) and perimortem Caesarean section (PMCS)

Maternal resuscitation in a cardiac arrest situation follows the standard trauma and Advanced Life Support (ALS) but with some modifications and special consideration for pregnant patients, as listed in Table I.

One of the essential modifications in maternal resuscitation is LUD or manual uterine displacement to relieve aortocaval compression. Manual uterine displacement (Figure 2) is preferable over LUD as it avoids total tilt of the body, allows easier airway access, ease of defibrillation, and enables more effective chest compression.[7,11]

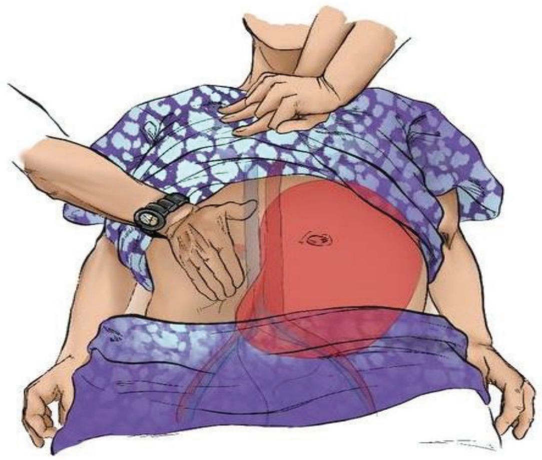


Figure 2: Manual uterine displacement during maternal resuscitation

Perimortem Caesarean section should be considered when the uterine fundus is palpable at or above the level of the umbilicus, i.e., from approximately 20 weeks, to improve resuscitative effort. It should be performed if no return of spontaneous circulation (ROSC) is achieved at 4 minutes of cardiac arrest and delivery is completed by 5 minutes.[8,18,19]

A proposed approach for evaluation and management of traumatic parturient is summarised in Figure 3.

ROLE OF ANAESTHESIOLOGIST IN OBSTETRIC TRAUMA MANAGEMENT

Anaesthesiologists play a vital role within the orchestra of multidisciplinary teams managing pregnant patients with major trauma. They are experienced in advanced airway management, management of critically ill, provision of anaesthesia for surgical interventions, and management of pain.

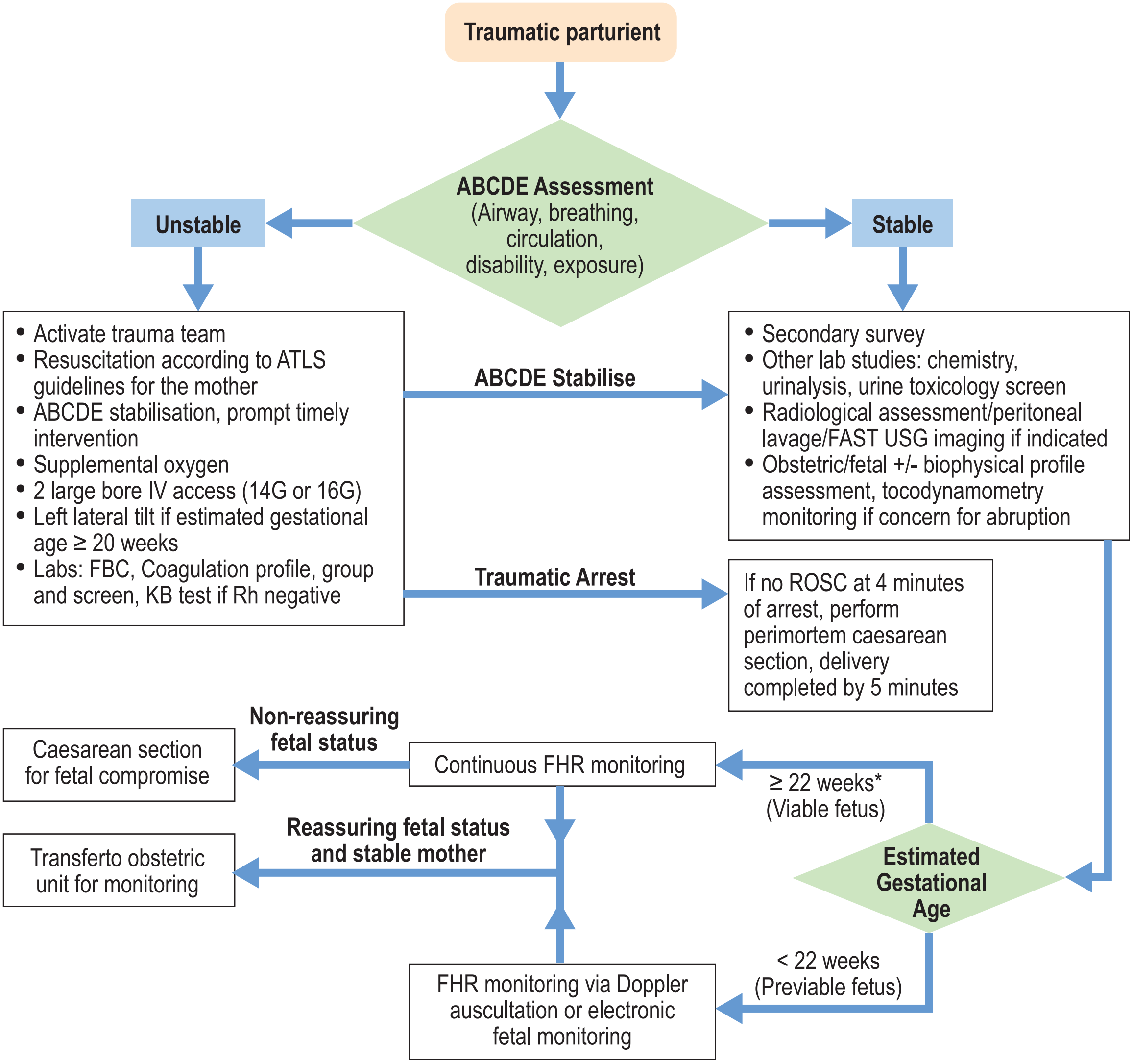
Table I: Modifications of cardiopulmonary resuscitation in traumatised pregnant patients

Modification to basic / advanced life support	Rationale
Rapid notification to the maternal cardiac arrest response team* and request specialised equipment† to be brought over.	Best care can be provided by a multidisciplinary team. PMCS can be performed immediately if ROSC is not achieved by 4 minutes.
Left lateral tilt 15 to 30 degrees positioning or continuous manual uterine displacement.	To relieve aortocaval compression.
Chest compression slightly above the centre of the sternum.	Gravid uterus causes cephalad displacement of organs within thoracic cavity.
Insert intravenous access above diaphragm.	Aortocaval compression.
Early endotracheal intubation, to be performed by experienced personnel. Use appropriate airway management algorithm.‡ Use short handle laryngoscope and smaller endotracheal tube.	High likelihood of a difficult airway. To ensure minimal or no disruption in chest compressions during attempts of intubation. Airway edema and large breasts.
The lateral defibrillator pad/paddle should be placed under the breast tissue.	To reduce impedance.
Remove fetal (external and internal) and uterine monitor prior to defibrillation.	Produce skin burns at monitor sites and to avoid electrical arcing during defibrillation.
Consider using AED in areas with infrequent use of defibrillator e.g., labour room.	To ensure early defibrillation (if indicated). Staff may not be able to interpret ECG rhythm or unfamiliar with the use of manual defibrillator.
Perform PMCS if no maternal response at 4 minutes after the onset of cardiac arrest.	Evacuation of foetus relieves aortocaval compression and improve venous return.

AED, automated external defibrillator; *ECG*, electrocardiography, *PMCS*, perimortem caesarean section; ROSC, return of spontaneous circulation.
*Maternal cardiac arrest team would ideally be composed of an adult resuscitation team, obstetrics, anaesthesia care providers, and neonatology teams.
†Include PMCS tray (must include a scalpel at a minimum), equipment for difficult airway and neonatal resuscitation equipment.
‡ Example of a suggested algorithm is Obstetric Anaesthetists' Association/Difficult Airway Society (OAA/DAS) Obstetric Airway Guidelines 2015.

Information taken from:

- *Jeejeebhoy FM, Zelop CM, Lipman S, Carvalho B, Joglar J, Mhyre JM, Katz VL, Lapinsky SE, Einav S, Warnes CA, Page RI. Cardiac arrest in pregnancy: a scientific statement from the American Heart Association. Circulation. 2015 Nov 3:132(18): 1747-73.*
- *Berg RA, Hemphill R, Abella BS, Aufderheide TP, Cave DM, Hazinski MF, Lerner EB, Rea TD, Sayre MR, Swor RA. Part 5: adult basic life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2010 Nov 2;122(18_suppl_3):S685-705.*



FAST, Focused assessment with sonography in trauma; *FBC*, full blood count; *FHR*, fetal heart rate; *KB*, Kleihauer-Betke; *USG*, ultrasonography; *ROSC*, return of spontaneous circulation.

** Reference:*

1. *World Health Organization, International Statistical Classification of Diseases and Related Health Problems (10th Revision). 2010.*
2. *Ministry of Health Malaysia, Guidelines for Stillbirth and Under-five Mortality Reporting Sustem. Julv 2013.*

Figure 3: A proposed approach for evaluation and management of pregnant trauma patients

Pregnant women involved in MVA have a high incidence of surgical procedures and Caesarean delivery.[10]

Adequate pre-oxygenation, the anticipation of a difficult airway and having a provisional plan in the event of failed intubation is of critical importance for safe airway management in pregnant patients. Difficult airway equipment should be prepared prior to induction. The use of a short-handle laryngoscope may improve the ease of laryngoscope blade insertion. Video laryngoscope can be utilised for better visualisation of the vocal cord. It also promotes safety by reducing exposure to airway secretion. This advantage is more pronounced during the Covid-19 pandemic. Smaller sized endotracheal tube (ETT) should be used for intubation as airway oedema in pregnancy may make inserting a standard size ETT difficult.[18]

Induction of anaesthesia should be undertaken with an effort to avoid vasodilation and hypotension irrespective of the maternal hemodynamic state. A full stomach should be assumed while managing any pregnant trauma patient. Thus, general anaesthesia should always be induced with rapid sequence induction (RSI) with cricoid pressure and placement of a cuffed ETT. Other measures to reduce aspiration risk include administering a non-particulate antacid. Balanced anaesthesia with propofol and/or ketamine is recommended. Muscle relaxation for RSI is best obtained with succinylcholine or rocuronium.[4,10,18] The paediatrician attending to the neonate should be informed of any use of drugs that cross the placenta because this may cause temporary neonatal depression and flaccidity.[10]

Standard monitoring, as recommended by the American Society of Anesthesiologists, should be used for all pregnant trauma patients undergoing surgery. Invasive haemodynamic monitoring such as arterial blood pressure and central venous pressure measurement should be considered in any haemodynamically unstable patient. Foetal heart rate monitoring should continue during surgery in a viable foetus if the surgical site is permissible.[10]

PREVENTION AND RECOMMENDATION

Prenatal counselling should incorporate education about reducing the risk of injury from an MVA and evaluation for DV since most maternal trauma is related to these two entities.

Use of seat belts and airbags

Unbelted or improperly applied seat belts are associated with an increased risk of maternal bleeding, intra-uterine injury and foetal death. The ACOG recommends that pregnant women wear a three-point seat belt at all times when travelling. The correct way to use a seat belt for pregnant women is to place the lap belt across the hips and below the uterus, the shoulder belt between the breasts and diagonally above the abdomen and there should be no excessive slack in either belt (Figure 4).[20,21]

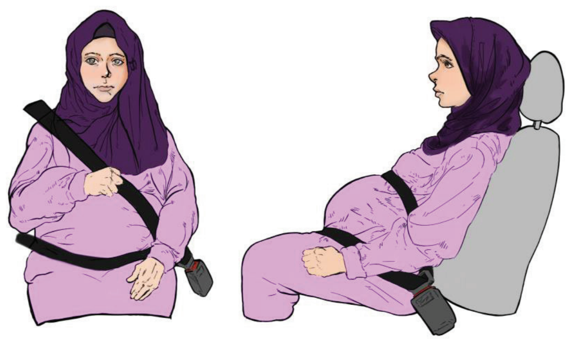


Figure 4: The correct way to wear a seat belt in pregnancy

In addition to using seat belts, ACOG recommends not turning off airbags when travelling. Airbag deployment reduces injury to pregnant women and does not increase the risk of adverse pregnancy outcomes.[22]

Screening of intimate partner violence (IPV)

Intimate partner violence during pregnancy is a serious public health concern that has a significant negative impact on the health implications for women and children. The IPV prevalence in

Malaysia ranges between 4.94 and 35.9%, which includes emotional or psychological, physical and sexual violence.[23]

The ACOG recommends universal screening for intimate partner violence during pregnancy.[24] According to a systematic review on the prevalence of IPV in Malaysia, common factors associated with IPV include lower education background, lower socio-economic status, history or current substance abuse, exposure to prior abuse or violence, violence-condoning attitude, and lack of social support.[23] All practitioners should be alert for physical and behavioural signs and symptoms associated with abuse or neglect. Depression, suicide attempts, frequent visits to the emergency department, vague or inconsistent history of trauma, self-blame for injuries and symptoms suggestive of substance abuse should raise the suspicion of IPV. Identified patients should receive appropriate counselling and referral.[24]

CONCLUSION

Trauma-related pregnancy is associated with significant maternal and perinatal morbidity and mortality. A concerted multidisciplinary team effort is vital to ensure an optimal and favourable outcome for both mother and foetus. Knowledge of appropriate treatment and management of pregnant trauma patients is important to help improve their outcome and chance of survival.

References

1. Hill CC, Pickinpaugh J. Trauma and surgical emergencies in the obstetric patient. *Surg Clin North Am* 2008 Apr 1;**88**(2):421-40

2. Deshpande NA, Kucirka LM, Smith RN, Oxford CM. Pregnant trauma victims experience nearly 2-fold higher mortality compared to their non-pregnant counterparts. *Am J Obstet Gynecol* 2017 Nov 1;**217**(5):590-e1

3. Mendez-Figueroa H, Dahlke JD, Vrees RA, Rouse DJ. Trauma in pregnancy: an updated systematic review. *Am J Obstet Gynecol* 2013 Jul 1;**209**(1):1-0

4. Adekanye K, Theron A. Maternal physiology, Obstetric Anaesthesia, 2nd edition. New York, Oxford University Press, 2020, pp 45-67

5. Flood P, Rathmell JP, Shafer S. Stoelting's Pharmacology and Physiology in Anesthetic Practice, 5th edition. United States, Wolter Kluwer Health, 2015 pp. 850-861

6. Banks A, Norris A. Massive haemorrhage in pregnancy. *Continuing Education in Anaesthesia, Critical Care and Pain* 2005 Dec 1;**5**(6):195-8

7. Adult Retrieval Victoria. 2014. Obstetric Trauma Guideline. [https://trauma.reach.vic.gov.au/guidelines/obstetric-trauma/key-messages] Accessed March 15, 2022

8. Vanden Hoek TL, Morrison LJ, Shuster M, Donnino M, Sinz E, Lavonas EJ, Jeejeebhoy FM, Gabrielli A. Part 12: cardiac arrest in special situations: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2010 Nov 2;**122**(18_suppl_3): S829-61

9. Murphy NJ, Quinlan JD. Trauma in pregnancy: assessment, management, and prevention. *Am Fam Physician* 2014 Nov 15;**90**(10):717-22

10. Refa N, Ali RA, Gomaa H. Update in obstetric trauma management. [https://resources.wfsahq.org/wp-content/uploads/Update_34_Obstetric_Edition_Sept_2019_final.pdf] Accessed March 2022

11. Jain V, Chari R, Maslovitz S, Farine D, Bujold E, Gagnon R, Basso M, Bos H, Brown R, Cooper S, Gouin K. Guidelines for the management of a pregnant trauma patient. *J Obstet Gynaecol Can* 2015 Jun 1;**37**(6):553-71

12. Pearlman MD, Tintinalli JE, Lorenz RP. A prospective controlled study of outcome after trauma during pregnancy. *Am J Obstet Gynecol* 1990 Jun 1;**162**(6):1502-10

13. American College of Obstetrician and Gynecologists. ACOG educational bulletin. Obstetric aspect of trauma management. Number 251, September 1998 (Replaces Number 151, January 1991, and Number 161, November 1991). *Int J Gynaecol Obstet* 1999;**64**:87-94

14. Awwad JT, Azar GB, Seoud MA, Mroueh AM, Karam KS. High-velocity penetrating wounds of the gravid uterus: review of 16 years of civil war. *Obstet Gynecol* 1994 Feb 1;**83**(2):259-64

15. ACOG Committee on Obstetric Practice. ACOG Committee Opinion. Number 299, September 2004, Guideline for diagnostic imaging during pregnancy. *Obstet Gynecol* 2004;**104**:647-651

16. Tauchi M, Hasegawa J, Oba T, Arakaki T, Takita H, Nakamura M, Sekizawa A. A case of uterine rupture diagnosed based on routine focused assessment with sonography for obstetrics. *J Med Ultrason* 2016 Jan;**43**(1):129-31

17. Mirza FG, Devine PC, Gaddipati S. Trauma in pregnancy: a systematic approach. *Am J Perinatol* 2010 Aug;**27**(07):579-86

18. Collis R, Harries S, Theron A. Obstetric Anaesthesia, 2nd edition. New York, Oxford University Press, 2020, pp 564-568

19. Katz V, Balderston K, DeFreest M. Perimortem cesarean delivery: were our assumptions correct? *Am J Obstet Gynecol* 2005 Jun 1;**192**(6):1916-20

20. Klinich KD, Flannagan CA, Rupp JD, Sochor M, Schneider LW, Pearlman MD. Fetal outcome in motor-vehicle crashes: effects of crash characteristics and maternal restraint. *Am J Obstet Gynecol* 2008;**198**(4):450.e1-9

21. American College of Obstetricians and Gynecologists. 2019. Car Safety for Pregnant Women, Babies and Children. [https://www.acog.org/womens-health/faqs/car-safety-for-pregnant-women-babies-and-children]. Accessed April 25, 2022

22. Schiff MA, Mack CD, Kaufman RP, Holt VL, Grossman DC. The effect of air bags on pregnancy outcomes in Washington State: 2002-2005. *Obstet Gynecol* 2010;**115**(1):85-92

23. Kadir Shahar H, Jafri F, Mohd Zulkefli NA, Ahmad N. Prevalence of intimate partner violence in Malaysia and its associated factors: a systematic review. *BMC Public Health* 2020 Dec;**20**(1):1-9.

24. American College of Obstetricians and Gynecologists. Intimate partner violence. Committee opinion no. 518. *Obstet Gynecol* 2012 Feb;**119**(2):412-7

Paediatric Trauma and Anaesthesia

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INTRODUCTION

Traumatic injuries remain the main cause of death and result in serious long-term morbidity in the paediatric population. In the United States, the leading cause of death for children over 1 year old is trauma and the majority of the cases occurs in motor vehicle accidents.[1-3] In younger children, child abuse is the most common cause of trauma in infants and falls from height in toddlers.[1,3] In 2010, data from the Malaysian Trauma Database (NTrD) registry estimated about 12.7% paediatric patients admitted to emergency departments in Selangor and Kuala Lumpur following trauma suffered from brain injuries.[5]

ROLE OF ANAESTHETISTS

Anaesthesiologists have many roles in the care of paediatric trauma patient including the following scenarios:[1]

1. Initial stabilisation in the emergency department
2. Monitored sedation for radiological imaging
3. Emergency surgeries for example laparotomies and craniotomies
4. Semi-elective surgeries
5. Management in the intensive care unit
6. Acute pain management

Anaesthesiologists therefore must have clear understanding of different aspects of paediatric trauma in order to conduct safe anaesthesia.

INITIAL ASSESSMENT AND MANAGEMENT

Primary Survey

The initial phase of patient assessment and resuscitation focuses on potential life-threatening injuries that may have ultimate impact on oxygenation and circulation. These include immediate assessment of the "ABCDEs" of the Advanced Trauma Life Support (ATLS) protocol and a continuous re-evaluation of the adequacy resuscitation strategies.[2] The attending physician should be aware of the anatomical and physiological differences when attending to such patients (Table I).

Airway and Breathing

During emergency, airway management is most important in the management of paediatric trauma. However, the management of the airway can be very challenging due to anatomical difference compared to adult.

Paediatric airway characteristics[2]

- Relatively small oral cavity, large tongue, prominent adenoids and tonsils contribute to higher chance of airway obstruction especially in patients with poor conscious level.
- The neck tends to flex during supine position due to large occiput. This can lead to airway obstruction and an increased risk of injury to the unstable cervical spinal cord.
- Anterior larynx is more cephalad (C2-C5) and this can result in poor visualisation of the glottis.
- The epiglottis is U-shaped as well as floppy. The laryngoscopist may opt to use a straight blade to ease the visualisation of vocal cords.
- The narrowest airway passage is at the cricoid cartilage, and this may limit tracheal tube size.
- Performing needle cricothyroidotomy can be difficult as the tracheal diameter is narrow and the distance between tracheal rings is small.
- The risk of accidental endobronchial intubation is more common as the tracheal is short.

Table I: Anatomical and physiological differences in paediatric population relevant to trauma[2]

Anatomical and physiological differences	Anaesthetic implications
Neurological • Relatively large head, thinner cranial bones, higher centre of gravity • Cartilaginous vertebral bodies, elastic ligaments, horizontal facet joints, underdeveloped neck musculature and large head → • Subluxation and dislocation are common	• Higher incidence of TBI, tolerate expanding intracranial haematoma • Increased spinal mobility, rare to have spinal cord injury; if these occur, it is a high spinal cord injury (C1-C3); fulcrum of spinal flexion is C2-C3 in children and C5-C6 in an older child • Up to 50% of spinal cord injuries in children <10 years of age may exist without radiological evidence (SCIWORA), children > 10 years of age usually have fractures
Airway • Large protuberant occiput creating natural flexion, large tongue, anterior and cephalad larynx • Aerophagia, gastric inflation with assisted ventilation, traumalic gastric paresis	• Careful positioning, the potential for difficult airway particularly if a C-spine injury • May need to consider versions of controlled or modified RSI, consider inserting a nasogastric tube to decompress the stomach • May need to avoid nasotracheal intubation, particularly if a base of skull fractune is suspected
Respiratony • ↑ RR, ↑ oxygen consumption, ↓ FAC, ↑ CC • Increased chest wall compliance • Elastic ribs • Diaphragm easily fatiqued and displaced	• Assess, establish and maintain airway urgently, early desaturation and decompensation • High possibility of collapse and hypoxia • Rarely have rib fractures, but impact of energy may be transferred to inner organs (pulmonary contusion most common)
Cardiac • Cardiac output is rate-dependent; during major haemorrhage, child compensates by constriction and ↑ SVR • Smaller vessels, more subcutaneous Lissue	• Tachycardia is the first sign of hypovolaemia; hypolension is a late sign of haemorrhage that may not occur until > 25-40% of EBV is lost. Do not delay fluid resuscitation • Approximated 5^{th} percentile systolic pressure: • SP (5^{th} percentile) = 70 mmHg + 2 X (age in years) • Vascular access may be difficult; consider intraosseous (ideally < 6 years of age)/central venous cannulation or cut-down
Abdominal • Dimensions of the torso with pliable ribs and easily displaced diaphragm, increase vulnerability of intra-abdominal organs	• Most frequently injured organ in descending order: spleen, liver, renal, intestine then pancreas
Other • Large head and organs, large surface area to body mass ratio	• Prone to hypothermia

Prevention of hypoxia is mandatory as children have a tendency to desaturate faster. Children have lower functional residual capacity (FRC) and high oxygen consumption compared to adult. Children who presented with respiratory distress should receive high oxygen supplement and have continuous pulse oximetry monitoring. Tracheal intubation is indicated in paediatric trauma patients including:[1,2]

- Poor bag-valve-mask ventilation and/or need for longer definitive ventilation in the intensive care
- Airway protection in children with poor Glasgow Coma Scale (GCS) score <8
- Respiratory failure following thoracic or abdominal trauma (splinting abdomen)
- Haemodynamic instability (decompensated shock)
- Significant burn with airway injury

In children with trauma, orotracheal intubation is preferred. Nasotracheal intubation can cause bleeding at the adenoids and intracranial tube placement unintentionally especially in children with base of skull. In children who is suspected to have cervical spine injury, a neutral, straight head and neck position can be done with a blanket or pad placed under child's torso in supine position.

Cuffed endotracheal tubes are widely used in the operating theatre and in the intensive care unit. Cuffed tubes have advantages in term of reducing the risk air leak especially in case of poor lung compliance and the risk of tracheal tube dislodge.[1,2]

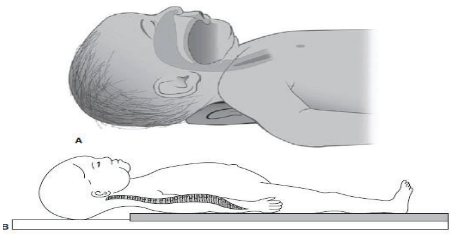

Figure 1: A blanket or pad placed under the torso of a supine infant or young child will achieve a neutral, straight head and neck position.[1]

Following formula can be used to estimate the endotracheal tube size based on patient age:

Uncuffed
Tracheal tube size (mm ID) = 4 + (age in years/4)

Cuffed
Tracheal tube size (mm ID) = 3.5 + (age in years/4)

In children, the depth of the oral tracheal tube can be estimated by multiplying the internal diameter of the tracheal tube by three or by adding ten to age. In infants, the depth of tube insertion is calculated according to their body weight, using rule "1,2,3 and 4 kg equals 7,8,9, and 10 cm," respectively.[2]

CIRCULATION

Recognising hypovolaemic shock in children with major trauma is mandatory. In children, range of vital signs vary with age (Table II).

Table II: Normal haemodynamic parameters.[2]

Age (years)	Weight (kg)	Heart rate(bpm)	Blood pressure (mmHg)	Respiratory rate (per min)	Urine output (mL/kg/hr)
Infant-1	0-10	<160	>60	<60	2
1-3	10-14	<150	>70	<40	1.5
3-5	14-18	<140	>75	<35	1.0
6-12	18-36	<120	>80	<30	1.0
>12	36-70	<100	>90	<30	0.5

Haemorrhagic shock is common in children who have sustained polytrauma. During initial cardiovascular assessment, regular blood pressure, pulse rate, rhythm, peripheral pulses and peripheral perfusion are needed. Delayed capillary refill time (more than 2 seconds), coolish extremities, cyanosis, and skin mottling are signs indicating of poor perfusion. Children are often able to compensate by vasoconstriction and tachycardia despite having significant hypovolemia. Therefore, blood pressure is a poor indicator of hypovolemia in children.[4,6]

Resuscitation can be started with the administration of warmed balanced crystalloid solution 20 mL/kg bolus. This bolus can be given once or twice after the initial bolus, failing which colloid and blood product should be considered.[1,2]

VASCULAR ACCESS

Obtaining intravenous (IV) access in paediatric patients can be challenging. Children with hypovolaemia needs minimum two relatively large-bore peripheral IV lines. There are 22 gauge for newborns and infants up to 3 years old, 20 gauge for children 4-8 years old, and 20 or 18 gauge for children over 8 years old. IV access can be inserted peripherally or centrally. These can be done percutaneously or by cutdown, or through an intraosseous (IO) route.[1,2]

DISABILITY OR NEUROLOGIC EVALUATION

Assessment of disability includes initial neurologic evaluation of the children. This assessment will be the baseline reference for next review and further assessments. The mnemonic AVPU refers to awareness (A), response to verbal (V) stimuli and pain (P), and unresponsive to stimuli (U).[2]

Paediatric GCS (Table III) is used for assessment of the children neurological status. This measurement is used for those under 2 years of age and is modified according to verbal development appropriate for the child's age. Standard GCS can be used in children older than 2 years old.[2]

Table III: The Paediatric Glasgow Coma Scale (GCS).[2]

Standard GCS	Score	Paediatric
Eye-opening		
Spontaneous	4	Spontaneous
To speech	3	To speech
To pain	2	To pain
None	1	None
Verbal response		
Orientated	5	Age-appropriate
Confused	4	Irritable, cries
Inappropriate words	3	Cries to pain
Incomprehensible	2	Moans to pain
None	1	None
Motor response		
Obeys commands	6	Spontaneous movement
Localises to pain	5	Withdraws to touch
Withdraws to pain	4	Withdraws to pain
Abnormal flexion	3	Abnormal flexion
Extensor response	2	Extensor response
None	1	None

EXPOSURE AND ENVIRONMENTAL CONTROL

Thorough examination of the paediatric trauma patient requires the child to be completely undressed. The child needs to be covered properly once the examination is done to avoid hypothermia. Infants and children lose body heat quickly due to their anatomical body which has large surface areas relative to body weight. They have thinner skin with less subcutaneous fat to contain heat. Body temperature must be monitored regularly, and active measures should be taken in order to prevent hypothermia. Ambient room temperature should be adjusted before the child's arrival. Warm blankets and forced-air convective heating blankets are effective in preventing heat loss. Fluid warmers may be considered during infusion of fluid and blood products.[1,2]

SECONDARY SURVEY

Once secondary survey is initiated, diagnostic testing is also completed during this period. Definitive care can be planned and lay out once the child's condition is stabilised and all injuries are identified.

Secondary survey involves evaluation of each organ system, a detailed head-to-toe examination and re-evaluation of hemodynamic parameters systematically. Additional diagnostic procedures which are indicated should be performed according to clinical need and ATLS guidelines. Consultations and discussion with other expert services or units is done as necessary.[2]

ANAESTHETIC MANAGEMENT

Preoperative evaluation and preparation

A thorough history and physical examination should be conducted if possible. However, in urgent need of surgical intervention, brief history outlined by AMPLE mnemonics may be adequate.

A = Allergies
M = Medications
P = Past medical history
L = Last oral intake, last tetanus immunization
E = Events related to the injury

To prepare the operating room, one should prepare the anaesthesia cart according to age, label the medications according dose per weight and increase the ambient temperature to 26°C for smaller children. Rapid-infusion devices, fluid warmers and infusion pumps should be prepared and made available.[4]

Induction and intubation

The paediatric trauma patients should always be considered as full stomach patients, and many are at risk of cervical spine injury. Rapid sequence induction and intubation (RSI) is preferred and manual in-line C-spine stabilization is required. The choice of induction agents depends on the child's injury, the presence of traumatic brain injury (TBI) and hemodynamic stability. Below are the characteristics of preferred intravenous induction agents for rapid sequence induction (Table IV).[1]

Succinylcholine, in a dose of 2mg/kg, is considered for RSI. It rapidly provides optimum intubating condition with a fast offset in effect. Rocuronium is an intermediate acting muscle relaxant. A dose of 1.2mg/kg can provide similar intubating conditions to succinylcholine. Rocuronium can be rapidly reversed using 16mg/kg of sugammadex in situation of 'cannot intubate, cannot ventilate'.[10,11]

Table IV: Characteristics of preferred intravenous sedative agents for rapid sequence induction

Drug	Class	Dose	Onset of action	Duration of action	Side effects	Contraindications
Propofol	Non-barbiturate, sedative-hypnotic	Adult 1.5-2.5mg/kg Children 2.5-3.5mg/kg	<1 min	3-10 min	Hypotension, injection pain	Haemodynamic instability
Thiopental	Barbiturate	Adult 3-5mg/kg Children <12 years 5-6mg/kg	0.5-1 min	10-30 min	Decreased cardiac output, hypotension, bronchospasm	Haemodynamic instability, status asthmaticus
Etomidate	Imidazole, hypnotic	0.2-0.3mg/kg	<1 min	4-10 min	Adrenal suppression, myoclonus	Focal seizure disorder, adrenal insufficiency
ketamine	Dissociative agent	1-3mg/kg	<2 min	10-30 min	Emergence phenomena, tachycardia, hypertension, hypersalivation, increase ICP, nystagmus	Head trauma, hypertension, penetrating eye injury

Modified RSI

Compared to adults, younger paediatric patients can desaturate more quickly even with short periods of apnoea during RSI. Modified RSI can be considered which include minimal bag-mask ventilation prior to intubation.[10,11] Gentle positive-pressure ventilation by bag and mask is performed during apnoea period. Inflation pressures should be less than 15-20 cmH_2O to minimize gastric distention. As an alternative, induction with inhalational agent can be considered in a non-cooperative child and cricoid pressure is applied as the child loses consciousness. The risks and benefits of each induction technique must be discussed especially aspiration risks and worsening of injuries due to movement during preoxygenation and airway manipulation.

Maintenance of anaesthesia

The maintenance of anaesthesia should follow the principles of balanced anaesthesia to provide adequate hypnosis, analgesia and muscle relaxation. No single anaesthetic technique is ideal and superior compared to others. Both inhalational anaesthesia and total intravenous anaesthesia (TIVA) are proven to be safe in paediatric trauma patients. Total intravenous anaesthesia technique may carry more benefit.[6]

Intraoperative fluid management

Compared to adult, even a minimal blood loss can be relatively harmful in children. Their normal circulating blood volume are relatively small to that of an adult. Fluid replacements include the administration of crystalloids, colloids, and blood products. Preoperative and intraoperative fluid losses are mostly isotonic. These can be replaced by lactated Ringer's or 0.9% normal saline solutions. Lactated Ringer's solution is slightly hypotonic and contains electrolytes. It is considered the most physiologic solution and is safe if infused in large volume. In contrast, large volume infusion of 0.9% normal saline leads to hyperchloremic metabolic acidosis. Colloids such as 5% albumin can be considered in paediatric patients, limited data to show their advantage over crystalloids.[2,3]

Dextrose-containing solutions are usually not used due to their hypotonicity which can contribute to the development of cerebral oedema.[1] However, hypoglycaemia is also harmful. Therefore dextrose-containing solutions can be given as part of maintenance fluid in patients at risk of hypoglycaemia.[1]

Transfusion of blood and blood products

Damage control resuscitation is the strategy of treating massive haemorrhage. The strategies are to transfuse blood products with the closest resemblance of whole blood.[2,3] The literature evidence for these practices is still scarce. Crystalloid predominant resuscitation has negative effects on mortality, duration of hospital and intensive care stay, and increase in ventilator days.[3] It is recommended to start blood transfusion, whole blood or packed red blood cells, when clinical improvement is not seen with two fluid boluses of 20mls/kg.[1]

Massive transfusion blood and blood products may be required for severe trauma cases. Many protocols suggested to use fixed ratio of red blood cells: fresh frozen plasma (FFP): platelets, which most of them suggesting 1:1:1 ratio. Some other protocols occasionally suggested 2:1:1 ratio.[3,7] There are no specific massive transfusion guidelines that is ideal for paediatric population.[3]

Factors such as haemodilution, hypothermia, consumption of clotting factors and metabolic derangements can result in trauma-induced coagulopathy (TIC). Hypothermia and acidosis are commonly combined with coagulopathy resulting in the "deadly triad".[3,7]

Use of tranexamic acid (TXA) in paediatric haemorrhagic trauma

Tranexamic acid reduces amount blood loss and transfusion requirements in paediatric cardiac surgery, scoliosis surgery, and craniosynostosis repair.[4] The side effects of TXA in paediatric population are very rare. These include gastrointestinal effects, hypotension induced during rapid intravenous injection, dizziness, headache, muscle pain, and postoperative convulsions in children who received high dose of TXA during cardiac surgery. No potential risk of thrombosis has been identified.[4]

The safety and efficiency of tranexamic acid in adult trauma has been well documented in the Clinical Randomization of an Antifibrinolytic in Significant Haemorrhage 3 (CRASH-3) trial which assessed the effects of early (<3 hours) infusion of TXA in adult trauma patients in particularly those with traumatic brain injury (TBI). The study showed that TXA reduced the risk of death from bleeding with no increase in fatal or non-fatal vascular occlusive.[9] Similar findings have been observed in the studies involving paediatric population.[6]

Many dosage regimes have been suggested for paediatric population. The dose ranged from a single 20mg/kg dose to 1g IV over 10 minutes followed by 1g over 8 hours (for children above 12 years old).

For children who are less than 12 years of age, the dose recommended is a loading dose of 15mg/kg (max 1g) over 10 minutes followed by 2mg/kg/h for at least 8 hours or until bleeding stops.[3,6]

Emergence and postoperative care

The decision for weaning and extubating postoperatively depends on the severity of initial injury, intraoperative condition and haemodynamic stability, and the need for postoperative ventilatory support. Children who are stable can be extubated at the end of operation. A child must be awake and alert, vital signs are stable without any inotropic support, normothermia and able to maintain adequate oxygenation and ventilation with spontaneous respirations.[4] Good pain control may reduce anxiety and fear. Multimodal analgesia including regional anaesthesia can be considered.

CONCLUSION

Trauma is the main cause of morbidity and mortality in children. Anaesthesiologists play vital roles in the care of injured children. Deep understanding and knowledge of paediatric trauma ensure anaesthesiologists to be vigilant, efficient and safe when attending and resuscitating this cohort of patients.

References

1. Ivashkov Y, Bhananker SM. Perioperative management of paediatric trauma patients. *Int J Crit Illn Inj Sci* 2012;**2**(3):143-8
2. Ramaiah R, Sharar S R. Anesthetic Management of the Paediatric Trauma Patient. Essential of trauma anaesthesia. Chapter 30 Section 3:275-289
3. Mogane P. Trauma anaesthesia in paediatrics. *Southern African Journal of Anaesthesia and Analgesia* 2021;**27**(6 Suppl 1):S11-16
4. Loy M L Paediatric trauma and anesthesia. Trauma Anesthesia, 2nd Edition, ed. Charles E. Smith. Published by Cambridge University Press. © Charles E. Smith, 2015
5. Tay et al The epidemiology of childhood brain injury in the state of Selangor and Federal Territory of Kuala Lumpur, Malaysia. BMC Paediatrics (2016) 16:56
6. Paneitz D C, Ahmad M S. Paediatric Trauma Update. *Mo Med* 2018;**115**(5):438-42
7. Diab Y A, Wong E C C, Luban N L C. Massive transfusion in children and neonates. *Br J Haematol* 2013;**161**(1):15-26
8. Beno S, Ackery A D, Callum J, Rizoli S. Tranexamic acid in paediatric trauma: why not? *Critical Care* 2014;**18**:313
9. The CRASH-3 trial collaborators. Effects of tranexamic acid on death, disability, vascular occlusive events and other morbidities in patients with acute traumatic brain injury (CRASH-3): a randomised, placebo-controlled trial. *Lancet* 2019;**394**:1713-23
10. Abdallah C, Hannallah R. Use of modified rapid sequence tracheal intubation in paediatric patients. Saudi Journal of Anesthesia. Vol. 8, Issue 2, April-June 2014
11. Newton R. Place of rapid sequence induction in paediatric anaesthesia. BJA Education, Volume 16, Issue 4, April 2016, Pages 120-123

Regional Anaesthesia for Acute Trauma: An Ideal Approach to Improve Outcomes

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THE BURDEN OF TRAUMA

Trauma secondary to road traffic and unintentional injuries is a significant World Health Organisation (WHO) indicator of global disease burden. It is one of the leading causes of death and disability worldwide. Every year, more than 45 million people worldwide are estimated to suffer from moderate to severe disability caused by trauma. WHO data revealed that road traffic and fall injuries accounted for nearly 2 million deaths in 2019.[1] By 2030, trauma is expected to rise to the third leading cause of disability worldwide, with a forecast of 14.3 death in 100,000 population.[2,3] In the initial stage of trauma, resuscitation and stabilisation of patients are prioritised over other treatments. However, pain is one of the most prevalent complaints among trauma patients in the emergency department (ED).

There is growing evidence that pain in trauma patients is frequently undertreated. A study in the United States and Canada showed that 74% of patients were discharged from the ED with moderate to severe pain. Other data from Italian ED showed that only 32% of moderate to severe pain patients received analgesia.[4] In Malaysia, acute severe pain requiring analgesia was reported in up to 44% of ED patients, and majority of patients reporting moderate pain score were not prescribed pain relieving medication.[5]

SYSTEMIC ANALGESIA (OPIOIDS VS NON-OPIOIDS) IN TRAUMA

The pharmacological technique of analgesia is the mainstay of treatment for pain in the emergency and critical areas. Non-opioid simple analgesics such as paracetamol and non-steroidal anti-inflammatory drugs (NSAIDs) are the medication of choice in treating mild to moderate pain and opioids for moderate to severe pain.[6] Based on clinical efficacy, the number-needed-to-treat (NNT) for at least 50% pain relief for NSAIDs is better than opioids in the acute pain model.[7] However, the NSAIDs and paracetamol lack dose titratability and safety in organ-impaired individuals. At the time of acute injury, an intravenous form of NSAIDs or paracetamol, either alone or in combination, provides early-onset and effective multimodal analgesia treatment.[6]

An opioid is associated with multiple potential adverse effects, including nausea and vomiting, sedation, respiratory depression, delirium, constipation, pruritus and haemodynamic instability.[8] In two systematic reviews of opioid adverse effects from three main routes of administration (intravenous patient-controlled analgesia, intramuscular, and epidural route), the mean incidences of nausea, vomiting, sedation, and urinary retention are 25.2%, 20.2%, 23.9% and 23% respectively. The incidence of respiratory depression indicated by low oxygen saturation (<90%) is 17%. Pruritus and hypotension each account for 14.7% and 4.7%.[8,9]

These unwanted side effects negate the aim of primary resuscitation and stabilisation. A priority for trauma patients who present with hypovolemia and shock is resuscitation; the use of opioids has the potential to worsen hypotension. Likewise, the use of opioids in traumatic brain injury may cause sedation and delirium, which would lead to unnecessary intubation. In acute traumatic chest injury, the use of opioids could lead to respiratory depression and oxygen desaturation. These barriers prevent adequate pain management in trauma patients.[8]

REGIONAL ANAESTHESIA IN TRAUMA

When Henrik Kehlet first proposed perioperative multimodal intervention in 1997, the aim was to improve recovery and reduce morbidity and overall costs.[11] He set the trend towards an opioid-sparing, multimodal analgesia approach in pain management. Examples of multimodal non-opioid agents are NSAIDs, paracetamol and adjuvants such as ketamine, clonidine, lignocaine, and other local anaesthetics delivered via neuraxial or peripheral nerve blocks. The non-pharmacological technique includes a splint and cast for fractures, binders for stabilisation and surgery for internal fixation.

About 60% of injuries involve the extremities.[12] Regional anaesthesia (RA) delivers high-quality and effective analgesia, especially for extremities, compared with systemic opioids. Other advantages include a reduced length of stay (LOS) in the ED, improved comfort and safety for transport and cost savings. It also reduces labour cost as stable RA patients would not need continuous observation compared to systemic opioids with side effects of sedation and delirium.[8]

Preemptively, RA can be administered as a multimodal therapy or as a part of a clinical pathway from the ED in the form of a single bolus or catheter-based technique to facilitate clinical examination, transportation, procedure, treatment, and corrective surgery (Figure 1).

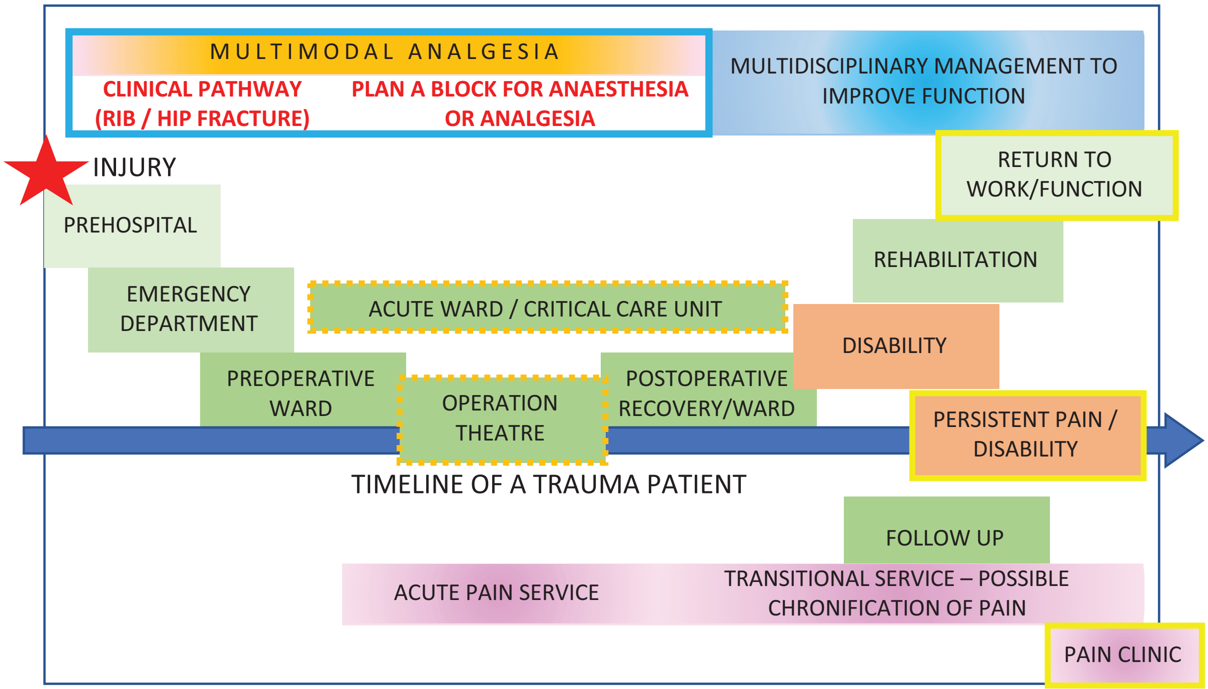

Figure 1: Timeline of a trauma patient from injury to discharge. The patient may eventually return to normal function after a period of rehabilitation or suffer from temporary or persistent pain and disability that requires long term follow-up

CHRONIC POST TRAUMATIC PAIN SYNDROME

Following recovery after trauma, the next prevailing issue is the development of chronic post-traumatic pain syndrome or chronic postsurgical pain syndrome (CPSP). It is defined by the International Association for the Study of Pain (IASP) in the latest International Classification of Disease (ICD) version 11, as a chronic pain that develops or increases in intensity after a surgical procedure or a tissue injury and persists beyond the healing process, at least three months after the surgery or tissue trauma (Figure 2).[13]

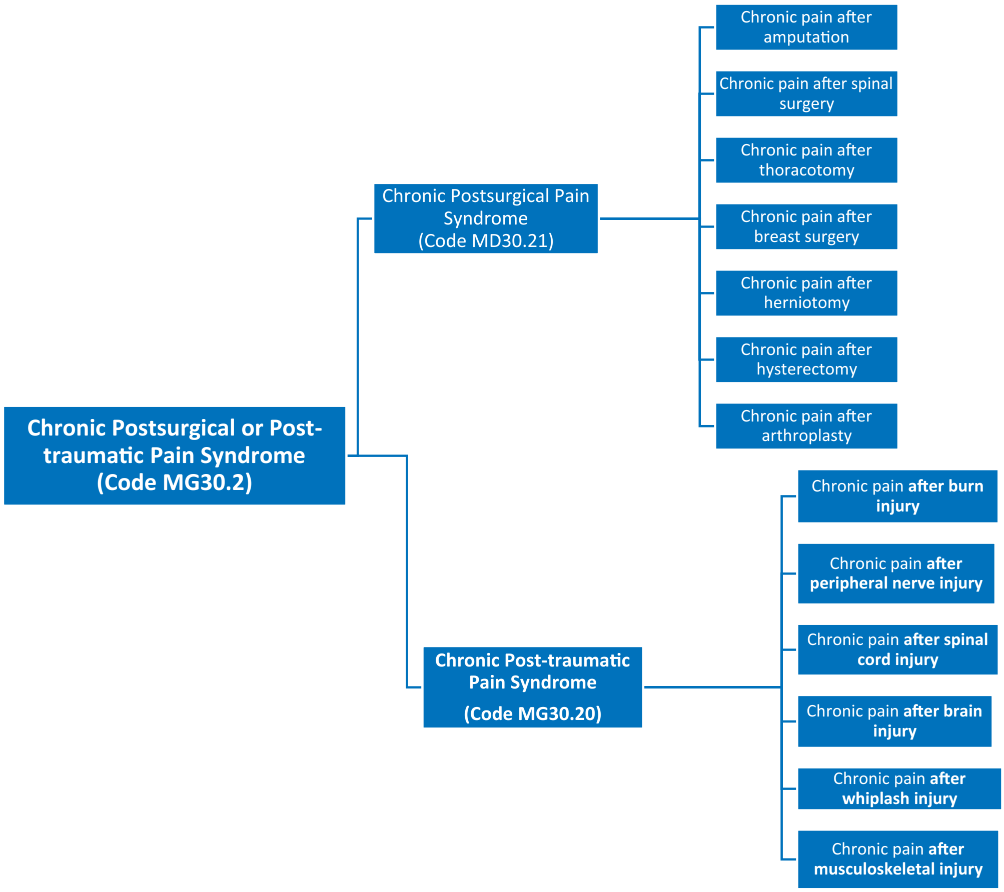

Figure 1: The ICD 11 Classification of Chronic Post-surgical and Post-traumatic Pain Syndrome

Risk factors to develop CPSP include a younger age group, co-morbidities, psychiatric diseases, depression or anxiety states, alcohol and tobacco consumption, surgical techniques, type of procedure and severe acute perioperative pain.[14] The latter seem to have a consistent association with CPSP. Currently, the best predictor of CPSP comes from trajectory analysis of acute postoperative pain studies. High intensity acute pain trajectory after surgery or trauma occurs in subjects with risk factors for CPSP (Figure 3). Understanding the high intensity trajectory allows clinicians to distinguish characteristics of patients who would require early intervention to prevent pain chronification.[15,16] As 50 to 70% of CPSP is associated with nerve damage, performing a neuropathic pain assessment using established tools such as Douleur Neuropathique (DN4) and PainDETECT is highly recommended during the recovery phase of trauma.[17] The RA plays a significant role in preventing central sensitization that initiates CPSP in the transition stage.[18]

Local anaesthesia (LA) applied topically or infused intravenously has been proven effective in preventing central sensitization and chronic pain.[19,20] The impact outlasts the half-life of the medicine by 5.5 times, promoting LA as a preventive analgesic agent that inhibits central sensitization.[21] Earlier systematic reviews of RA involving epidural and paravertebral techniques for major CPSP-prone surgery showed effective role of RA as preventive analgesic strategies to reduce either incidence of chronic pain or clinical severity and its impact on physical and mental health.[22,23] The result has been extrapolated to trauma situation that involves more tissue damage.

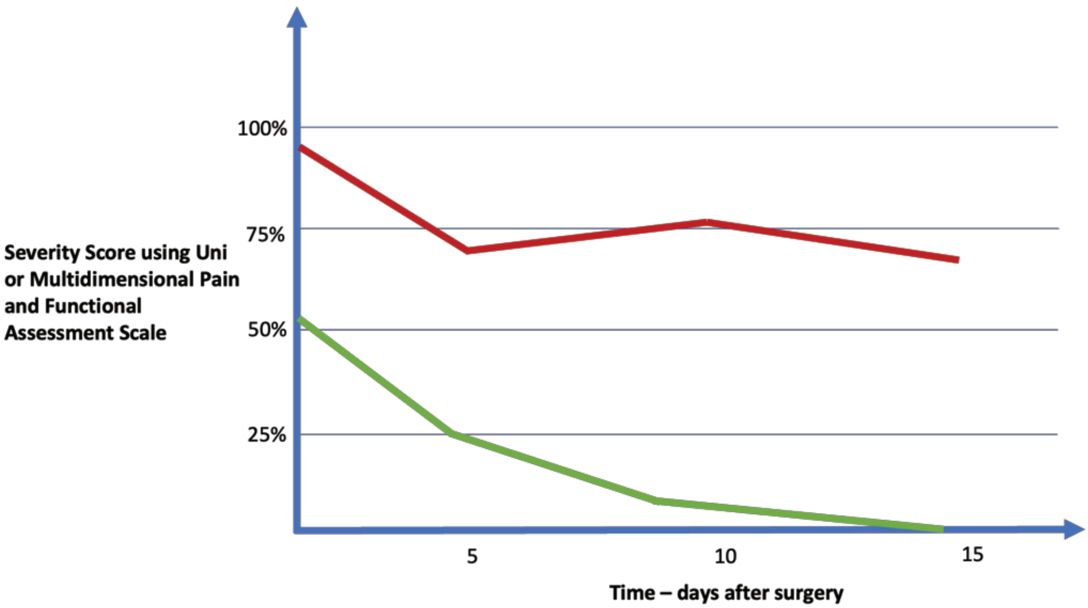

Figure 3: Trajectory analysis of acute postoperative pain using uni or multidimensional assessment tools. The red line indicates a high intensity trajectory in persistent postoperative or post-traumatic pain, and the green line indicates a low intensity trajectory in normal postoperative or post-traumatic recovery

RA IN THE EMERGENCY DEPARTMENT AND PRE-HOSPITAL SETTING

Despite numerous advantages of RA, the application is not common in the ED due to several constraints and limitations. Most importantly, RA performance requires supervised training, standard protocols and types of equipment to achieve safe and effective service. A service and training partnership aiming at mutual benefits between units and departments may promote and improve the conduct of RA delivery in this area.[24] For example, organizing an interdisciplinary collaboration between ED and Acute Pain Service (APS) team for training, delivering and post-block monitoring by the APS team in the hospital. Furthermore, implementing a clinical pathway such as the elderly neck of femur fracture pathway is a stepping stone to an effective RA service in trauma, which may attract greater acceptance and recognition by healthcare providers and administrators.[25]

Some clinicians were inhibited by RA complications, including nerve injury, injury to nearby structures leading to pneumothorax, visceral perforation, or hematoma. RA is known to cause local anaesthetic systemic toxicity (LAST) in inadvertent intravascular injection. However, with ultrasound guidance and intralipid antidote, these complications can be identified early and managed appropriately in an area with resuscitation equipment, especially in the ED.

In 2020, the emergency medicine ultrasound experts' group has identified core elements of competencies needed for the training of emergency physicians in ultrasound-guided RA. This was divided into ten categories which include patient and provider benefits, risks, indications and contraindications, local anaesthetics, technique and procedural skills, and educational resources.[26,27] The expert group also highlighted ten RA techniques in their consensus statement that are highly beneficial in ED practices: Interscalene brachial plexus block, supraclavicular brachial plexus block, RA at the forearm (median, ulnar and radial nerve block), serratus anterior plane block, femoral nerve block, fascia iliaca block, popliteal sciatic and posterior tibial nerve block.[26]

In the pre-hospital setting, a recent systematic review of pre-hospital analgesia includes fascia iliaca plane block as part of analgesia for hip fracture, administered by paramedics on the scene.[28] The success rate of included studies in the review ranges from 92-100%. However, there are concerns about prolonged scene time, adverse effects, and complications.[25] Pre-hospital superficial blocks have been successfully performed using the landmark or nerve stimulator technique.[29-31]

ROLE OF ULTRASOUND-GUIDED RA IN TRAUMA

The accuracy and safety of RA have improved markedly with the use of peripheral nerve stimulator, ultrasound, and block needle. Ultrasound (US) offers an accurate real-time image of essential structures such as blood vessels, muscles, and nerves. It also enables an estimate of accurate depth, approach angle, and visualization of needle path as it advances to the targeted structure. The LA spread can be seen in real time.[32] The US-guided approach is safer as it reduces the incidence of LAST, pneumothorax, peripheral nerve injury and hemidiaphragmatic paresis.[32]

On the other hand, the portability of an US machine and the trend for point of care ultrasound (POCUS) in critical areas, have made enthusiastic RA practitioners embrace POCUS seamlessly in their practice. The POCUS has been widely practiced by anaesthesiologist, intensivist, emergency and trauma physician, obstetric, cardiology and internal medicine specialities, to provide a precise, cost-effective, and non-invasive diagnosis at the bedside.[33]

HIGH-VALUE RA - 'PLAN A BASIC BLOCK'

Basic high-value blocks are several RA approaches with widespread implementation across the vast majority of trauma or surgery. Instead of 'many blocks for few indications', the Regional Anaesthesia-UK (RA-UK) adopted an all-inclusive strategy of 'few good blocks for many indications' as a learning package for general anaesthesiologists. The seven basic blocks are bundled as essential 'Plan A Block' to facilitate competency training and engage more anaesthesiologists in delivering RA services to patients (Table I).[34,35]

Fundamental to basic RA block is a consistent, universally accepted approach to scanning techniques and orientation, as well as visualisation and identification of sono-anatomical structures in each block. The high-value blocks and recommended anatomical structures to be insonated are listed below based on international consensus.[36]

APPLICATION OF RA IN SPECIFIC INJURIES

A. Hip Fracture

Osteoporotic hip fractures are common in the elderly population. Over 90% of hip fractures are fall-related. Based on Australia and New Zealand, hip fracture registry, 40% occurred in people older than 84 years with multiple co-morbidities.[37] Three months after fracture, mortality is about 10% and only 23-26% return to pre-injury activities.[6]

Regional anaesthesia in the form of a femoral nerve block (FNB) or fascia iliaca compartment block (FICB) reduce pain at rest and on movement within 30 minutes of LA deposition.[38] It can be given as a single shot bolus or continuous infusion. FICB, when given before positioning, results in lower pain during spinal anaesthesia attempts.[6]

Arthroplasty surgery is the most effective surgical treatment compared to internal fixation or dynamic hip screw. Guidelines to achieve earlier door-to-surgery time resulted in better hospital discharge and less morbidity. The hip fracture clinical pathway ideally incorporates multidisciplinary team members comprising and often led by orthogeriatrician, orthopaedic surgeons, anaesthesiologists, rehabilitative physicians, physiotherapists, occupational therapists and social workers.[39] Adherence to care bundles and clinical care standards in the clinical pathway improve patient's outcome.

Table I: Peripheral nerve block, clinical indications in trauma and possible complications.[34,35,36]

High-Value RA	Clinical Indications in Trauma	Minimum sonoanatomy structure visualisation (block view)	Possible Complications
Interscalene Brachial Plexus (ISBP)	Shoulder dislocation/ shoulder injury, humerus fracture	Anterior and middle scalene, C5 and C6 nerve roots	Pneumothorax, nerve injury, Horner's syndrome
Axillary Brachial Plexus (AxBP)	Forearm or hand soft tissue or bone injuries	Axillary artery and veins, conjoint tendon of latissimus dorsi/teres major, median nerve, musculocutaneous nerve, radial and ulnar nerve	LAST, hematoma, nerve injury, inadequate block
Erector Spinae Plane Block (ESP)	Chest wall injury/ multiple rib fractures	Transverse process (thoracic vertebra), erector spinae muscle groups	LAST, hematoma, pneumothorax, inadequate block, hemodynamic instability
Femoral Nerve block (FNB)	Hip, thigh, femur, patella fractures and persistent pain	Common femoral artery, iliacus/iliopsoas, femoral nerve, fascia iliaca	Inadequate block, hematoma, nerve injury
Adductor Canal (ACB)	Knee, medial and posterior knee	Superficial femoral artery, sartorius, saphenous nerve/nerve complex	LAST, vessel injury, hematoma, inadequate block
Rectus Sheath Plane Block (RSB)	Midline laparotomy	Rectus abdominis, anterior and posterior layer of rectus sheath, peritoneum	Inadequate block, hematoma, peritoneal/ bowel injury
Popliteal Sciatic Nerve Block (SNB)	Calf and foot surgery	Sciatic nerve, sciatic nerve bifurcation, tibial nerve, common fibular nerve	Nerve injury, hematoma, inadequate block

A guiding principle in the clinical pathway is pre-surgery and perioperative pain control, often done with regional block to minimize medication adverse systemic effects. No significant major complications from FNB or FICB were reported in a recent systematic review of 31 RCTs involving 1760 hip fracture patients.[38] Pericapsular nerve group block (PENG Block) is the latest ultrasound-guided RA approach targeting the hip genicular nerves with promising outcomes in providing analgesia for hip fracture (Table II).

B. Chest Wall Injury

The Trauma Audit Research Network (TARN) in 2018 indicated a mortality rate of 11% after chest wall injuries, with prolonged LOS and 63% of patients with severe pain. Only a quarter of patients in the registry received any form of RA.[43]

Similar to elderly hip fractures, bundled multidisciplinary clinical pathway for a rib fracture is generally recommended to improve morbidity and mortality.[44] The pathway includes the protocolised

Table II: Characteristic of studies using the new PENG Block in hip fracture

Author	Study design/ population	Type of RA	Outcome	Complications
Gullupinar B et al., 2022[40]	Prospective Randomized Controlled Trial (RCT)/ Hip fracture in ED (n=39)	PENG Block vs Control	PENG block significantly reduced pain score Reduced opioid use	No complications
Mosaffa F et al., 2022[41]	Prospective RCT - double-blinded/ Analgesia for hip fracture in ED (n=52)	PENG vs FICB	PENG block significantly reduces VAS score immediate and 12 hours post-surgery. Reduced 24 hours morphine use in PENG group	No complications
Lin DY et al., 2022[42]	Prospective RCT/ Analgesia for hip fracture perioperative (n=60)	PENG vs FNB	PENG showed shorter recovery and time to discharge	No complications

approach, multimodal analgesia, catheter-based epidural or peripheral nerve blocks, pulmonary hygiene, and surgical fixation.[6,44] A systematic review by Peek et. al. concluded that continuous paravertebral, intercostal and thoracic epidural analgesia are superior to intravenous analgesia, with no difference in the secondary outcomes involving mortality, length of ICU stay, length of mechanical ventilation days or analgesia-related complications.[45]

A less invasive and more contemporary fascial plane blocks have gained traction as much safer alternatives and are included in trauma guidelines to replace more invasive thoracic epidural or paravertebral blocks (Table III).

C. Shoulder Injury

Shoulder dislocation is the commonest joint dislocation in the ED, accounting for around 50% of all dislocations, especially in the 15-29 year age group.[51] Successful reduction of shoulder dislocation often requires procedural sedation.[6] The RA techniques such as interscalene block (ISBP) and suprascapular nerve block (SSB) are useful in the reduction of shoulder dislocation and avoiding the need for sedatives or strong opioids (Table IV).

D. Compartment Syndrome

Acute compartment syndrome (ACS) may occur following long bone trauma within the myofascial compartment leading to critical limb ischaemia. It is reversible if identified early, as ACS may lead to tissue necrosis, infection, sepsis, and potential mortality. ACS typically presents with disproportionate pain and signs of circulatory deficiency.

There are concerns and debates on whether dense neuraxial or peripheral nerve blockade leads to a delay in diagnosis as it masks pain symptom.[56] The current existing literature suggests no association between low concentration nerve blocks (either single-shot or continuous) without adjuncts, and failure to detect compartment syndrome. This issue is acknowledged in the recent guideline on regional anaesthesia for lower limb with trauma, published by the Association of Anaesthetists of Great Britain and Ireland (AAGBI).[57] The guidance recommended

Table III: Characteristic of studies using the new fascial plane blocks for multiple rib fractures

Author	Study design/ population	Type of RA	Outcome	Complications
Martel ML et al., 2020[46]	Retrospective, Observational cohort - feasibility of continuous nerve block in ED for rib or hip fracture (n=41)	- Serratus Anterior Plane Block - Intercostal Nerve Block - Fascia Iliaca Compartment Block	All effective and feasible. Opioid reduction by 58%	Most common: catheter dislodgement
Laura Beard et al., 2020[47]	Retrospective, observational multicentre, longitudinal cross-sectional study (n=354)	- Serratus Anterior Plane Block - Paravertebral Catheter - Thoracic Epidural Analgesia	Overall effective Reduced pain severity >34%, Increase inspiratory lung volume, no difference in mortality	Not mentioned
Tekşen, Ş et al., 2021[48]	Prospective RCT (n=60)	- Serratus Anterior Plane Block vs Control	Reduced pain score and opioid use Reduce chronic pain at 3 months	No complications
Adhikary S.D. et al., 2019[49]	Retrospective observational study (n=79)	- Erector Spinae Plane Block Single shot (n=16) Continuous Block (n=61)	Reduced pain intensity Improved incentive spirometry volume	Not discussed
Zhao Y et al., 2022[50]	RCT (n=80)	Erector Spinae Plane vs Retrolaminar Block	Retrolaminar block is a more effective RA for pain relief	No complications

avoiding neuraxial or peripheral RA techniques that resulted in long-duration dense blocks that significantly exceed the duration of surgery.[57]

The AAGBI also recommended appropriate post-surgery and postoperative surveillance to recognize ACS early. The American Society of Regional Anesthesia (ASRA) and European Society of Regional Anaesthesia (ESRA) in their 2015 guideline suggested the use of 0.1% to 0.25% LA concentration for single-shot RA and 0.1% concentration for continuous infusion.[58] Since the publication of ASRA/ESRA guideline, there is no reported cases of ACS associated with RA. On the contrary, there are more case series of successful ACS diagnosis in children receiving RA.[57]

CONCLUSION

In conclusion, RA is not just part of a multi-modal analgesia strategy. It is a crucial element of therapy in the acute and rehabilitative stages of trauma. The benefits range from suppressing pathophysiological response to injury at the early phase (hence preventing CPSP) to an extensive role in improving functions and return to normality.

Table IV: Characteristic of studies using RA for shoulder dislocation

Author	Study design/ population	Type of RA	Outcome	Complications
Michael Blaivas et al., 2011[52]	Prospective RCT / shoulder dislocation in ED (n=42)	ISBP vs traditional procedural sedation analgesia (PSA) (etomidate) for shoulder reduction	LOS and one-on-one healthcare provider time were significantly less in the ISBP group. No significant difference in pain experience in both groups	Hypoxia & hypotension No significant difference
Raeyat Doost et al., 2017[53]	RCT / shoulder dislocation in ED (n=60)	ISBP vs PSA (propofol & fentanyl) for shoulder reduction	LOS significantly less in ISBP, however pain score is less in PSA group	Not mentioned
Onur Tezel et al., 2014[54]	Prospective RCT / shoulder dislocation in ED (n=41)	SSB vs PSA (ketamine) for shoulder reduction	Time spent in emergency department significantly less for the SSB group. No difference in shoulder reduction and pain intensity	No complications
Liwei Yao et al., 2022[55]	RCT / shoulder dislocation in ED (n=66)	ISBP vs PSA (propofol & fentanyl)	Pain score & shoulder reduction attempt were lower in PSA group. However, LOS and complications were lesser in ISBP group	Nausea, vomiting, headache & hypoxia more frequent in PSA group

References

1. WHO Global Health Estimates 2020: Deaths by Cause, Age, Sex, by Country and by Region, 2000-2019. 2020, World Health Organization: Geneva

2. Mathers, C.D. and D. Loncar, Projections of global mortality and burden of disease from 2002 to 2030. *PLoS Med* 2006;**3**(11):p.e442

3. Inada, H., et al., Forecasting global road traffic injury mortality for 2030. *Inj Prev* 2020;**26**(4):p.339-343

4. Dißmann, P.D., et al., A Review of the Burden of Trauma Pain in Emergency Settings in Europe. *Pain Ther* 2018;**7**(2):p.179-192

5. Fathil, S.M., et al., Audit of pain management in the emergency department. *Med J Malaysia* 2011;**66**(2):p.89-91

6. Schug SA, et al., Acute Pain Management: Scientific Evidence (5th edition). ANZCA & FPM, Melbourne

7. Moore, R.A., et al., Single dose oral analgesics for acute postoperative pain in adults - an overview of Cochrane reviews. Cochrane Database Syst Rev, 2015(9): p. CD008659

8. Gadsden, J. and A. Warlick, Regional anesthesia for the trauma patient: improving patient outcomes. *Local Reg Anesth* 2015;**8**:p.45-55

9. Dolin, S.J. and J.N. Cashman, Tolerability of acute postoperative pain management: nausea, vomiting, sedation, pruritus, and urinary retention. Evidence from published data. *Br J Anaesth* 2005;**95**(5):p.584-91

10. Cashman, J.N. and S.J. Dolin, Respiratory and haemodynamic effects of acute postoperative pain management: evidence from published data. *Br J Anaesth* 2004;**93**(2):p.212-23

11. Kehlet, H., Multimodal approach to control postoperative pathophysiology and rehabilitation. *Br J Anaesth* 1997;**78**(5):p.606-17

12. Banerjee, M., et al., Epidemiology of extremity injuries in multiple trauma patients. *Injury* 2013;**44**(8):p.1015-21

13. Schug, S.A., et al., The IASP classification of chronic pain for ICD-11: chronic postsurgical or post-traumatic pain. *Pain* 2019;**160**(1):p.45-52

14. Schug, S.A. and J. Bruce, Risk stratification for the development of chronic postsurgical pain. *Pain Rep* 2017;**2**(6):p.e627

15. Thomazeau, J., et al., Predictive Factors of Chronic Post-Surgical Pain at 6 Months Following Knee Replacement: Influence of Postoperative Pain Trajectory and Genetics. *Pain Physician* 2016;**19**(5):p.E729-41

16. Sun, EC, et al., Making a business plan for starting a transitional pain service within the US healthcare system. *Reg Anesth Pain Med* 2021;**46**(8):p.727-731

17. Rosenberger, D.C. and E.M. Pogatzki-Zahn, Chronic post-surgical pain - update on incidence, risk factors and preventive treatment options. *BJA Educ* 2022;**22**(5):p.190-196

18. Radresa, O., et al., Current views on acute to chronic pain transition in post-traumatic patients: risk factors and potential for pre-emptive treatments. *J Trauma Acute Care Surg* 2014;**76**(4):p.1142-50

19. Kukreja, P., et al., The Role of Regional Anesthesia in the Development of Chronic Pain: a Review of Literature. Current Anesthesiology Reports, 2022. Topical Collection on Regional Anesthesia

20. Bailey, M., et al., Perioperative lidocaine infusions for the prevention of chronic postsurgical pain: a systematic review and meta-analysis of efficacy and safety. *Pain* 2018;**159**(9):p.1696-1704

21. Katz, J., H. Clarke, and Z. Seltzer, Review article: Preventive analgesia: quo vadimus? *Anesth Analg* 2011;**113**(5):p.1242-53

22. Andreae, M.H. and D.A. Andreae, Regional anaesthesia to prevent chronic pain after surgery: a Cochrane systematic review and meta-analysis. *Br J Anaesth* 2013;**111**(5):p.711-20

23. Karmakar, MK, et al., Thoracic paravertebral block and its effects on chronic pain and health-related quality of life after modified radical mastectomy. *Reg Anesth Pain Med* 2014;**39**(4):p.289-98

24. Stone, A., et al., Ultrasound-guided regional anesthesia in the emergency department: an argument for multidisciplinary collaboration to increase access while maintaining quality and standards. *Reg Anesth Pain Med* 2021;**46**(9):p.820-821

25. Newton-Brown, E., L. Fitzgerald, and B. Mitra, Audit improves emergency department triage, assessment, multimodal analgesia and nerve block use in the management of pain in older people with neck of femur fracture. *Australas Emerg Nurs J* 2014;**17**(4): p.176-83

26. Tucker, R.V., et al., Defining an Ultrasound-guided Regional Anesthesia Curriculum for Emergency Medicine. *AEM Educ Train* 2021;**5**(3):p.e10557

27. Malik, A., et al., Regional Anesthesia in the Emergency Department: an Overview of Common Nerve Block Techniques and Recent Literature. *Current Emergency and Hospital Medicine Reports* 2022;**10**:p.54-56

28. Davis, S., et al., Review article: Paramedic pain management of femur fractures in the pre-hospital setting: A systematic review. *Emerg Med Australas* 2021;**33**(4):p.601-609

29. Gros, T., et al., [Sciatic nerve block in pre-hospital care]. *Ann Fr Anesth Reanim* 2010;**29**(2):p.162-4

30. Gros, T., et al., [Interscalene brachial plexus block in pre-hospital medicine]. *Ann Fr Anesth Reanim* 2008;**27**(10):p.859-60

31. Simpson, P.M., et al., Paramedic-performed digital nerve block to facilitate field reduction of a dislocated finger. *Prehosp Emerg Care* 2012;**16**(3):p.415-7

32. Suzanne Carty, B.M.F. and M.F. Barry Nicholls, Ultrasound-guided regional anaesthesia. Continuing Education in Anaesthesia Critical Care & Pain, 2007. Volume 7(Issue 1)

33. Arnold, M.J., C.E. Jonas, and R.E. Carter, Point-of-Care Ultrasonography. *Am Fam Physician* 2020;**101**(5):p.275-285

34. Turbitt, L.R., E.R. Mariano, and K. El-Boghdadly, Future directions in regional anaesthesia: not just for the cognoscenti. *Anaesthesia* 2020;**75**(3):p.293-297

35. RA-UK. Plan A Block. 2022; Available from: https://www.ra-uk.org/index.php/plan-a-blocks-home

36. Bowness, JS, et al., International consensus on anatomical structures to identify on ultrasound for the performance of basic blocks in ultrasound-guided regional anesthesia. *Reg Anesth Pain Med* 2022;**47**(2):p.106-112

37. AIHW, Hip fracture incidence and hospitalisations in Australia 2015-2106. 2018, AIHW

38. Guay, J. and S. Kopp, Peripheral nerve blocks for hip fractures in adults. *Cochrane Database Syst Rev* 2020;**11**:p. CD001159

39. Riemen, A.H. and J.D. Hutchison, The multidisciplinary management of hip fractures in older patients. *Orthop Trauma* 2016;**30**(2):p.117-122

40. Güllüpınar, B., et al., Effectiveness of pericapsular nerve group block with ultrasonography in patients diagnosed with hip fracture in the emergency department. *Ulus Travma Acil Cerrahi Derg* 2022;**28**(6):p.832-838

41. Mosaffa, F., et al., Comparison of pericapsular nerve group (PENG) block with fascia iliaca compartment block (FICB) for pain control in hip fractures: A double-blind prospective randomized controlled clinical trial. *Orthop Traumatol Surg Res* 2022;**108**(1):p.103135

42. Lin, D.Y., et al., Pericapsular nerve group block results in a longer analgesic effect and shorter time to discharge than femoral nerve block in patients after hip fracture surgery: a single-center double-blinded randomized trial. *J Int Med Res* 2022;**50**(3):p.3000605221085073

43. Ingoe, H.M., et al., Epidemiology of adult rib fracture and factors associated with surgical fixation: Analysis of a chest wall injury dataset from England and Wales. *Injury* 2020;**51**(2):p.218-223

44. Witt, C.E. and E.M. Bulger, Comprehensive approach to the management of the patient with multiple rib fractures: a review and introduction of a bundled rib fracture management protocol. *Trauma Surg Acute Care Open* 2017;**2**(1):p.e000064

45. Peek, J., et al., Comparison of analgesic interventions for traumatic rib fractures: a systematic review and meta-analysis. *Eur J Trauma Emerg Surg* 2019;**45**(4):p.597-622

46. Martel, M.L., et al., Feasibility and initial experience with continuous nerve blocks by emergency physicians. *Am J Emerg Med* 2020;**38**(6):p.1203-1208

47. Beard, L., et al., Multicenter longitudinal cross-sectional study comparing effectiveness of serratus anterior plane, paravertebral and thoracic epidural for the analgesia of multiple rib fractures. *Reg Anesth Pain Med* 2020;**45**(5):p.351-356

48. Tek en, ., et al., Analgesic efficacy of the serratus anterior plane block in rib fractures pain: A randomised controlled trial. *Am J Emerg Med* 2021;**41**:p.16-20

49. Adhikary, S.D., et al., The effect of erector spinae plane block on respiratory and analgesic outcomes in multiple rib fractures: a retrospective cohort study. *Anaesthesia* 2019;**74**(5):p.585-593

50. Zhao, Y., et al., Effects of erector spinae plane block and retrolaminar block on analgesia for multiple rib fractures: a randomized, double-blinded clinical trial. *Braz J Anesthesiol* 2022;**72**(1):p.115-121

51. Hayashi, M., et al., Success rate of anterior shoulder dislocation reduction by emergency physicians: a retrospective cohort study. *Acute Med Surg* 2022;**9**(1):p. e751

52. Blaivas, M., S. Adhikari, and L. Lander, A prospective comparison of procedural sedation and ultrasound-guided interscalene nerve block for shoulder reduction in the emergency department. *Acad Emerg Med* 2011;**18**(9):p.922-7

53. Raeyat Doost, E., et al., Ultrasound-guided interscalene nerve block vs procedural sedation by propofol and fentanyl for anterior shoulder dislocations. *Am J Emerg Med* 2017;**35**(10):p.1435-1439

54. Tezel, O., et al., A comparison of suprascapular nerve block and procedural sedation analgesia in shoulder dislocation reduction. *Am J Emerg Med* 2014;**32**(6): p.549-52

55. Yao, L., et al., Ultrasound-guided interscalene block versus intravenous analgesia and sedation for reduction of first anterior shoulder dislocation. *Am J Emerg Med* 2022;**56**:p.232-235

56. Dwyer, T., et al., Regional anesthesia and acute compartment syndrome: principles for practice. *Reg Anesth Pain Med* 2021;**46**(12):p.1091-1099

57. Nathanson, M.H., et al., Regional analgesia for lower leg trauma and the risk of acute compartment syndrome: Guideline from the Association of Anaesthetists. *Anaesthesia* 2021;**76**(11):p.1518-1525

58. Ivani, G., et al., The European Society of Regional Anaesthesia and Pain Therapy and the American Society of Regional Anesthesia and Pain Medicine Joint Committee Practice Advisory on Controversial Topics in Pediatric Regional Anesthesia. *Reg Anesth Pain Med* 2015;**40**(5):p.526-32

Prehospital Assessment of Trauma

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It was quite cold outside, 11 pm on a rainy day. Riding a 250cc Yamaha R25, Matt took the highway route back to his hometown in Kangar some 400 km away. It was a long quiet road. There were hills by the side and hardly any traffic, so he was riding faster than usual. At around 1 am, he saw a yellow light coming nearer to him in the middle of the road. Matt thought it was just another car. The visibility was low because of the heavy rain. That vehicle was coming closer. He was just wondering why that vehicle had just one light blinking or maybe its other front light was damaged. Suddenly, a van hit his bike and it went out of control! He was knocked unconscious.

Sairi was the medical assistant on duty that night in the emergency department, and Ram was the ambulance driver. Sairi had been trained in advanced trauma life support (ATLS) and Ram had been trained in Basic Life Support. Just as they were completing the essential checks on the ambulance, they received an emergency call. With the ambulance lights on, off they went. Arriving at the scene, Sairi assessed the safety and triage. The van driver was not injured. Sairi noticed Matt was unconscious on the road, not responding to call, with a Glasgow Coma Scale of 3/15.

Ram opened up Matt's airway with a jaw thrust maneuver, and Sairi stabilised his cervical spine with a hard collar. Subsequently, Matt was transferred to their type A ambulance via a spinal board.

Further assessment in the ambulance revealed that Matt's breathing was laboured and he looked cyanosed although his pulses were present. There were some abrasions over the chest and abdomen, but no gross deformity or bleeding was noted over his trunks and limbs.

As an ATLS provider, Sairi intubated Matt to secure his airway, inserted a large bore branula and connected to one pint of normal saline. Matt's oxygen saturation picked up.

A portable wireless monitor system was attached to Matt, and parameters such as ECG, heart rate, SpO_2 and SpHb were able to be shared in real-time with the emergency department of the hospital. The intensive care unit was alerted. Placement of ETT was reconfirmed by portable ultrasound.

Focused assessment with sonography in trauma (FAST) scan was performed to look for pathology in the heart, lungs, and abdomen. A significant amount of free fluid was detected at the Morrison's Pouch. A barcode sign was noted during the right lung scan. Coupled with reduced air entry and hyperresonance on percussion on right chest, a diagnosis of right pneumothorax was made. Meanwhile, Matt's blood pressure was noted to be low and his SpO_2 started to drop. Without further ado, needle thoracocentesis was performed on the right chest to release the pneumothorax. Sairi conveyed the findings to the emergency trauma team, and the trauma operating theatre was alerted.

Ram turned on the ambulance siren and light and rushed to the hospital, while Sairi continued the resuscitation. Once they reached the hospital, Matt was resuscitated by the emergency trauma team, and he successfully underwent life-saving surgery. A combination of the accurate assessment and critical care provided by Sairi and Ram at the accident scene and the speed in getting to definitive treatment in hospital had left a significant impact on Matt's recovery.

(Disclaimer: This is a narration of fiction. Any similarity to actual persons or actual event, is purely coincidental.)

INTRODUCTION

Historically, there was a dramatic improvement in prehospital emergency trauma care during the mid-1950s due to advancement in the automobile industry and the corresponding construction of interstate highways after World War II.[1]

The highway network of Malaysia is considered amongst the best in Asia.[2] However, Malaysia also recorded the third highest death toll from road accidents in Western Pacific region.[3] Most trauma cases in Malaysia are due to road traffic accidents. Other types of trauma include industrial injury, fall, thermal injury, domestic injury or interpersonal violence. Prehospital trauma care is an important component of our healthcare system and is life-saving.

THE STRUCTURE

Prehospital care is part of the seamless continuum of trauma care that begins with efforts from the first responder, which is usually the public, up to the definitive surgical intervention, intensive care and rehabilitation programme at the hospital (Figure 1). In Malaysia, prehospital trauma care is provided by the emergency departments from both the government sector (with medical assistants as the main providers) and non-government organisations, e.g. the Red Crescent and St John Ambulance (by healthcare volunteers). Once reaching hospital, the subsequent trauma resuscitation is usually conducted by the emergency departments. Unlike many European countries, direct physician participation in prehospital trauma care in Malaysia is still uncommon.[1]

Prehospital trauma care providers are either trained in basic life support (BLS) or advanced trauma life support (ATLS). BLS includes airway assessment and non-invasive ventilation techniques, vital sign measurements, cardiopulmonary resuscitation, automated external defibrillation, basic bleeding control, as well as fracture and spine immobilisation. ATLS providers are trained for invasive airway method including endotracheal intubation (ETI), intravenous (IV) access, fluid and medication administration.

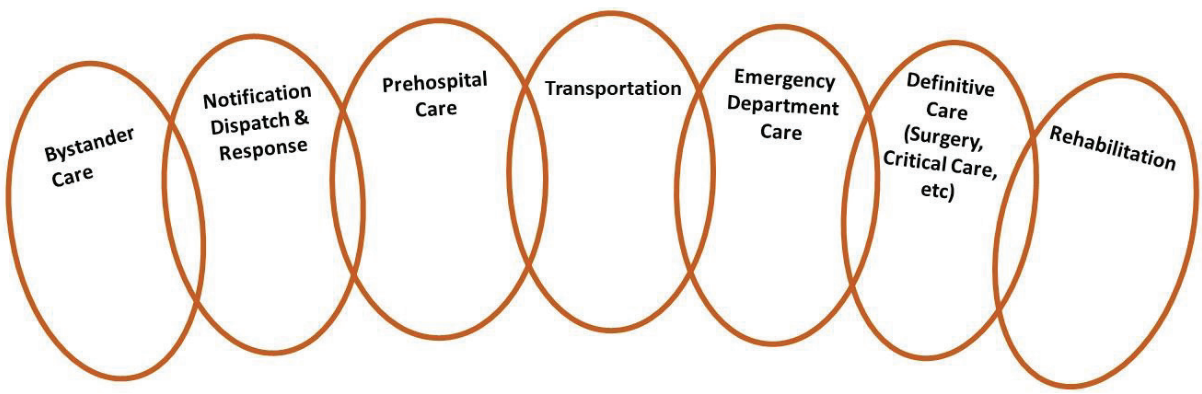

Figure 1: Chain of comprehensive care during trauma illustrated by Sikka and Margolis. (Adapted from Ref 4 with permission.)[4]

TRIAGE

Triage is the process of rapidly and accurately evaluating patients to determine the appropriate level of care required. The goal is to transport seriously injured patients to medical facilities capable of providing appropriate care according to the level of injury. For example, a patient with a traumatic brain injury, once identified at scene, will be diverted to a hospital with neurosurgery service, regardless of the origin of the ambulance. This overall movement of the patients is controlled mainly by the state level medical emergency coordinating centre (MECC), with emergency physicians being the medical directors.

In times of mass casualty incident (MCI), field triage is one of the most important aspects in prehospital trauma care. Priority is placed on providing care to victims that are most likely to survive. A number of prehospital traige scoring systems have been developed (referring to systems in Table I). They usually incorporate simple assessments of neurologic, respiratory, and circulatory function. Performance of these scoring system differs in sensitivity and specificity. In field triage for MCI, algorithm such as Simple Triage and Rapid Treatment (START) system is commonly used by Malaysian prehospital care providers.[5,6]

Table I: Prehospital trauma triage scoring systems for individual care[7]

Name	Parameters
Prehospital Index	Systolic BP Pulse rate Respiratory rate Consciousness Penetrating wounds (chest or abdomen)
Revised Traura Score	Systolic BP Respiratory rate GCS
GC5 (Glasgow Coma Scale)	Eye response Verbal response Motor response
mREMS (modified Rapid Emergency Medicine Score)	Age Systolic BP Heart rate Respiratory rate Oxygen saturation GOS

PRIMARY SURVEY

The ATLS guidelines emphasise a systematic approach to injured patients, i.e. primary "focused" assessments followed by secondary "detailed" assessments. The primary survey follows the ABCDE pattern i.e. Airway (with cervical spine control), Breathing, Circulation, Disability (Neurological status) and Exposure.

Airway assessment is of utmost importance. If the airway is not patent, a jaw thrust manoeuvre should be performed to open the airway. Airway adjuncts such as oropharyngeal airway is often used. Simultaneously, restriction of the cervical spine motion should be performed.

If a patient is indicated for intubation, laryngeal mask airway is commonly used at the scene before definite airway is established upon arrival to an emergency department. If a provider is trained in ETI, he may proceed with drug assisted intubation (formerly called rapid sequence intubation) to secure the airway. The portable video-assisted laryngoscopes have already been introduced to prehospital care providers since the COVID-19 pandemic. Video laryngoscopes are especially useful for suspected spine injury cases where neck movement needs to be avoided.

After airway assessment, attention will be turned to "Breathing". In patients who are able to maintain their own airway, supplementary oxygen such as nasal oxygen cannula or non-rebreather mask is an option. If breathing is impaired, assisted ventilation should be provided using a bag-valve mask ventilation with airway adjuncts. In cases when brain injury is suspected, nasopharyngeal airway is contraindicated with the concern of basal skull fracture. Further assessment includes assessment of respiration and auscultation to identify life-threatening injuries such as tension pneumothorax, open pneumothorax and haemothorax. When a tension pneumothorax is identified at scene, needle thoracocentesis are now recommended at

5th intercostal space, mid-axillary line for adults, whereas 2nd intercostal space for children. Chest drainage for haemothorax is usually not done prehospital due to the inconvenience in the confined space in an ambulance. However, if the procedure is done by an experienced ATLS provider, a smaller calibre 28-32 Fr chest tube is preferred as compared to 36-40 Fr chest tube.

In "Circulation", prehospital care providers manage any external active haemorrhage first using direct pressure, haemostatic agents with packing or dressings, as well as tourniquet application whenever appropriate. Subsequent abdomen assessment and pelvic spring are performed to look for any signs of intraabdominal injuries. Open book fracture can be stabilised by applying a pelvic binder or pelvic wrap. Ideally, blood pressure measurements should be obtained. Studies suggest that prehospital hypotension (Systolic blood pressure <90mmHg) is associated with an increased risk of mortality particularly in head-injured patients.[8] Providers will attempt to establish IV access when feasible, but should not delay the prehospital transport time. Generally, up to two attempts is acceptable at scene, after which an intraosseous route is considered if clinically indicated. Ambulances in Malaysia do not carry blood products for prehospital resuscitation, thus crystalloid remains the de facto resuscitation fluid along the journey to the emergency department. As per latest ATLS guideline, 1-liter bolus of crystalloid (preferably an isotonic solution) for adults may be administered judiciously during prehospital, however one should receive blood transfusion in emergency department if remain unresponsive to initial fluid resuscitation.[9]

After applying appropriate haemorrhage control technique, neurological status is assessed using assessment of AVPU (i.e. Alert, responds to Voice, responds to Pain, or Unresponsive) or more commonly, the GCS score. The size and reactivity of pupils to light is also assessed. Healthcare providers will subsequently expose the patient adequately to look for any hidden injury such as entry and exit wounds and fracture over the extremities.

Prehospital care providers will then relay the information of the patient, clinical findings and the initial resuscitation performed to the MECC during transportation. This can be summarised using Situation, Background, Assessment, Recommendation (SBAR) method per latest ATLS recommendation. Concise information is necessary to prepare the trauma team in the hospital where the subsequent advanced trauma care will be provided seamlessly.

SECONDARY SURVEY

After the primary survey, the prehospital care provider performs a quick but thorough review from head to toe, i.e. the secondary survey. This is to identify any injuries that may be missed during the primary survey.

Providers are trained to inspect the commonly missed areas e.g. the back, the axillae, the gluteal and inguinal regions. A periodic primary survey reassessment is also recommended by the ATLS guidelines, especially in a critically ill trauma patient.

OTHER ASSESSMENT AND CONCERNS

Spinal immobilisation is continuously maintained during transportation. Some newer guidelines have moved away from using a spinal board and only focus on cervical spine immobilisation.[10]

If a patient is to be transported from one place to another, it is mandatory to reassess ETT placement once the move is complete. Paramedics often confirm placement by 5 quadrant auscultation. However, this approach is sometimes difficult to perform in a noisy prehospital environment. End tidal carbon dioxide ($ETCO_2$) may provide a more accurate assessment for successful endotracheal intubation. Pulse oximetry is also important.

Tranexamic acid (TXA) is an anti-fibrinolytic agent that sometimes may be administered in prehospital care of trauma patients. The latest ATLS guidelines recommended early administration of 1 gram TXA within 3 hours of injury. Following a bolus dose of TXA given at the scene, a follow up infusion of TXA 1 gram over 8 hours should be administered in the hospital. For severe bleeding trauma patients known to be on anticoagulants, reversal agent administration may be helpful.

Studies have shown that pain control is often neglected in prehospital trauma care.[11] This may be due to concerns of the masking effect of analgesic medications which may lead to diagnostic difficulty, haemodynamic instability, and respiratory depression as well as an altered sensorium. If a patient is obviously in pain, a single dose of IV tramadol 1-2mg/kg is usually given.[12] Paramedics should carefully assess and monitor the respiratory and haemodynamic status of any patient receiving opioids.

For patients with significant burns (e.g. large body surface area, inhalation injury, high voltage electrical source), fluid resuscitation is important in prehospital care. Transportation to a trauma centre with burn unit is preferred.

ADVANCED DEVICES

Point of Care Ultrasound in Prehospital Trauma Assessment

Point of care ultrasound (POCUS) is an advancement of technology in trauma care. It is now a feasible technology that is affordable to the personal budget of a medical practitioner. Ultrasound technology can greatly enhance our assessment skills and scope of practice. Ideally, POCUS should be performed once the spine is stabilised, bones splinted, and bleeding stopped, after the patient is transferred into an ambulance. Through a probe connected via an USB adapter into a smartphone or tablet, three primary anatomical areas can be assessed easily - the heart, the lungs and the abdomen.

Latest literature suggests that among trained paramedics, point of care ultrasound can be an excellent tool in secondary survey.[13] Providers will be able perform FAST examination, transthoracic echocardiography, Rapid ultrasound in Shock (RUSH) protocol, vascular access, confirmation of endotracheal intubation and identify the fractures.[14] During a traumatic cardiac arrest, POCUS will be useful to identify the reversible cause of cardiac arrest such as cardiac tamponade.

FAST Scan of the Abdomen

Scanning free fluid around the liver, spleen, kidneys and even the bladder can all raise alarm to intra-abdominal injury. Such patients may need blood transfusions and surgery.

Followed by the Heart

A cardiac tamponade can easily be detected by a transthoracic cardiac scan. Subxiphoid and parasternal views can show views of the chambers, ventricular wall movement, and also pericardial sac integrity.

Assessing the Lungs

Bar codes signs and lung point indicate pneumothorax. Coupled with reduced air entry and hyper-resonance on percussion, a pneumothorax can be detected early. Detection of fluid in pleural cavity may suggest a haemothorax.

ETT Placement

Additionally, point of care ultrasonography can be used to confirm endotracheal intubation. With tracheal and thoracic scan, it can detect main stem intubations, and guide tube positioning at scene.

Vascular Access

POCUS in the prehospital care setting can provide us with some accurate assessment of internal clarity. Besides, it can be used to guide vascular access. Lack of data on improved patient outcomes, high equipment costs and training difficulties are recognised barriers to the use of POCUS in prehospital care.[15] Other barriers and challenges in using POCUS include lack of direct supervision, lack of time for POCUS due to heavy workload and absence of quality assurance processes.[16]

An introduction to POCUS in the context of prehospital care has been produced by Mr Saiful Nizam Bin Sairi (Figure 2), a registered medical assistant and his team from Hospital Sultanah Bahiyah, Kedah and can be viewed online (https://youtu.be/ID_F1SvkP8Q). Mr Saiful Nizam has been active in providing training sessions on point of care ultrasound (Figure 3) and had contributed to a guide book called "Simple Guide to Point of Care Ultrasound".[17]

Figure 2: Mr Saiful Nizam attending to a teenager who had fallen from a height of more than 30 feet. He performed a lung scan and detected a pneumothorax. A needle thoracocentesis was subsequently performed and helped in stabilising the patient

Figure 3: Mr Saiful Nizam (man in blue shirt) has been active in providing training sessions on point of care ultrasound

Advancement in Monitoring

Monitoring of serial vital signs while transporting patients is important to raise any red flags. Latest monitors include Corpuls3 has module for 12-lead ECG with analysis, blood pressure, heart rate, oxygen saturation (SpO_2), carbon monoxide level (SpCO), methaemoglobin level (SpMet,) non-invasive and continuous haemoglobin monitoring (SpHb), capnography ($ETCO_2$), temperature and microphone for audio recording. It also has telemedicine application which enables real-time transmission of data to any suitable computer connected to it. Thus, medical data can be shared live, no matter how far away the mission site is from the hospital or the specialist.

A new development in patient monitoring is the transcutaneous measurement of tissue haemoglobin oxygenation (StO_2).[18] It gives prehospital providers a tool to assess hypoperfusion in the field in which an StO_2 value of 75% and below indicates hypoperfusion. The future may see other monitoring modalities being introduced and used, such as a point-of-care lactate test (much like a glucometer) because lactate has been shown to be associated with tissue hypoperfusion and shock.

PREHOSPITAL POINT OF CARE BLOOD PARAMETER ASSESSMENT

Potential point of care blood test that can be used in prehospital care include the i-STAT device (Abbott Point of Care, Abbott Park, Illinois) (Figure 4).[19] The i-STAT is a portable handheld blood analyser that produces immediate results with only a few mls of blood. Parameters that can be tested include serum lactate, blood gases, serum electrolytes, cardiac markers, PT/INR, ACT and haematological parameters. In a trial on prehospital trauma assessment using i-STAT device where 16 tests were compared, lactate was shown to outperform vital signs and shock index for detecting shock and predicting the need for live-saving interventions. A lactate level of more than 4mmol/L was found to be highly alarming in a prehospital severe trauma assessment.[9] However, some of these portable tests are classified as moderate-complexity, and thus the laboratory using the cartridge must obtain proper accreditation and maintenance.

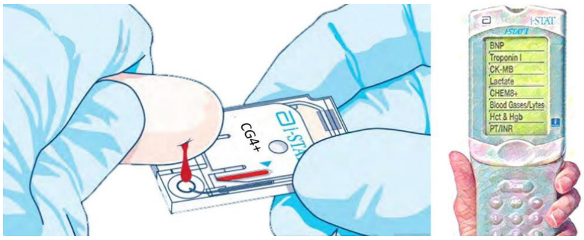

Figure 4: Point of care test is becoming easier with the use of portable handheld blood analyser that produces immediate laboratory results such as serum lactate which may guide resuscitation

CONCLUSION

Prehospital trauma care is an important component of healthcare that determine patients' survival. A systematic approach and initial life-saving procedures can be performed on-site to improve the survival rate of trauma patients. Thus providers are encouraged to equip themselves with up-to-date knowledge and skills according to local as well as international guidelines. The prehospital system needs to be reviewed regularly and providers need to be credentialed from time to time in order to be able to perform the necessary prehospital trauma care. If appropriate, new technologies such as POCUS in trauma, techniques and tools can be adopted and has the potential of improving prehospital resuscitation and patient survival.

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References

1. Brown J, Sajankila N, Claridge JA. Prehospital Assessment of Trauma. *Surg Clin North Am* 2017;**97**(5):961-983. DOI: 10.1016/j.suc.2017.06.007

2. Ibrahim Z, Asari A. The Development Of Wind Power Energy For Lighting System In The Highway. *Malaysian Journal of Industrial Technology* 2019;**2**(1):1-6. (https://www.researchgate.net/profile/Zulfahmi-Ibrahim/publication/334362075_The_Development_Of_Wind_Power_Energy_For_Lighting_System_In_The_Highway/links/5d25835b92851cf44074deba/The-Development-Of-Wind-Power-Energy-For-Lighting-System-In-The-Highway.pdf)

3. Organization WH. The World Health Organization Launches the Global Plan for the Decade of Action for Road Safety 2021 - 2030. (https://www.who.int/malaysia/news/detail/28-10-2021-the-world-health-organization-launches-the-global-plan-for-the-decade-of-action-for-road-safety-2021-2030)

4. Sikka N, Margolis G. Understanding diversity among prehospital care delivery systems around the world. *Emerg Med Clin North Am* 2005;**23**(1):99-114. DOI: 10.1016/j.emc.2004.09.007

5. Management CHEM. START Adult Triage Algorithm. (https://chemm.hhs.gov/startadult.htm)

6. Benson M, Koenig KL, Schultz CH. Disaster triage: START, then SAVE--a new method of dynamic triage for victims of a catastrophic earthquake. *Prehospital and disaster medicine* 1996;**11**(2):117-24. (In eng). DOI: 10.1017/s1049023x0004276x

7. Blackwell T. Prehospital care of the adult trauma patient. UpToDate, Waltham, MA 2011

8. Spaite DW, Hu C, Bobrow BJ, et al. The Effect of Combined Out-of-Hospital Hypotension and Hypoxia on Mortality in Major Traumatic Brain Injury. *Ann Emerg Med* 2017;**69**(1):62-72. (In eng). DOI: 10.1016/j.annemergmed.2016.08.007

9. Galvagno SM, Jr., Sikorski RA, Floccare DJ, et al. Prehospital Point of Care Testing for the Early Detection of Shock and Prediction of Lifesaving Interventions. *Shock* 2020;**54**(6):710-716. DOI: 10.1097/SHK.0000000000001567

10. White CCt, Domeier RM, Millin MG. EMS spinal precautions and the use of the long backboard - resource document to the position statement of the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma. *Prehosp Emerg Care* 2014;**18**(2):306-14. (In eng). DOI: 10.3109/10903127.2014.884197

11. Hennes H, Kim MK, Pirrallo RG. Prehospital pain management: a comparison of providers' perceptions and practices. *Prehosp Emerg Care* 2005;**9**(1):32-9. DOI: 10.1080/10903120590891705

12. Davidson EM, Ginosar Y, Avidan A. Pain management and regional anaesthesia in the trauma patient. *Current opinion in anaesthesiology* 2005;**18**(2):169-74. (In eng). DOI: 10.1097/01.aco.0000162836.71591.93

13. El Zahran T, El Sayed MJ. Prehospital Ultrasound in Trauma: A Review of Current and Potential Future Clinical Applications. *J Emerg Trauma Shock* 2018;**11**(1):4-9. DOI: 10.4103/JETS.JETS_117_17

14. Amaral CB, Ralston DC, Becker TK. Prehospital point-of-care ultrasound: A transformative technology. *SAGE Open Med* 2020;**8**:2050312120932706. DOI: 10.1177/2050312120932706

15. Bøtker MT, Jacobsen L, Rudolph SS, Knudsen L. The role of point of care ultrasound in prehospital critical care: a systematic review. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine* 2018;**26**(1):51. DOI: 10.1186/s13049-018-0518-x

16. Wong J, Montague S, Wallace P, et al. Barriers to learning and using point-of-care ultrasound: a survey of practicing internists in six North American institutions. *The Ultrasound Journal* 2020;**12**(1):19. DOI: 10.1186/s13089-020-00167-6

17. hafiza Yezid N. Simple Guide to Point of Care Ultrasound: Ultrasound: FizaYezid, 2021

18. Sagraves SG, Newell MA, Bard MR, et al. Tissue oxygenation monitoring in the field: a new EMS vital sign. *J Trauma* 2009;**67**(3):441-3; discussion 443-4. DOI: 10.1097/TA.0b013e3181b88de7

19. i-STATProduct Catalog. (https://www.globalpointofcare.abbott/en/product-details/apoc/i-stat-system.html)

Geriatric Trauma and Anaesthesia

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THE AGING POPULATION

There are three groups of elderly described: young-old aged 65-74 years, mid-old aged 75-84 years and oldest-old aged 85 and above.[1] With advances in healthcare and disease management, there has been an increase in life expectancy. A Malaysian baby born in 2021 is expected to live up to 75.6 years, 1.3 years longer than a baby born in 2011.[2] The World Health Organisation predicted that by 2030, 1 in 6 people will be 60 years or older worldwide.[3] Geriatric trauma, the fifth commonest cause of mortality in the elderly, has also increased from 18 to 30% between 2005 and 2015.[4,5]

Although the nature of injuries in the elderly patients are generally less severe compared to younger patients, the mortality rate is higher due to aging physiology, co-morbidities and frailty.[5,6] Falls, mostly at ground-level, are the commonest mechanism of injury in the elderly.[5] Annually, 33% adults aged over 65 years fall due to the following risk factors: previous episode of a fall, living alone, walking aids, depression, cognitive deficit and polypharmacy.[5,7] Apart from fractures, of which hip fractures are the commonest, these fall can also result in traumatic brain injury, which further contributes to the morbidity and mortality in this age group.[5]

THE AGING PHYSIOLOGY

There is a general decline of physiological function with age.[8] Increased collagen and fibrous tissue in the myocardium reduce both the ventricular compliance and early left ventricular diastolic filling.[1,6] The diastolic filling is further impaired in the presence of tachycardia. The cardiac output is on the flatter part of the Starling curve with less reserve and is very sensitive to the effects of anaesthesia. The decreased cardiac output may be profound as there is poor response to inotropes. The elderly is often hypertensive at baseline due to co-morbidities and decreased vascular elasticity.[6] The baroreceptors in the aortic arch and carotid sinuses are also less sensitive to hypotension. As a result, haemodynamic instability due to significant blood loss may be slow to develop. Furthermore, compensatory tachycardia may not occur in patients on β-blockers.

Gradual calcification, together with atherosclerotic plaques reduces vascular compliance and elasticity, leading to an increased afterload.[1,6] There is also calcification and fibrotic changes of the conducting pathway leading to susceptibility of developing arrhythmias.[1] Atrial fibrillation is the commonest arrhythmia in the elderly, affecting 9% of octogenarians.[9] Although the intrinsic sinus rate is lowered, the overall heart rate is almost preserved by the sympathetic tone. Calcification also affects the cardiac valves, causing them to thicken and dilate.[1]

There is a slight dilatation of the trachea and small airways with increasing age, leading to an increase of dead space.[1] The lung's compliance increases with age, leading to small airway compression during expiration. Closing volume is equal to the erect functional residual capacity by age 66 years. Although the total lung capacity is generally preserved, the vital capacity reduces by 26 and 22ml per year in men and women, respectively.[1,6] The reduced muscle mass and innervation together with a slower contraction-relaxation cycle leads to progressive weakening of the respiratory muscles.[1] Both the forced vital capacity and forced expiratory volume at 1 second are reduced in the elderly.[1,6] The pulmonary artery pressure is raised up to 30% but the wedge pressure is unchanged if the left heart remains healthy.[1]

Apart from kidney shrinkage, the number of glomeruli also decreases from 1,000,000 at age 30 to 700,000 at age 65, leading to reduced creatinine and urinary drug clearance.[1,6] Even though serum electrolytes remain constant for those with healthy kidneys, the elderly are prone to electrolyte and water imbalance due to deteriorating counter-current mechanism in the loop of Henle.[1] Angiotensin II and aldosterone are less active due to a reduced renin release. Potassium retention is more likely especially with those who are taking angiotensin converting enzyme inhibitors. The kidney is less able to excrete acid load with advancing age, causing an outward potassium shift from the cells. More than 90% of males aged 80 will have developed symptomatic prostatic hyperplasia, predisposing to urinary infections.

There is brain atrophy with very little loss of cells.[1] The cerebrospinal fluid (CSF) volume increases without any increase in CSF pressure. Both cerebral blood flow and oxygen demand decrease, but vascular degenerative changes increases. Nerve conduction velocity is slower due to deterioration of myelin sheath both centrally and peripherally.

With age, there is an increased sympathetic activity accompanied by reduced parasympathetic tone.[1] Attenuation of sinus arrhythmia is observed with respiration, plus diminished response to Valsalva manoeuvres. Adrenoreceptors are downregulated in most organs with an overall reduced adrenal secretion.[10] There may also be impaired of both vision and hearing together with problems with balance, gait and memory.[1] Tendons are stiffer causing reduced joint mobility. Osteoporosis, cartilage degeneration, subchondral bone thickening and bone cysts are common in the elderly.[6] These combined with unsteady gait and poor visual acuity predispose the geriatric population to orthopaedic trauma.[1]

The aging oesophagus has less motility, predisposing the elderly to delayed gastric emptying and constipation.[1] In the elderly, the liver volume and blood flow are reduced by 20-40% and 35-50%, respectively.[11] However, liver functions are relatively well preserved. The α_1 acid glycoprotein concentration increases with a reduction of albumin concentration, which may affect the pharmacokinetics of a single intravenous bolus.[1] This is counterbalanced by changes in clearance producing equilibrium.

Vasoconstriction and shivering responses to hypothermia are impaired in the elderly.[1] In the aged, shivering is triggered at an average core temperature of 35.2ºC compared to 36.1ºC in a younger adult. When shivering occurs, it is also less efficient to a reduced muscle mass.

PRE-OPERATIVE MANAGEMENT

The aims of pre-operative assessment in the elderly are to assess physiological reserve, evaluate co-morbidity and optimisation prior to surgery.[1] It is estimated that beyond the age of 70 years, a person will have at least five co-morbidities, of which the main ones are listed in Table I.[12] These co-morbidities, together with the associated prescribed medications pose a challenge to the anaesthesiologist as the period of optimisation for a trauma case is limited compared to an elective procedure. Some of the medications may also be long-acting, such as antiplatelet agents.

Table I: Main co-morbidities beyond the age of 70 years[12]

Co-morbidities	Frequency (%)
Hypertension	50-60
Hearing loss	35
Degenerative joints	30
Dementia	30
Repeated falls	25
Visual impairment	20
Cancer	20
Coronary artery disease	15
Cardiac failure	15
Diabetes	10-20

History of cardiorespiratory illness may be masked by poor mobility prior to the trauma and pre-operative examination may not be full and thorough due to positioning and immobility.[1] Baseline investigations, which are full blood count, urea, electrolytes, blood glucose, ECG and chest X-Ray must be obtained. Further investigations may be necessary based on co-morbidities, nature of injury and medication.

In most circumstances, patient optimisation must be balanced with the need for an early surgery, mobilisation and rehabilitation, as delayed surgery has been shown to have a higher degree of mortality.[12] Optimisation includes pre-operative correction of derangement (e.g. dehydration, anaemia, electrolyte disturbances, coagulopathy and arrhythmias) and disease modification (e.g. cardiac disease, respiratory impairment and renal failure). Some of the disease modification may not be possible within the timeframe, and in this circumstance must not be reason to delay surgery. In circumstances where disease modification is not possible, a multi-disciplinary discussion should be conducted to weigh the benefit vs risk and formulate a management plan to achieve the best possible outcome for the patient.

Each of the patients' medication must also be properly reviewed for continuation or to be withheld pre-operatively. Sedative pre-medication can be unpredictable in the elderly, causing confusion rather than anxiolysis.[1] Glycopyrrolate is preferred over atropine, an anti-sialagogue, as it does not cross the brain-brain barrier.

GENERAL VS REGIONAL ANAESTHESIA

Compared to general anaesthesia, regional anaesthesia is associated with fewer short-term complications and better post-operative analgesia.[1] Epidural analgesia also reduces the incidence of deep vein thrombosis, cardiorespiratory complications and renal failure. However, the patient must be able to tolerate the trauma pain during the positioning required for epidural insertion and subsequently, during the procedure. Central neuraxial block produces sympathetic blockade, reducing both preload and afterload, therefore, care must be taken in patients with limited cardiac output.[8] Neuraxial blocks are contraindicated in uncorrected anticoagulated patients.[12] The choice of anaesthesia depends on the patient's general condition, surgical procedure and anaesthesiologist's experience.[8] In terms of long-term outcome, such as mortality, the choice of either general or regional anaesthesia was similar, perhaps due to the factors associated with aging and co-morbidities.[13,14]

In the elderly, a reduced local anaesthetic dose is needed for peripheral nerve blocks, and possibly central neuraxial block.[1] This is probably due to the demyelination of the nerve with age. Following an epidural delivery of local anaesthesia, a higher upper level of anaesthesia is seen in the elderly, attributed to reduced local anaesthesia leakage from sclerotic closure of the intervertebral foramina.[8] The reduction of renal, hepatic and plasma esterase function decreases local anaesthesia clearance from the circulation, thus careful titration and monitoring is needed for elderly patients who receive post-operative local anaesthetic infusions.[1,8]

GENERAL ANAESTHESIA

The lack of cartilaginous and muscular support in the elderly face leads to substantial air leak during pre-oxygenation, which is further exacerbated in edentulous individuals.[1] Laryngoscopy and intubation may be difficult in the presence of loose teeth, stiff temporomandibular joint and ankylosing spondylitis.[8]

Both pharmacodynamic effects and pharmacokinetic drug behaviour are altered in the elderly.[1] Furthermore, polypharmacy, which is a common issue among the elderly population, may pose interactions with anaesthetic agents.[1,5] The total body water and intravascular compartment size decreases with age, leading to smaller volume of distribution and higher plasma concentration for an intravenous bolus agent.[1]

In the elderly, an intravenous drug may take a longer time to exert an effect due to delayed effector site delivery.[1] Extra time in between titrations must be given for the effect to occur, to avoid inadvertent overdose. Apart from delayed onset, many drugs also have prolonged effect due to decreased renal and hepatic clearance, leading to accumulation of active metabolites.

Propofol has a lower volume of distribution and higher plasma concentration due to changes with age.[1] The dose for loss of consciousness and apnoea are reduced.[15] Hypotension due to propofol is exaggerated compared to younger patients, but the effect has a delayed onset.[1] For thiopentone, although the dose needed for anaesthesia is reduced, the loss of consciousness occurs at the same plasma concentration as younger adults.[1] Albumin binding is slightly reduced, thus the plasma concentration of thiopentone is further increased if delivered too fast. Although, the geriatric patient is more sensitive to inhalational anaesthetic agents, modern anaesthetic machines are programmable to take the patients' age into account.[1] Elderly patients have been reported to recover faster from desflurane compared to sevoflurane following surgery lasting for at least two hours.[16]

Muscle relaxants have a delayed onset in the elderly due to reduced muscle blood flow.[1] Except for atracurium and cis-atracurium, the duration of muscle relaxants is prolonged when there is reduced metabolism and clearance. Atracurium undergoes a mixture of spontaneous Hofmann degradation and hepatic metabolism, whereas cis-atracurium is 83% cleared by Hofmann degradation.

The volume of distribution of opioid in the geriatric patient is about half of a younger patient.[1] This together with reduced clearance in the elderly leads to an enhanced sensitivity to opioids. Reduced dosage and careful titration are essential in this population.

Positioning of the elderly patients during general anaesthesia must be done gently and with great care. Adequate padding must be applied as there is risk of pressure damage due to fragile skin and lack of muscle mass.[1]

Maintenance of the core temperature is very important in the elderly during general anaesthesia. Hypothermia is associated with impaired coagulation, sympathetic response and poor wound healing.[1] Furthermore, stored blood will increase the effect of hypothermia when transfused. Multiple measures, which include forced-air warming blanket, warming mattress, passive insulation and warmed intravenous infusion are used to help maintain temperature intraoperatively. The geriatric trauma patients also fare better with liberalised compared with restrictive transfusion protocol as anaemia is poorly tolerated in the elderly.[6]

POST-OPERATIVE CARE

Many of the immediate post-operative anaesthetic problems are the residual effects due to reduced clearance and prolonged action of the anaesthetic drugs.[1] The residual effects can result in hypoventilation, hypoxia, hypotension, somnolence, delirium and hypothermia, further compounded by trauma. Thus, a period of monitoring in a high dependency area may be required.

As there is a fear of overdosing, pain control in the elderly may be suboptimal. If left untreated, this may lead to cardiorespiratory complications, altered mental status and chronic pain.[1] Good analgesia is essential in the geriatric trauma patients to promote early mobilisation and rehabilitation process. A multimodal approach helps to provide better analgesia with minimal side-effects.

Paracetamol is the first-line option for mild and moderate pain.[1] Although there is reduced clearance, no dose adjustment is needed unless there is hepatic impairment. Non-steroidal anti-inflammatory drugs must be utilised with care in the elderly. When prescribed, it should be lowest therapeutic dose for the shortest possible time with renal function monitoring.[1] As mentioned above, opioids requirement for the elderly are lower, thus patient-controlled analgesia devices are programmed at half the usual dose for the geriatric patients.

SUMMARY

Even though the nature of injury may seem trivial, geriatric trauma pose a challenge to the anaesthesiologist due to the aging physiology, co-morbidities and polypharmacy. Optimisation is ideal but may be limited as early surgery is beneficial in promoting mobilisation and rehabilitation. The choice of anaesthesia depends on the patient's condition, nature of surgery and anaesthesiologist's experience. Care must be taken intraoperatively to help ensure a good recovery.

References

1. Spoors C, Kiff K. Training in Anaesthesia- the essential curriculum, 1st Edition. Oxford Specialty Training, 2010, pp 518-25

2. Department of Statistics Malaysia Official Portal. Life Expectancy at Birth. Department of Statistics Malaysia Official Portal (dosm.gov.my) Accessed June 10, 2022

3. Ageing and health. Ageing and health (who.int) Accessed June 10, 2022

4. Jiang L, Zheng Z, Zhang M. The incidence of geriatric trauma is increasing and comparison of different scoring tools for the prediction of in-hospital mortality in geriatric trauma patients. *World Journal of Emergency Surgery* 2020:**15**;59

5. Adams SD, Holcomb JB. Geriatric trauma. *Curr Opin Crit Care* 2015;**21**(6):520-26

6. Scher CS. Trauma and transfusion in the geriatric patient. *Curr Opin Anesthesiol* 2018;**31**(2):238-42

7. Carpenter CR, Avidan MS, Wildes T, Stark S, Fowler SA, Lo AX. Predicting Geriatric Falls Following an Episode of Emergency Department Care: A Systemic Review. *Acad Emerg Med* 2014;**21**:1069-82

8. Potocnik I, Novak-Jankovic V. Intraoperative Problems and Management in Geriatric Trauma Patients. Biomedical Journal of Scientific & Technical Research 2018;6(5)

9. Diez-Villanueva P, Alfonso F. Atrial fibrillation. *J Geriatr Cardiol* 2019;**16**(1):49-53

10. Yiallouris A, Tsioutis C, Agapidaki E, Zafeiri M, Agouridis AP, Ntourakis D et al. Adrenal Aging and Its Implications on Stress Responsiveness in Humans. *Front Endocrinol* 2019;**10**:54

11. Tajiri K, Shimizu Y. Liver physiology and liver diseases in the elderly. *World J Gastroenterol* 2013;**19**(46):8459-67

12. Boddaert J, Raux M, Khiami F, Riou B. Perioperative Management of Elderly Patients with Hip Fracture. *Anesthesiology* 2014;**121**:1336-41

13. Davis FM, Woolner DF, Frampton C, Wilkinson A, Grant A, Harrison RT et al. Prospective, Multi-Centre Trial of Mortality Following General or Spinal Anaesthesia for Hip Fracture. *BJA* 1987;**59**:1080-88

14. Urwin SC, Parker MJ, Griffiths R. General versus regional anaesthesia for hip fracture surgery: a meta-analysis for randomized trials. *BJA* 2000;**84**(4):450-55

15. Dundee JW, Robinson FP, McCollum JSC. Sensitivity to propofol in the elderly. *Anaesthesia* 1986;**41**:482-85

16. Heavner JE, Kaye AD, Lin B-K, King T. Recovery of elderly patients from two or more hours of desflurane or sevoflurane anaesthesia. *BJA* 2003;**91**(4):502-6

Trauma Involving Airways and Ventilation Strategies

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INTRODUCTION

Injuries and deaths related to trauma account for a significant worldwide health problem. In Malaysia, it increases the morbidity and mortality of those 40 years old and below. According to the Malaysia Health Fact 2008, trauma is the third leading cause of admission to hospitals following admissions caused by pregnancy and childbirth complications.[1] Airway trauma due to blunt or penetrating injuries to the neck and chest can be life-threatening. Chest trauma alone contributed up to 25% of all deaths.[2] Failure to recognize the simultaneous other injuries and airway trauma may delay the treatment and lead to fatal outcomes. The complications of airway injuries include respiratory failure, airway obstruction, tension pneumothorax, or late sequelae of tracheal stenosis.

Most airway trauma can be managed by interventions such as intercostal chest tube drainage, supplemental oxygen, and analgesia. However, severe airway injury that leads to respiratory failure might need mechanical ventilation.

PATHOPHYSIOLOGY OF RESPIRATORY AND CARDIOVASCULAR IMPAIRMENT

Airway injuries of the neck involve direct penetrating or blunt trauma. The neck hyperextension during injury may cause tracheal tears, laryngotracheal separation, or paramedian vertical fractures of the larynx and trachea. Direct blows to the neck usually cause thyroid and cricoid cartilage injuries.

Direct traumatic pulmonary injury increases vascular permeability and extravasation of fluid that alters surfactant composition, resulting in progressive respiratory failure.[3,4] The reduction of lung compliance, functional residual capacity, ventilation-perfusion mismatch, and pulmonary capillaries disruption with blood extravasation into alveolar spaces could lead to an intrapulmonary shunt, raising the partial pressure of carbon dioxide ($PaCO_2$) levels with a reduction in oxygenation. Blood or gastric aspiration and fat embolism can result in acute lung injury (ALI) or acute respiratory distress syndrome (ARDS).[5] Besides the lungs, associated damage or fractures to the rib and sternum results in destabilisation of the rib cage which will substantially impair the spontaneous breathing mechanics. These situations can be amplified further due to pain. Tension pneumothorax, pericardial tamponade or massive haemothorax could reduce the intraventricular filling, eventually leading to a life-threatening reduction of cardiac output and cardiovascular impairment.

IMMEDIATE MANAGEMENT

Immediate assessment and identification of airway or chest injuries is an essential step to alert early interventions to restore respiratory and circulatory stability in order to minimise secondary insult to other vital organs, particularly the brain. Detail history of a mechanism of injury provides a clue about the severity of injuries, other related injuries, and the need for an extensive workout.

Initial management of trauma patients includes a primary survey followed by a brief neurological examination, examination of visible injuries and diagnostic testing. The primary survey includes airway, breathing and circulation. Airway patency is ensured by administering oxygen, and at the same time, the assessment of adequacy in ventilation should be performed. Two large bores of intravenous cannula are sited for fluid administration to avoid circulatory compromise. Any obvious external bleeding should be controlled. Intravenous analgesia is given to minimise respiratory compromise due to severe pain. Complete exposure of the patient to facilitate examination of the chest is required and proceed with further intervention if in need.

Life-threatening chest injuries that need to be ruled out during the primary survey are tension or open pneumothorax, massive haemothorax and pericardial tamponade. Patients who are presented with chest trauma may have the clinical signs as below:

- External signs of contusion, lesion, gash, external bleeding, instability of thorax
- Dyspnoea, haemoptysis
- Hypoxaemia
- Tracheal deviation
- Emphysema
- Side-specific breathing sounds such as crepitations and bronchial breath sounds
- Vena cava superior syndrome
- Intrathoracic bowel sound

THE ROLE OF RADIOLOGICAL ASSESSMENT IN AIRWAY AND CHEST TRAUMA

Imaging is critical in diagnosing and localising the side of airway injury. Radiographs can be an adjunct to the primary survey to provide valuable clues in detecting occult airway injuries which can be difficult to diagnose if based solely on physical examination. Further investigation with computed tomography (CT) scan is warranted if there is any suspicious of airway injury on the chest radiographs. However, using radiographs as an adjunct should not hinder or postpone resuscitation and treatment of airway injury.

A chest x-ray (CXR) is the initial workup to assess the airway injury. The commonest CXR features of airway injuries include pneumothorax, pneumomediastinum, and subcutaneous emphysema. Transection of the cervical trachea is highly suspicious if lateral cervical x-ray showed subcutaneous emphysema with hyoid bone dislocation.[6] Other radiological findings of trachea transection include a defect in the tracheal contour and displacement of the endotracheal tube with the cuff seen beyond the edge of the tracheal wall.[7]

Ultrasound thorax is highly sensitive in detecting indirect signs of lower airway injury, such as small pneumothorax and subcutaneous emphysema.[8-10] The study had shown that CT thorax can detect up to 70% of airway injuries.[11]

AIRWAY MANAGEMENT

Tracheobronchial Injury

Endotracheal intubation in airway injury can be tragic. Cricoid pressure may dislocate the fractured cricoid cartilage and further distort the upper airway, which leads to a difficult airway visualization or complete airway transection or obstruction.[12] Passing an endotracheal tube blindly over an injured upper airway may worsen the injury and create a false tube passage. Intravenous induction and neuromuscular blockade agent should be avoided as they can lead to loss of smooth muscle tone and cause the collapse of a distorted airway.[13,14] The patient's spontaneous breathing should be maintained until the airway has been secured.

Flexible bronchoscope-guided endobronchial intubation is the preferred method for intubation and assessing a tracheobronchial injury.[15,16] A patient who is hypoxaemic and haemodynamically unstable are unable to cooperate with the flexible bronchoscope. Under such circumstances, a rigid bronchoscope with inhalational anaesthesia while maintaining spontaneous ventilation is recommended.[17,18] Rigid bronchoscopy is contraindicated in a condition where cervical spine injury is suspected. Patients with tracheobronchial injury might need double-lumen intubation for isolation lung ventilation.[19]

Flail Chest

Paradoxical chest wall movement in flail chest results in elevated respiratory effort, dyspnoea and hypoxaemia. Adequate pain relief is required for the optimisation of the ventilation. Intravenous analgesia, regional anaesthesia with intercostal block, paravertebral block and thoracic epidural might be helpful. Pneumatic stabilization can be treated by non-invasive positive pressure ventilation (NIPPV) or invasive positive pressure ventilation

(IPPV). Flexible bronchoscopy is sometimes applied to remove the excessive secretions or blood from the airway. Surgical chest wall stabilization will be needed in severe cases.[20]

Pneumothorax

Most blunt or penetrating chest injuries are associated with pneumothorax. Occult pneumothorax is diagnosed in 2% to 55% of the blunt chest trauma via CT scan.[21] Tension pneumothorax causes displacement of the mediastinal structures, reduces the venous flow to the heart, and subsequently reduce cardiac output. Suspected tension pneumothorax required immediate decompression by thoracotomy with intercostal chest tube insertion. Other form of pneumothorax is managed according to the size of the pneumothorax. An intercostal chest tube size of 28 or 32 French is sufficient for the patient with pneumothorax on mechanical ventilation. A larger chest tube might be considered for drainage of haemothorax.

Haemothorax

Haemothorax could result from intercostal or mammary vessel injury, myocardial ruptures, aortic rupture, and injuries to the hilar structures. Intercostal chest tube drainage is the initial treatment for drainage of haemothorax. Urgent surgical thoracotomy is warranted for chest tube drainage of more than 1,500mL (≥ 20ml/kg) or approximately 300 to 500ml/H.

Lung Contusion

Lung contusion commonly occurs in blunt trauma. Impairment of oxygenation in lung contusion correlates with the involvement of lung tissue or severity of the injury.[22] Oxygenation can be improved with positive-pressure ventilation, adequate pain relief to prevent breath holding, chest physiotherapy and pulmonary drainage of the hemopneumothorax. Invasive mechanical ventilation is indicated in severe hypoxaemic failure.

VENTILATION STRATEGY

There is no blanket approach to apply the optimal ventilation strategy for all chest trauma patients. A ventilation strategy for respiratory support is according to the underlying pathophysiology of the lung injury and aims to prevent ventilator-associated lung injury (VALI). Ventilator-associated lung injury may induce ALI or ARDS. Ventilator-associated lung injury results from large tidal volumes, a high fraction of inspired oxygen (FiO2), overdistension of the alveoli, and elevated pulmonary pressures. By limiting the plateau airway pressures and the tidal volumes helps to minimize the risk of VALI. Therefore, the respiratory physiological parameters such as oxygen saturation, carbon dioxide level, and pH need not be corrected to the physiologic norm, except in a patient with a raised intracranial pressure where normoventilation should be achieved to prevent compromise to the brain perfusion.

It is challenging for the clinician to achieve the balance between ventilation, oxygenation, and adequate cardiac output in the mechanically ventilated trauma patient where the PPV reduces venous return due to a rise in intrathoracic pressure.

Non-invasive positive pressure ventilation (NIPPV)

The NIPPV delivers positive pressure ventilation via nasal, full face or helmet interfaces. It should be used in hemodynamically stable and cooperative patients.

A previous study showed that using NIPPV in non-severe chest trauma is associated with shorter length of ICU stay, reduce duration of mechanical ventilation, improvements in oxygenation and reduced incidence of intubation in patients with chest trauma-induced hypoxaemia.[23-25] The use of NIPPV should be considered the first choice in chest trauma patients unless contraindicated. Non-compliance or failure to respond to NIPPV is an indication for invasive mechanical ventilation, for which the commencement of IPPV should never be delayed.

Advantages of NIPPV include ease of starting and discontinuation, avoiding the use of sedation and paralysis, and complications related to endotracheal intubation, The disadvantages of NIPPV are an inappropriate selection of mask size that could lead to an air leak, skin necrosis and the lack of a protected airway.

Invasive positive pressure ventilation

The IPPV is indicated in patients who need a definitive airway either as a result of severe hypoxaemia, failure of NIPPV therapy, haemodynamically instability and prevention from aspiration such as poor conscious level as well as inability to protect the airway.

Ventilator settings

The NIPPV delivers positive ventilation through continuous positive airway pressure (CPAP) or bilevel positive airway pressure (BiPAP). The CPAP maintains functional residual capacity and prevents alveoli collapse and atelectasis. In BiPAP mode, ventilators are set to provide the lowest inspiratory pressures or volumes needed to obtain improved gas exchange and tailored to the patient's comfort. The patient will trigger the ventilator to provide a variable flow of gas that increases until airway pressure reaches a set limit. Inspiratory positive airway pressure (IPAP) and expiratory airway pressure (EPAP) were set in BiPAP mode, starting with an EPAP of 3cmH2O and gradually increasing every 5 minutes according to the patient's response and comfort. A 5cm H2O pressure difference should always be maintained between the IPAP and EPAP. In cases of EPAP more than 12cmH2O, IPPV is indicated. A protective mechanical ventilation strategy is implemented in NIPPV or IPPV to limit peak lung distension and, at the same time, prevent end-expiratory collapse. It is also important to minimize the airway pressure in mechanically ventilated trauma patients as the positive end-expiratory pressure (PEEP) higher than 5 cm H2O can easily exacerbate hypotension in haemorrhagic shock patients. The lung-protective ventilation strategies include:

- *Low tidal volumes*
  Ensure tidal volumes of 6 to 8ml/kg of predicted body weight.

- *Limited plateau pressure, less than 30cmH_2O*
  Plateau pressure (Pplat) less than 28cmH_2O results in less tidal hyperinflation and is more protective than a Pplat of less than 30cmH_2O in patients with a large, dependent and non-aerated lung compartment.[26] Patients with morbid obesity may need a higher pressure to adequately distend the lung, to lift the restricted chest wall from the lung.

- *Fraction of inspired oxygen that is as low as possible*
  Fractioned inspired oxygen should be adjusted to obtain a partial pressure of oxygen of 60 to 80mmHg or oxygenation saturation of more than 90% in a controlled condition in the intensive care unit. The prescription of FiO_2 can be optimised and regulated by using closed-loop control systems.

- *Optimal PEEP*
  Titrate PEEP incrementally to optimise oxygenation and carbon dioxide elimination. This may range from 14 to 16cmH_2O in patients with severe lung injury.[27] Hypotension secondary to reduced cardiac output should be avoided.

- *Permissive hypercapnia*
  Raised $PaCO_2$ levels can be tolerated as long as the pH is greater than 7.2, except in patients with elevated intracranial pressures.

Other strategies

Prone position

Prone position leads to a more homogenous alveolar ventilation, distribution and perfusion and hence improves oxygenation.[28]

Nitric oxide

Administration of nitric oxide to either normal lungs or both the lungs causes vasodilation and subsequently decrease in ventilation-perfusion mismatch which will result in improvement of oxygenation along with differential ventilation.[29]

Extracorporeal Membrane Oxygenation (ECMO)

Extracorporeal Membrane Oxygenation is a technique of providing gas exchange outside the body that expose the lungs to minimal pressure, volume, Fio2 and rate. Extracorporeal Membrane Oxygenation proven benefit in treating ALI and ARDS after trauma[30-33] and can improve the survival of trauma patients.[34] However, ECMO needs systemic anticoagulation and may pose the risk of bleeding in patients with multiple trauma. Selection of patients is important as the high cost of establishing ECMO services could be a limitation. Thus, it is only reserved for patients with isolated lung injuries.[35]

References

1. Malaysia MoH. Health fact. 2008
2. Devitt JH, McLean RF, Koch J-P. Anaesthetic management of acute blunt thoracic trauma. *Canadian Journal of Anaesthesia* 1991;**38**(4):506-10
3. Kummer C, Netto FS, Rizoli S, Yee D. A review of traumatic airway injuries: potential implications for airway assessment and management. *Injury* 2007;**38**(1):27-33
4. Bertelsen S, Howitz P. Injuries of the trachea and bronchi. *Thorax* 1972;**27**(2):188-94
5. Raghavendran K, Notter RH, Davidson BA, Helinski JD, Kunkel SL, Knight PR. Lung contusion: inflammatory mechanisms and interaction with other injuries. *Shock* 2009;**32**(2):122-30
6. Stark P. Imaging of tracheobronchial injuries. *J Thorac Imaging* 1995;**10**(3):206-19
7. Juntima Eusthrongchit M, Nisa Thoongsuwan, MD, Eric J. Stern, MD. Nonvascular Mediastinal Trauma. Radiologic clinic of North America 2006:251-8
8. Wilkerson RG, Stone MB. Sensitivity of bedside ultrasound and supine anteroposterior chest radiographs for the identification of pneumothorax after blunt trauma. *Academic emergency medicine: official journal of the Society for Academic Emergency Medicine* 2010;**17**(1):11-7
9. Soldati G, Testa A, Pignataro G, Portale G, Biasucci DG, Leone A, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. *Ultrasound in medicine & biology* 2006;**32**(8):1157-63
10. Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: diagnostic accuracy of lung ultrasonography in the emergency department. *Chest* 2008;**133**(1):204-11
11. Chen JD, Shanmuganathan K, Mirvis SE, Killeen KL, Dutton RP. Using CT to diagnose tracheal rupture. *AJR American journal of roentgenology* 2001;**176**(5):1273-80
12. William E. Huford MD RPM. Management of tracheal trauma. Canadian Journal of Anaesthesia 2003
13. Abernathy JH, 3rd, Reeves ST. Airway catastrophes. *Current opinion in anaesthesiology* 2010;**23**(1):41-6
14. Cicala RS, Kudsk KA, Butts A, Nguyen H, Fabian TC. Initial evaluation and management of upper airway injuries in trauma patients. *Journal of clinical anesthesia* 1991;**3**(2):91-8
15. Karmy-Jones R, Wood DE. Traumatic injury to the trachea and bronchus. *Thoracic surgery clinics* 2007;**17**(1):35-46
16. Cassada DC, Munyikwa MP, Moniz MP, Dieter RA, Jr., Schuchmann GF, Enderson BL. Acute injuries of the trachea and major bronchi: importance of early diagnosis. *The Annals of thoracic surgery* 2000;**69**(5):1563-7
17. Chhabra A, Rudingwa P, Panneer Selvam SR. Pathophysiology and management of Airway Trauma. *Trends in Anaesthesia and Critical Care* 2013;**3**(4):216-9
18. Corneille MG, Stewart RM, Cohn SM. Upper airway injury and its management. *Seminars in thoracic and cardiovascular surgery* 2008;**20**(1):8-12
19. Johnson S. Tracheobronchial Injury. *Seminars in thoracic and cardiovascular surgery* 2008;**20**:52-7

20. Tanaka H, Yukioka T, Yamaguti Y, Shimizu S, Goto H, Matsuda H, et al. Surgical stabilization of internal pneumatic stabilization? A prospective randomized study of management of severe flail chest patients. *The Journal of trauma* 2002;**52**(4):727-32; discussion 32

21. Ball CG, Kirkpatrick AW, Laupland KB, Fox DI, Nicolaou S, Anderson IB, et al. Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. *The Journal of trauma* 2005;**59**(4):917-24; discussion 24-5

22. Mizushima Y, Hiraide A, Shimazu T, Yoshioka T, Sugimoto H. Changes in contused lung volume and oxygenation in patients with pulmonary parenchymal injury after blunt chest trauma. *The American journal of emergency medicine* 2000;**18**(4):385-9

23. Antonelli M, Conti G, Rocco M, Bufi M, De Blasi RA, Vivino G, et al. A comparison of noninvasive positive-pressure ventilation and conventional mechanical ventilation in patients with acute respiratory failure. *The New England journal of medicine* 1998;**339**(7):429-35

24. Gregoretti C, Beltrame F, Lucangelo U, Burbi L, Conti G, Turello M, et al. Physiologie evaluation of non-invasive pressure support ventilation in trauma patients with acute respiratory failure. *Intensive care medicine* 1998;**24**(8):785-90

25. Hernandez G, Fernandez R, Lopez-Reina P, Cuena R, Pedrosa A, Ortiz R, et al. Noninvasive ventilation reduces intubation in chest trauma-related hypoxemia: a randomized clinical trial. *Chest* 2010;**137**(1):74-80

26. Terragni PP, Rosboch G, Tealdi A, Corno E, Menaldo E, Davini O, et al. Tidal hyperinflation during low tidal volume ventilation in acute respiratory distress syndrome. *American journal of respiratory and critical care medicine* 2007;**175**(2):160-6

27. Papadakos PJ, Karcz M, Lachmann B. Mechanical ventilation in trauma. *Current opinion in anaesthesiology* 2010;**23**(2):228-32

28. Pelosi P, Caironi P, Taccone P, Brazzi L. Pathophysiology of prone positioning in the healthy lung and in ALI/ARDS. *Minerva anestesiologica* 2001;**67**(4):238-47

29. Johannigman JA, Campbell RS, Davis K, Jr., Hurst JM. Combined differential lung ventilation and inhaled nitric oxide therapy in the management of unilateral pulmonary contusion. *The Journal of trauma* 1997;**42**(1):108-11

30. Anderson HL, 3rd, Shapiro MB, Delius RE, Steimle CN, Chapman RA, Bartlett RH. Extracorporeal life support for respiratory failure after multiple trauma. *The Journal of trauma* 1994;**37**(2):266-72; discussion 72-4

31. Voelckel W, Wenzel V, Rieger M, Antretter H, Padosch S, Schobersberger W. Temporary extracorporeal membrane oxygenation in the treatment of acute traumatic lung injury. *Canadian journal of anaesthesia = Journal canadien d'anesthesie* 1998;**45**(11):1097-102

32. Senunas LE, Goulet JA, Greenfield ML, Bartlett RH. Extracorporeal life support for patients with significant orthopaedic trauma. Clin Orthop Relat Res 1997(339):32-40

33. Cordell-Smith JA, Roberts N, Peek GJ, Firmin RK. Traumatic lung injury treated by extracorporeal membrane oxygenation (ECMO). *Injury* 2006;**37**(1):29-32

34. Michaels AJ, Schriener RJ, Kolla S, Awad SS, Rich PB, Reickert C, et al. Extracorporeal life support in pulmonary failure after trauma. *The Journal of trauma* 1999;**46**(4):638-45

35. Rico FR, Cheng JD, Gestring ML, Piotrowski ES. Mechanical ventilation strategies in massive chest trauma. *Critical care clinics* 2007;**23**(2):299-315, xi

Trauma Care in the Field from a Military Perspective

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INTRODUCTION

Trauma care approach in the military and civilian settings are somewhat similar, sharing common historical roots. It is recognized that the civilian trauma protocol is much inspired by past military combat experiences.[1] In high income countries, every successful military conflict engagement has indirectly paved ways to improvements in military trauma care. This in turn has been translated into the civilian healthcare system. For example, the Korean war and the Vietnam war fought by the United States (US) in 1950 and 1975 respectively, had pioneered the concept of helicopter evacuation and golden hour. These are two concepts currently practised globally for trauma care in civilian settings.[2-4] The battlefield has indeed been a key area for innovations in trauma care. This is clearly seen throughout the great wars within the last two centuries in which military and civilian trauma care have developed and matured side by side.

The importance of prompt attention to casualties, debridement of wounds and amputation to prevent systemic infections have been observed from as early as the Napoleon War and American Civil War.[5] These wars taught us the value of trauma care in preserving life. World War 1 witnessed the importance of early evacuation to reduce the time from point of injury to reaching the medical facility.[6] World War II was where the first use of blood transfusion and fluid resuscitation in a combat hospital setting was instituted.[5] These, alongside the introduction of antibiotics in the medical field, have improved the survival rates of those injured on the battlefield tremendously.[6-8] Military trauma care is well described in war surgical literatures but more commonly associated with Western military deployment to Vietnam, Israel, Falkland Island, Iraq and more recently Afghanistan. The evolution of military trauma care is still ongoing in the pursuit to save more lives in the battlefield.[9]

The echelons of trauma care in the field are more complex and dynamic than in civilian settings. For example, the point of injury until the point definitive treatment for a soldier is never certain and fully depends on the nature of a mission, its geographical terrain, the hostility of conflict area, on-site logistics and on-site equipment.[2,4]

Here in Malaysia, the Malaysian Armed Forces (MAF) is responsible in assisting civilian authorities to overcome international threats, preserve public order to coordinate teams during natural disasters and to uphold the national foreign policy under the guidance of the United Nations. The Kor Kesihatan Diraja (Royal Medical and Dental Corps - RMDC) of MAF is tasked to provide medical care in order to sustain the fighting force of the MAF troops.[10] This article will walk through the echelons of trauma care in the field and highlight the obstacles and differences in management of field trauma care as opposed to civilian trauma care.

FIELD TRAUMA CARE IN CONVENTIONAL WARFARE

The traditional doctrinal structure of a medical deployment is the rearward progression of casualties from Level 1 to Level 4 (Figure 1). Level 1 denotes the first responder care which is in the frontlines of a combat zone up to the Regiment Aid Post (RAP). Within this area, medical care is delivered by the Medical Corpsmen and the Regiment Medical Officer (RMO). The RAP is located near the forward line of the troops, and this makes the medical personnel equally vulnerable to the enemy.[13] This prehospital period is the most crucial as history of war tells us that almost 90% of death occurred before the casualty reached a medical treatment facility. Therefore, high volume of effort was put into further developing specific modules for early trauma care.[13]

Level 2 care provides a more advanced trauma management and emergency medical treatment with greater capability to resuscitate patients. At this level, it is also possible to conduct damage control surgery (DCS). The team comprises anaesthesiologists, surgeons, supporting clinical staffs and medical planners; however they have limited capabilities dictated by the logistics and equipment available.[2,13]

Level 3 medical care is in the division command post centre. It is deemed to be the safest zone in a combat area, allowing for the setup of a Combat Support Hospital. The hospital is staffed and equipped to provide care to all categories of patients which is more advanced than a Level 2 centre. This is because it is equipped with better lab facility and blood support. Patient care available here includes limited intensive critical care, wound surgery and post operative treatment.[13,14]

The Level 4 care functions like a General Hospital in a civilian setting, where a wide range of subspeciality management is available with comprehensive rehabilitation services.[17] The escalation to Level 4 usually involves travelling a long distance and transportation is commonly done via aeromedical evacuation. The movement of patients does not necessarily follow the step of level of care, but is rather affected by the tactical situation and evacuation suitability and feasibility.[16,17]

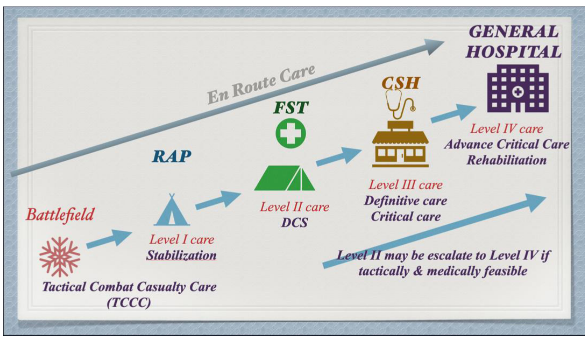

Figure 1: The schematic diagram of Level of Care in military perspective.
Regiment Aid Post (RAP), Forward Surgical Team (FST). Combat Support Hospital (CSH), Damage Control Surgery (DCS)

LEVEL 1 FIELD TRAUMA CARE

Level 1 Field Trauma Care is comparable to civilian prehospital care. However, it is medically and tactically important to start the trauma care from Ground Zero. Military injuries commonly involve mass casualties. It mainly comprises massive and complex traumas involving penetrating injuries and limb amputations rather than blunt traumas, as seen in a civilian environment. Many factors affect casualty care in the field. Therefore, it is challenging to apply effectively conventional approaches to trauma such as the Advanced Trauma Life Support (ATLS) protocol, in a hostile field area, let alone during a tactical combat environment.[13] This is true despite ATLS providing a very standardized and very successful approach to the management of trauma patients in a civilian hospital setting. Among the challenges in applying ATLS in the battlefield is a danger zone and hostile fire may still be present. Disaster also damaged accessible roads and basic infrastructure thus, prolonging evacuation. There is also limited medical equipment and trained personnel in the field. Field trauma care also requires tactical knowledge of the ongoing mission.

The military previously enforced the Combat Medic First Aid Course (COMFAC) on the frontline men. However, with more data and experiences with combat over the past 50 years, this conventional First Aid Course was replaced by a more practical course known as the Tactical Combat Casualty Care (TCCC).[13-15] TCCC focuses on assessment and recognition of trauma injuries with proper and timely intervention. It was pioneered by the US Department of Defence (DoD) and designed to reduce preventable death while maintaining operation success. TCCC protocol enables medical care in three main conditions which are Care Under Fire, Tactical Field Care and Tactical Evacuation Care. These approaches not only allow for care to be delivered in different hostile environments, but it also extends the coverage of trauma care by instilling appropriate trauma skills to all soldiers to perform at different level of care. All military personnel are taught a variety of basic first-aid procedures from Self-Aid to Buddy-Aid.[13] They are issued with a basic Individual First Aid Kit (IFAK) which includes haemostatic agents, torniquet to prevent exsanguination and basic airway management equipment with breathing kits (Figure 2). These equipment are particularly important for them to perform lifesaving tasks and to apply first aid to alleviate potential life-threatening situations.[13] A small number of men in every unit is also trained as the combat lifesavers. These are non-medical military personnel who are equipped with additional trauma management training beyond basic first-aid procedures.[14] The additional duties of combat lifesavers are to provide enhanced first aid for injuries before the main medical care arrives. Medical care by medical officers and medical corpsmen are usually stationed at RAP or Company Aid Post (CAP). This team is specialized to perform first aid, triage, resuscitation, stabilization, and evacuation of patient to the next level of care.[13-16]

Figure 2: IFAK Level 1 for All Troops (right) and IFAK Level 2 for Combat Medic/Paramedic/Doctor (left)

LEVEL 2 FIELD TRAUMA CARE

The Forward Surgical Team (FST) is a specialized team of a small and mobile surgical unit that can perform DCS for trauma care in field. Their main aim is to salvage life rather than to correct the anatomy.[16] The FST comprises the anaesthesiologist, general surgeon, orthopaedic surgeon, supporting clinical staff, logistic staff, and a medical planner (Figure 3). This team is usually kept at a small number, around 20 persons. The advantage of a FST is the flexibility to remain light with small logistic footprint, thus making the FST rapidly deployable by air, land or sea.[2] Their mobility makes it possible to send them further inside a combat zone, behind the frontline or deep into a disaster area. The concept of FST was coined to make the golden hour in trauma achievable during a military operation.[7,16] The experiences from countries involved in Afghanistan and Iraq conflicts showed the concept of FST has improved the outcome of their soldier's casualties.[7] Due to the evolving pattern of conventional warfare to modern warfare, the establishment of a FST makes it more practical to cover different parts of combat zones and missions effectively. Some of the more advanced military countries have even developed smaller FST of less than 8 personnel to perform surgery in austere environment and they are usually attached to the special operation forces.[9]

The FST can also expand its capabilities by adding more components to it such as a basic laboratory, radiographic abilities, and critical care services. Even though the FST is widely accepted in the military, the deployment of FST is demanding and needs a specialized team trained to achieve the desired level of competence.[7] The team must be able to work with limited medical equipment. The surgeon must be able to operate under stressful environment while anaesthesia must be delivered with sub-minimum monitoring. There is an overall limited hold capability, challenging post operative critical care and high dependency to the frequency of logistic resupply to ensure sustainability of care.[17] The doctrine of the FST states that it should be able to sustain for 72 hours while performing 30 surgeries before emergent of more medical supplies. The common setting inside the FST is shown in Figure 4. It also needs to balance the sterility practise in a field environment. Blood services also remain among the main challenges in delivering trauma care in FST, as limited blood supply brought by the team can be depleted by a single severe haemorrhagic casualty.[8,16,17]

Figure 3: FST is rapidly deployable as it is a small team with selective and small logistic footprint. Deployment by air force make the team flexible to be sent to almost any part of the world

Figure 4: A common setting inside the Operation Theatre in the Forward Surgical Team (FST). Picture taken during the deployment of MASMEDTIM to Yogjakarta for HADR earthquake
Photo courtesy of Brig Gen (R) Dato Dr Jegatheesan

LEVEL 3 AND 4 FIELD TRAUMA CARE

Combat Support Hospital (CSH) or commonly known as the Field Hospital denotes the biggest field medical set up and is in the safest zone of a mission area. It is also commonly attached to the division command post. The CSH is fully equipped with multidisciplinary general hospital services, which provides emergency and definitive care, intensive care, surgical, medical, and dental services with inpatient facilities. They also offer a more comprehensive laboratory, radiology, and pharmaceutical service. The medical logistician (MedLog) must be able to also support the Level 1 and 2 teams and sustain everyone for at least up to 60 days before requiring resupply.[7] The CSH is also responsible for advanced critical care evacuation to the next level. Civilian studies have clearly demonstrated that the survival of trauma casualties are better in hospitals that are fully resourced and specialised for the treatment of the injured. The level 3 hospital might not be suitable for more complex surgeries or that required multiple trauma surgery interventions, therefore those type of casualties will only be stabilized in a level 3 setting and evacuated to a level 4 care as earliest possible.[17]

The level 4 is basically a general hospital outside the mission area. It can be a civilian General Hospital (GH) or Military Hospital with comprehensive multidisciplinary subspecialities equipped with rehabilitation capabilities. For example, the US level 4 hospital during conflict in Afghanistan was located at Landstuhl Regional Medical Centre (LRMC) Germany.[7]

KEY ADVANCES IN FIELD TRAUMA CARE

The advancement of patient evacuation in military settings has dramatically improved survival odds for those injured in combat. In the civilian setting, it mainly depends on MEDEVAC (Medical Evacuation), which is the evacuation of a patient using standard or dedicated medical vehicle (e.g. ambulance, helicopter).[4] Patient is accompanied by a physician or nurse to provide en route primary care.[4] In a field setting, the military exercises Tactical Evacuation (TASEVAC) and Casualty Evacuation (CASEVAC) which refers to evacuation of a patient using transport that is not specifically designed for medical transport.[13] Helicopter evacuation is the most practised due to its agility and flexible landing space (refer to Figure 5). The time taken for casualty to be evacuated from a combat zone might increase due to the hostile environment.[13] The Medical Emergency Response Team (MERT) is a physician-led team to provide higher critical care during TASEVAC from hostile zone.[11] For those unstable critical care patients who require definitive surgery at a far level 4 facility, there is a dedicated Critical Care Air Transport (CCAT) team trained to evacuate the casualties even though they are on continuous renal replacement therapy (CRRT) or dependent on Extra Corporeal Membrane Oxygenation (ECMO).[1,2,4-6]

Figure 5: Field Trauma Care requires precise coordination during evacuation of casualties to transport patient through the echelons of field care.
MMU MINURSO (Western Sahara) CASEVAC Team. This team was ready around the clock throughout their 2-week rotation. The task was for evacuation from a Level 1 Trauma Care straight to a Level 4 facility in La Palma Spain's Canary Island or Tindouf, Algeria

It is a challenge to sustain a safe blood service in the field. The civilian setting can afford to have a systematic blood donation drive, collection, processing of packed cells and blood products and comprehensive blood bank services. This is difficult to replicate in the field.[18] The replication in combat zone requires a massive logistic supply of equipment and sustainable power supply to ensure the safe blood products chain is maintained. Ironically the common cause of death in combat is still haemorrhage, yet the mainstay of treatment of blood transfusion is limited. The restrictions are due to the limited pool of blood donors in the combat zone and disaster area, lack of massive equipment require for blood processing and lack of uninterrupted power supply to ensure the blood products are frozen.[19] The FST, which is supposed to buffer trauma injuries in the combat zone, faces many serious problems when dealing with blood services due to their nature of being a small logistic footprint. Therefore, the military practises whole blood transfusions, walking blood bank, pharmacological approach, and frozen blood products to sustain the field trauma service. Whole blood is preferred due to its volume expansion and coagulative advantages. The walking blood service is a system which all deployable soldiers and supporting staff will undergo standard pre-screening donor test, professional consultation and consent taken in pre-deployment phase. Their blood group eligibility will be listed and they will be given tag to wear at all times identifying their eligibility to donate. Hence when the need arises, the donor's blood will be drawn and instantly the recipient receives the whole blood after a single tier cross match.[19,20] Frozen Red Blood Cell is emerging in military medicine but the use of it limited due to the cost.[18-21] Pharmacologically, Tranexamic Acid (TXA) is commonly used in the field together with the Prothrombin Concentrate Complex (PCC). This was the treatment constituted in the Malaysian Field Hospital in Cox's Bazar Bangladesh. The introduction of fibrinogen concentrate could also be an alternative that could gain place in field trauma care in future.[22]

MALAYSIA ARMED FORCES FIELD TRAUMA CARE DEVELOPMENT

The MAF Royal Medical and Dental Corps (Kor Kesihatan Diraja/KKD) was established in March 1967. Its mission is to maintain the fighting force and support the MAF and country's mission during the communist insurgencies and border invasions. It also serves internationally under the flag of the United Nation and assists in many Humanitarian Assistance and Disaster Response (HADR). Since 1969, Malaysia's foreign policy has been based on the principle of neutrality and maintaining peaceful relations with all countries, regardless of their ideology or political system, and to further develop relations with other countries in the region. Ever since the end of communist insurgency in Malaysia (1968-89), the limited engagement in conflict has not impaired the readiness to respond in crisis. The development and training of field trauma care in MAF is sustained through international military exercises and war games such as the Cooperation Afloat Readiness and Training Exercise (Eksesais CARAT), Keris Strike Exercise and Rim of the Pacific Exercise (Eksesais RIMPAC) with the United States Indo Pacific Command (USINDOPACOM) and the Five Power Defence Arrangement (FDPA). The FDPA comprises Malaysia, Singapore, Australia, New Zealand and the United Kingdom - all Commonwealth members since 1971. The ongoing exercises and multilateral Subject Matter Expert Exchange (SMEE) during this peace time has helped the MAF in updating the military trauma capability. The MAF Level 1 trauma care is currently in the process of adapting the TCCC, in efforts to replace the conventional Combat Medic First Aid programme. The MAF has Level 2 trauma care ability with airborne FST under the Quick Reaction Force and Medical Commando Company to support the frontline troops. The MAF is also capable in providing Level 3 Field Hospitals, which are deployable under the medical battalion tactically stationed in the east and west of Malaysia. In the perspective of deployment experiences, MAF has an active role in supporting the UN mandate and HADR responses. Level of medical care provided are dependent on the requirement of the mission.

CONCLUSION

The echelons of field trauma care are more complex and influenced by multiple factors. However, the lessons learnt during combat and disaster can be translated further to improve trauma care in the civilian setting. It is important for a commander to understand the field trauma care from its nature of possible casualties, level of care required and the limitations that the team can endure. This is to help in planning the strategy to balance between accomplishing the mission and maintaining the wellbeing of the troops under their command.

Mission	Year	Level of care
MALBATT for UNPROFOR, Bosnia and Herzegovina	1993	Level 2 FST
MALBATT for UNOSOM, Somalia	1994	Level 2 FST
Malaysia Medical Team (MASMEDTIM) to Chaman, Pakistan	2001	Level 2 FST
Malaysia Medical Team (MASMEDTIM) to Acheh, Indonesia	2004	Level 2 FST
Malaysia Medical Team (MASMEDTIM) to Battagram, Pakistan	2005	Level 2 FST
Malaysia Medical Unit Mission for the Referendum in Western Sahara (MMU MINURSO)	2006 - 2009	Level 1 field trauma care
Malaysia Field Hospital (MFH) Cox's Bazar, Bangladesh	2018 - 2020	Level 3 Field Hospital
MALBATT and MALCON for UNIFIL	2007- present	Level 1 field trauma care

Figure 6: Keris Strike Exercise (US-MAF) 2017 during a subject matter expert exchange (SMEE) amongst the forward surgical teams involving anaesthesiologists, surgeons, nurses and medical planners. Continuous engagement with other countries is important for tactical partnership and exchange of ideas

Military surgical teams should always maintain their clinical skills and learn from active combat engaging countries through the regular strategic partnership military exercises including United Nations (UN) and HDAR deployments. This will keep our readiness when the call of duty rings. I believe that advances will continue in field trauma care resuscitation to increase survival of combat casualty, particularly in the area of haemorrhage control, best field blood practice and battlefield analgesia management. This will then help in extending the survival and time to operative intervention.

References

1. Muck AE, Givens M, Bebarta VS, Mason PE, Goolsby C. Emergency Physicians at War. *West J Emerg Med* 2018 May;**19**(3):542-547. doi: 10.5811/westjem.2018.1.36233. Epub 2018 Mar 8. PMID: 29760853; PMCID: PMC5942022

2. Hodgetts TJ, Davies S, Russell R, McLeod J. Benchmarking the UK military deployed trauma system. *Journal of the Royal Army Medical Corps* 2007 Dec;**153**(4):237-238. DOI: 10.1136/jramc-153-04-03. PMID: 18619155

3. Sloan EP, Callahan EP, Duda J, Sheaff CM, Robin AP, Barrett JA. The effect of urban trauma system hospital bypass on prehospital transport times and Level 1 trauma patient survival. *Ann Emerg Med* 1989 Nov;**18**(11):1146-50. doi: 10.1016/s0196-0644(89)80049-6. PMID: 2817557

4. Barr J, Montgomery S. Helicopter medical evacuation in the Korean War: Did it matter? *The Journal of Trauma and Acute Care Surgery* 2019 Jul;**87**(1S Suppl 1):S10-S13. DOI: 10.1097/ta.0000000000002218. PMID: 31246900

5. White MS, Chubb RM, Rossing RG, Murphy JE. Results of early aeromedical evacuation of Vietnam casualties. *Aerosp Med* 1971;**42**(7):780-784. DOI - 10.1097/TA.0b013e3182606001

6. Meier DR, Samper ER. Evolution of civil aeromedical helicopter aviation. *South Med J* 1989 Jul;**82**(7):885-91. doi: 10.1097/00007611-198907000-00022. PMID: 2665130

7. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB. Trauma system development in a theater of war: Experiences from Operation Iraqi Freedom and Operation Enduring Freedom. *J Trauma* 2006 Dec;**61**(6):1366-72; discussion 1372-3. doi: 10.1097/01.ta.0000245894.78941.90. PMID: 17159678

8. Beekley AC. United States military surgical response to modern large-scale conflicts: the ongoing evolution of a trauma system. *Surg Clin North Am* 2006 Jun;**86**(3):689-709. doi: 10.1016/j.suc.2006.02.007. PMID: 16781277

9. Garber, K., Kushner, A.L., Wren, S.M. et al. Applying trauma systems concepts to humanitarian battlefield care: a qualitative analysis of the Mosul trauma pathway. Confl Health 14, 5 (2020). https://doi.org/10.1186/s13031-019-0249-2

10. http://kkdhome.rmdc.online

11. Russell RJ, Blackbourne LH, Midwinter MJ, Rasmussen TE. En-route care capability from point of injury impacts mortality after severe wartime injury. *Ann Surg* 2013 Feb;**257**(2):330-4. doi: 10.1097/SLA.0b013e31827eefcf. PMID: 23291661

12. Chatfield-Ball C, Boyle P, Autier P, van Wees SH, Sullivan R. Lessons learned from the casualties of war: battlefield medicine and its implication for global trauma care. *J R Soc Med* 2015 Mar;**108**(3):93-100. doi:10.1177/0141076815570923. PMID: 25792616; PMCID: PMC4368459

13. Butler FK Jr, Holcomb JB, Giebner SD, McSwain NE, Bagian J. Tactical combat casualty care 2007: evolving concepts and battlefield experience. *Mil Med* 2007 Nov;**172**(11 Suppl):1-19. doi: 10.7205/milmed.172.supplement_1.1. PMID: 18154234

14. Blackbourne, L.H., Baer, D.G., Eastridge, B.J., Kheirabadi, B., Bagley, S., Kragh Jr., J.F., Cap, A.P., Dubick, M.A., Morrison, J.J., Midwinter, M.J., Butler, F.K., Kotwal, R.S. and Holcomb, J.B. (2012) Military Medical Revolution: Prehospital Combat Casualty Care. Journal of Trauma and Acute Care Surgery, 73, S372-S377. http://dx.doi.org/10.1097/TA.0b013e3182755662

15. Savage E, Forestier C, Withers N, Tien H, Pannell D. Tactical combat casualty care in the Canadian Forces: lessons learned from the Afghan war. *Can J Surg* 2011 Dec;**54**(6):S118-23. doi: 10.1503/cjs.025011. PMID: 22099324; PMCID: PMC3322653

16. Mancini DJ, Smith BP, Polk TM, Schwab CW. Forward Surgical Team Experience (FSTE) Is Associated With Increased Confidence With Combat Surgeon Trauma Skills. *Mil Med* 2018 Jul 1;**183**(7-8):e257-e260. doi: 10.1093/milmed/usy080. PMID: 29741715

17. Brisebois R, Hennecke P, Kao R, McAlister V, Po J, Stiegelmar R, Tien H; Canadian Forces Health Services Research Consortium. The Role 3 Multinational Medical Unit at Kandahar Airfield 2005-2010. *Can J Surg* 2011 Dec;**54**(6):S124-9. doi: 10.1503/cjs.024811. PMID: 22099325; PMCID: PMC3322658

18. World Health Organization. (2012). Blood donor selection: guidelines on assessing donor suitability for blood donataion. World health Organization. https://apps.who.int/iris/handle/10665/76724

19. Garcia Hejl C, Martinaud C, Macarez R, Sill J, Le Golvan A, Dulou R, Longin Roche C, De Rudnicki S. The implementation of a multinational "walking blood bank" in a combat zone: The experience of a health service team deployed to a medical treatment facility in Afghanistan. *J Trauma Acute Care Surg* 2015 May;**78**(5):949-54. doi: 10.1097/TA.0000000000000618. PubMed PMID: 25909414

20. Strandenes G, Berséus O, Cap AP, Hervig T, Reade M, Prat N, Sailliol A, Gonzales R, Simon CD, Ness P, Doughty HA, Spinella PC, Kristoffersen EK. Low titer group O whole blood in emergency situations. *Shock* 2014 May;**41** Suppl 1:70-5. doi: 10.1097/SHK.0000000000000150

21. Repine TB, Perkins JG, Kauvar DS, Blackborne L. The use of fresh whole blood in massive transfusion. *J Trauma* 2006 Jun;**60**(6 Suppl):S59-69. doi:10.1097/01.ta.0000219013.64168.b2. PMID: 16763483

22. Nascimento B, Callum J, Tien H, Peng H, Rizoli S, Karanicolas P, Alam A, Xiong W, Selby R, Garzon AM, Colavecchia C, Howald R, Nathens A, Beckett A. Fibrinogen in the initial resuscitation of severe trauma (FiiRST): a randomized feasibility trial. *Br J Anaesth* 2016 Dec;**117**(6):775-782. doi: 10.1093/bja/aew343. PMID: 27956676

Management of Trauma in COVID-19 Patients: An Adaptation of Practice

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INTRODUCTION

Over the past two and a half years, the world has been living in the shadow of the COVID-19 pandemic. Malaysia has been similarly affected, reporting a total of 4,575,809 cases and 35,784 deaths till 5th July 2022.[1] During this time, the medical field has learned to fight this virus and its complications. Public health measures such as mass vaccinations and infection control precautions were implemented to reduce the spread of COVID-19. Despite this, the COVID-19 virus continued to evolve, with no clear end in sight until today. Therefore, healthcare practitioners must remain constantly vigilant in the management of COVID-19 patients, regardless of whether infection rates spike or wane. This review aims to demonstrate the principles of management of COVID-19 patients presenting with trauma.

INITIAL ASSESSMENT AND MANAGEMENT

Triage

Patients presenting with trauma require urgent assessment and management. The triaging process is an important part of this assessment to identify patients with suspected, probable, or confirmed COVID-19 (Table I). The purpose of the triage is to protect staff and to prevent cross-infection with other patients. In addition, the identification of COVID-19 trauma patients will also guide their subsequent management in the hospital, given COVID-19 is a systemic illness which may complicate the patient's hospitalization. During triaging and subsequent management, healthcare providers need to wear appropriate personal protective equipment (PPE) to prevent transmission of infection (Table II).

Initial Management

Initial resuscitation in the emergency department should follow the Advanced Trauma Life Support protocol with modifications to ensure staff safety is always prioritized. Primary and secondary surveys should be done promptly while maintaining infection control practices to prevent transmission of infection.[4] The PPE worn by healthcare personnel may be physically limiting and impede the assessment of the patient. Hence, radiological examinations such as X-ray and ultrasonography may be utilized to complement the assessment of patients' conditions.[5,6]

Airway Management

Trauma patients may require urgent airway management for various reasons, and the difficult airway is common in this population. The complexity of airway management increases exponentially in the presence of COVID-19 illness, with extra considerations for infection control practices, limitations caused by PPE, and potentially compromised respiratory function caused by COVID-19.[7] Therefore, airway evaluation and planning are vital to ensure its success. The most experienced personnel should be responsible for performing endotracheal intubation, to prevent complications associated with multiple laryngoscopies and the spread of infection to staff. Teamwork and communication within the intubating team are essential. The usage of videolaryngoscopy has been encouraged to increase first-pass intubation success rate. Sufficient neuromuscular blocker to prevent cough reflex, avoidance of bag-valve-mask ventilation and modified rapid sequence induction have been recommended for emergent intubation in this population, to reduce aerosol generation. Readers are encouraged to refer to the consensus guideline for airway management in COVID-19 patients by the Difficult Airway Society, the Association of Anaesthetists, the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists.[8]

Table I: Case definitions of COVID-19 in Malaysia*

Case	Definition
Suspected case of SARS-CoV-2 infection (A, B or C)	1. A person who meets the clinical **AND** epidemiological criteria: • Clinical Criteria: 1. Acute onset of fever AND cough; **OR** 2. Acute onset of ANY TWO OR MORE of the following signs or symptoms: fever, cough, general weakness/fatigue, headache, myalgia, sore throat, coryza, dyspnoea, anorexia/nausea/vomiting, diarrhoea, altered mental status. • Epidemiological Criteria: 1. Residing or working in a setting with a high risk of transmission of the virus: for example, closed residential settings etc., any time within the 14 days before symptom onset; **OR** 2. Residing in or travelling to an area with community transmission anytime within the 14 days before symptom onset; **OR** 3. Working in a health setting, including within health facilities and within households, anytime within the 14 days before symptom onset. 2. A patient with severe acute respiratory illness (SARI: acute respiratory infection with history of fever or measured fever of ≥ 38ºC; and cough; with onset within the last 10 days; and who requires hospitalization); 3. An asymptomatic person not meeting epidemiologic criteria with a positive SARS-CoV-2 rapid test kit antigen (RTK-Ag).
Probable case of SARS-CoV-2 infection (A, B, C or D)	A. A patient who meets clinical criteria above **AND** is a contact of a probable or confirmed case or is linked to a COVID-19 cluster. B. A suspected case (described above) with chest imaging showing findings suggestive of COVID-19 disease. C. A person with recent onset of anosmia (loss of smell) or ageusia (loss of taste) in the absence of any other identified cause D. Death, not otherwise explained, in an adult with respiratory distress preceding death **AND** who was a contact of a probable or confirmed case or linked to a COVID-19 cluster2
Confirmed case of SARS-CoV-2 infection (A, B or C)	A. A person with a positive Nucleic Acid Amplification Test (NAAT); RT-PCR, Rapid Molecular, and Gene X-pert. B. A person with a positive SARS-CoV-2 RTK-Ag **AND** meeting either the probable case definition or suspected criteria C. An asymptomatic person with a positive SARS-CoV-2 RTK-Ag **AND** who is a contact of a probable or confirmed case

* Obtained from Ministry of Health Malaysia - Guideline (updated 23rd May 2022)[2]

Table II: Recommended personal protective equipment used when managing suspected/confirmed COVID-19 cases.

<table>
<tr><th>Activity</th><th>Type of PPE</th><th>Note</th></tr>
<tr><td>Activities that do not result in physical contact</td><td>• N95 mask
• Eye protection (face shield/goggles)</td><td>• Triaging areas in emergency department may use physical barriers (such as glass or plastic windows or face shield) to reduce exposure.</td></tr>
<tr><td>Activities that result in LOW CONTACT RISK i.e., activities that are unlikely to provide opportunities for the transfer of virus to clothing for example:
• Recording clinical vital assessment (Blood Pressure/Pulse Rate/ Oxygen Saturation/Temperature)
• Inserting a peripheral IV cannula
• Administering or changing IV fluids</td><td>• N95 mask
• Eye protection (face shield/goggles)
• Disposable plastic apron
• Gloves
• Fluid resistant isolation gown/ long sleeve plastic apron can be used if anticipating spillage/ difficult line insertion or any activities which increases the frequency of exposure</td><td rowspan="2">• HCW should maintain at least 1-meter spatial distance when possible.
• HCW should limit the time and frequency of exposure as permissible.
• Gowns and gloves should be changed between patients after high-risk contact activities, to minimise the risk of cross-transmission of other pathogens commonly encountered in healthcare settings.
• PPE should be exchanged between patients if visibly contaminated.</td></tr>
<tr><td>Activities that result in HIGH CONTACT RISK i.e. activities that involve a higher chance of transfer of virus to the clothing. This includes (but not limited to):
• Close contact for physical examination
• Wound care
• ANY activities where splashes/ sprays are anticipated</td><td>• N95 mask
• Eye protection (face shield/goggles)
• Gloves
• Isolation gown (fluid-repellent long-sleeved gown/apron) can be used if anticipated spillage/difficult line insertion or any activities which increase the frequency of exposure

*If the gown is not fluid resistant; it is advised to wear a disposable plastic apron over the gown

*Use of coverall does not offer additional protection and is not recommended</td></tr>
<tr><td>Performing Aerosol Generating Procedures
• Intubation, extubation and related procedures/CPR
• Tracheotomy/tracheostomy procedures
• Manual ventilation
• Suctioning
• Bronchoscopy
• Nebulization</td><td>• N95 mask/PAPR
• Eye protection (face shield/goggles)
• Isolation gown (fluid repellent long-sleeved gown)
• Gloves

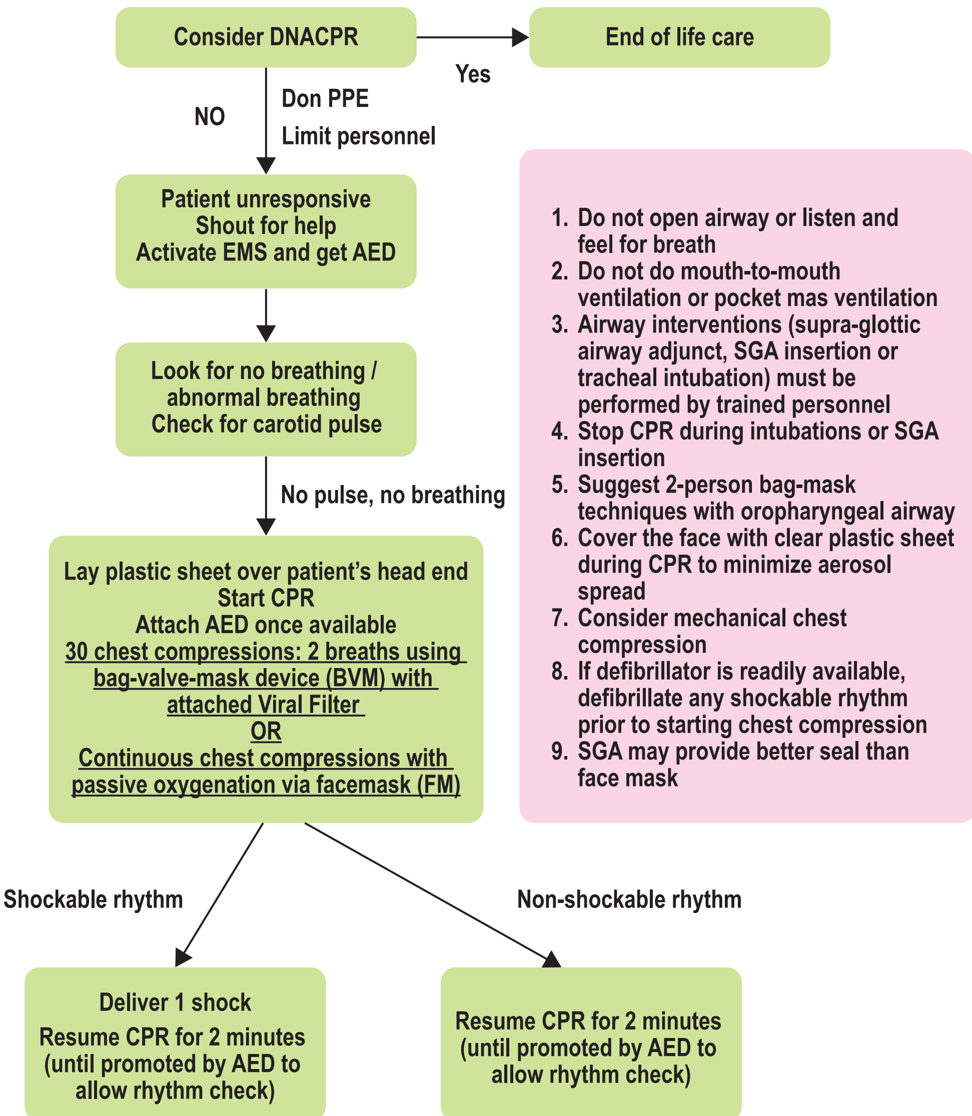
* Use of coverall does not offer additional protection and not recommended</td><td>• All PPE should be removed after procedure.</td></tr>
</table>

Note:
Abbreviations: HCW, healthcare worker; PAPR, powered air-purifying respirator; PPE, personal protective equipment.
*Adapted from Ministry of Health Malaysia guidelines (update 9th March 2022)[3]

Cardiopulmonary Resuscitation

Critically ill trauma patients may require cardiopulmonary resuscitation (CPR) upon presentation to the hospital. During CPR, the risk of transmission of COVID-19 increases drastically, as CPR involves multiple aerosol-generating procedures (chest compression, insertion of advanced airway, and positive pressure ventilation) and numerous medical personnel working at a close distance to the patient. Hence, the Ministry of Health Malaysia has stressed the mantra of "safety comes first" during CPR to prevent the transmission of infection to medical staff. If staff are not equipped with proper airborne precaution PPE, CPR is not to be performed. Advanced directives should also be discussed early on during the management of critically ill trauma patients with COVID-19.[9] Recommendations by the Ministry of Health Malaysia for CPR of COVID-19 patients can be found in Figure 1.

Adult BLS Algorithm in COVID-19 Pandemic



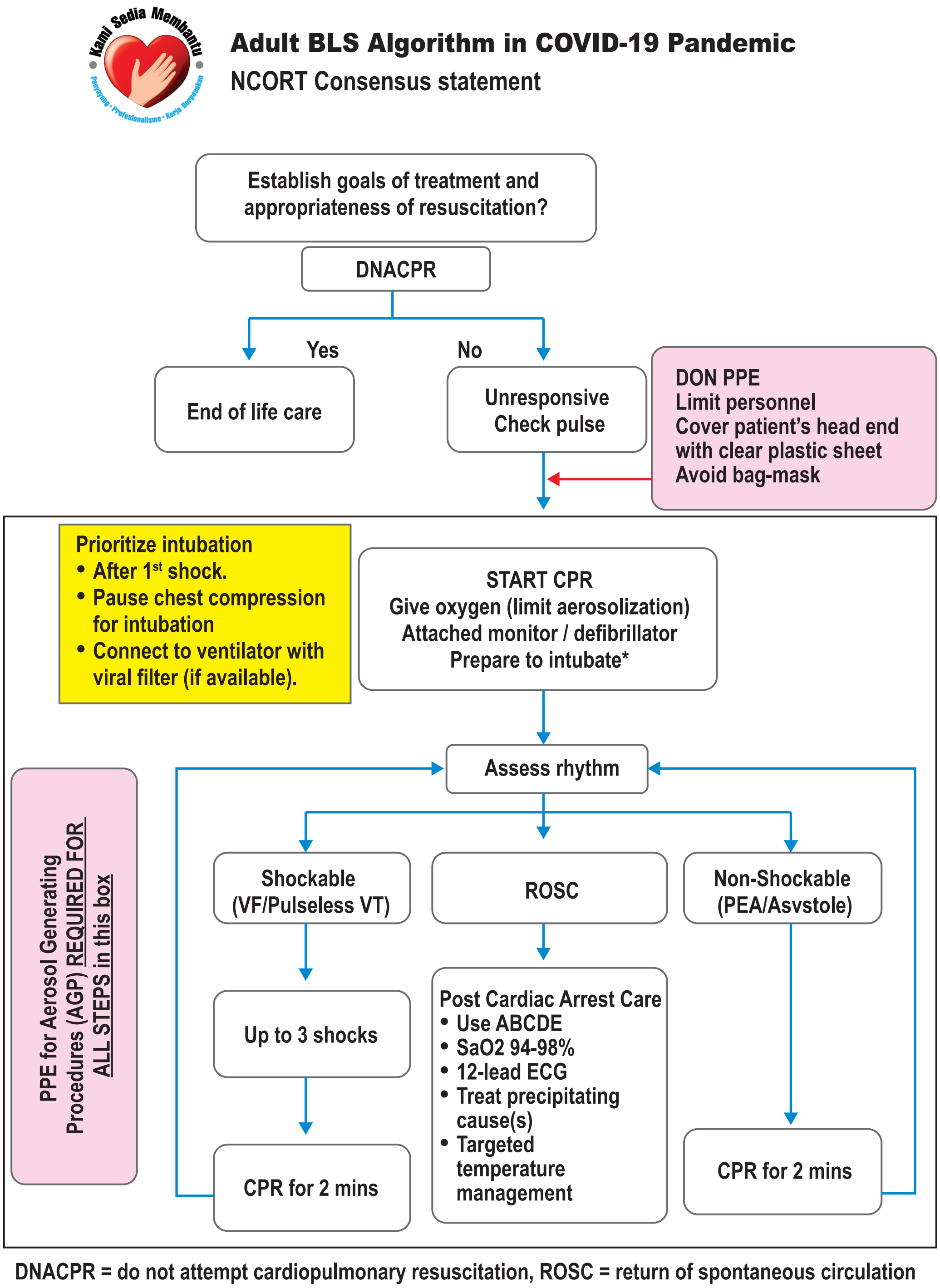


Figure 1: Adult Basic Life Support and Advanced Cardiac Life Support guidelines from the Ministry of Health Malaysia, with modifications for COVID-19 patients (Updated 17th June 2021)[9]

TRAUMA SURGERY

Many COVID-19 trauma patients presenting to the hospital may require surgery as corrective measures for their injuries sustained during the trauma. In addition, a certain proportion of patients presenting with severe trauma may require damage control surgery to preserve life. The decision for surgery should involve a multidisciplinary team discussion between the surgeon, the anaesthesiologist, and the infectious disease physician, in order to decide on the best course of action for the patient's management.

Equipment, facilities, and staffing

Throughout surgery for trauma patients with suspected or confirmed COVID-19, proper PPE should be always worn (Table II). The surgery should optimally be done in a negative pressure operating theatre (OT), or if not available, in an isolated OT away from the main OT. Signs indicating the COVID-19 exposure area should be well-placed outside the OT to serve as a warning for other staff. Unnecessary devices in the OT should be removed, while necessary items such as anaesthesia machines, drugs and airway trolleys should be covered with disposable plastic sheets. The number of staff allowed into the OT should also be limited to reduce staff exposure to COVID-19. Preferably only senior staff should be in the OT managing the patient. Surgeries should be performed by senior surgeons to reduce operative times and improve outcomes. Teamwork and communication among different teams are important to ensure a successful surgery, considering the physical limitations imposed by PPE making interaction difficult. After surgery, thorough disinfection of the OT should be carried out.[5-7,10]

Preoperative preparation

Preoperative assessment should optimally be done before the patient arrives in the OT. It is important to note that adequate resuscitation and stabilization before surgery are important to ensure the best patient outcomes. COVID-19 pneumonia patients may present with compromised respiratory function, which may be detected via an arterial blood gas. If present, appropriate steps need to be taken during induction of anaesthesia, to prevent hypoxaemia. Options include using proper preoxygenation, apnoeic oxygenation with a high-flow nasal cannula, and head-up positioning of patients for intubation. Another important consideration is the risk of coagulation disorders.[11] Patients with major haemorrhage from trauma may present with consumptive coagulopathy and disseminated intravascular coagulation. In addition, there is evidence to suggest COVID-19 patients are at high risk of having thrombocytopenia and a hypocoagulable state, which may influence the choice of anaesthesia and preparation for the possibility of intraoperative haemorrhage.[12]

Choice of anaesthesia

Choice of anaesthesia will depend on the patient's condition, type of trauma and planned surgery. If feasible, regional anaesthesia is preferred as it avoids manipulation of the airway, which leads to aerosolization of COVID-19. In addition, the risk of postoperative pulmonary complications can be reduced as patients' respiratory functions are preserved.[5]

Intraoperative phase

Cardiovascular system

For trauma patients with massive haemorrhage without traumatic brain injury (TBI), permissive hypotension whereby systolic blood pressure of 80-90mmHg (mean arterial pressure [MAP] 50-60mmHg) has been recommended until the major bleeding is stopped. Patients with severe TBI (Glasgow Coma Scale $\leq$8) should have their MAP maintained at $\geq$80 mmHg. Additionally, a restrictive fluid replacement strategy to achieve blood pressure targets until bleeding is controlled has been recommended.[13] It is important to remember that patients with COVID-19 pneumonia are at higher risk of having compromised respiratory functions due to fluid overload. Hence, optimal administration of fluid based on goal-directed fluid therapy is recommended.[7] Modalities that guide goal-directed fluid therapy can be the analysis of arterial waveforms (pulse pressure variations) or the usage of non-invasive haemodynamic monitoring. Caution should be practised when giving an allogeneic blood transfusion, due to the risks of transfusion-related lung injury and circulatory overload.[14] During the COVID-19 pandemic, there have been issues with shortage of blood products for various reasons. It is therefore sensible to practice blood conservation strategies to reduce blood transfusion rates.[7]

Respiratory system

Trauma patients with COVID-19 may have pulmonary contusions with concomitant infective changes. This "double-poison effect" will complicate intraoperative ventilatory strategies, resulting in hypoxaemia and organ injuries. Lung-protective ventilation strategies are therefore important to minimize the risk of ventilator-associated lung injury. A low tidal volume (6-8ml/kg of predicted body weight) and optimal positive end-expiratory pressures are recommended, along with intraoperative alveolar recruitment manoeuvres.[15] If endotracheal suctioning is planned, a closed-system should be used to minimize the risk of exposure to staff.

Analgesia

As with all surgeries, multimodal analgesia should be practised. Options include paracetamol, opioids, non-steroidal anti-inflammatory drugs, and regional analgesia techniques. Patients with COVID-19 may not be reviewed as frequently as non-infectious patients in the wards; therefore it is important to ensure that the analgesia given extends well into the postoperative phase. With regards to opioid usage, the risk of respiratory depression and carbon dioxide retention must be considered as these can aggravate lung problems in COVID-19 patients.

Postoperative management

Postoperatively, the decision to discharge a COVID-19 patient to the intensive care unit or ward should be done based on the patient's condition, the surgical outcome, and logistic issues (e.g. lack of isolation beds). Extubation is an aerosol-generating procedure, and hence it should be done in the OT itself after surgery. To prevent coughing during extubation, the usage of remifentanil can be considered.[16] Another method for smooth extubation is the laryngeal mask airway exchange technique (Bailey manoeuvre). This technique allows for minimal stimulation, while at the same time maintaining a patent airway.[7] After extubation, patients need to be monitored in the OT for about 20 to 30 minutes until they are suitable to be discharged based on appropriate scoring with postanaesthetic recovery score (e.g. Aldrete score).

Trauma patients have a high risk of developing venous thromboembolism (VTE). This risk increases further post-surgery due to Virchow's triad (blood stasis, endothelial damage, and hypercoagulability). In the presence of COVID-19, the risk of VTE rises even higher, which is attributed to inflammation and the activation of the serum complement system.[17] Taken together, this population of patients will require early VTE prophylaxis. This can be done with mechanical thromboprophylaxis (compression stockings and intermittent pneumatic compression devices), and chemical thromboprophylaxis (low-molecular-weight heparin or unfractionated heparin), which can be started when the risk of bleeding is deemed to be lower.

CHALLENGES

As Malaysia and the rest of the world move into the post-COVID-19 pandemic phase, multiple challenges remain in the management of trauma patients with COVID-19. One of these challenges is the need to increase trauma OT efficiency. Research has shown that during the COVID-19 pandemic, there were significantly increased operative, anaesthetic, change-over, and late-start times. These phenomena have been attributed to the implementation of safety precautions (e.g. PPE, OT cleaning, recovery of patients, etc).[18] The challenge is therefore to improve theatre efficiency without compromising patient safety.

In addition, physician psychological distress and burnout during the pandemic is a worldwide occurrence, potentially compromising the care of COVID-19 patients. In Malaysia up to 55.3% and 67.1% of anaesthesiologists managing COVID-19 patients were burnout and at risk of depression, respectively.[19] The acute management of trauma is by itself mentally taxing, and coupled with COVID-19 management, a recipe for increased burnout and psychological distress is created. Involvement of all stakeholders (doctors, hospital administrators, and politicians) are required to ensure the mental well-being of physicians is taken care of while the COVID-19 pandemic stretches on.

CONCLUSION

The care of trauma patients with COVID-19 is a challenging scenario. Despite that, anaesthesiologists have demonstrated the ability to improvise, adapt and overcome those challenges. Trauma care should not be compromised during the COVID-19 pandemic. At the same time, the safety of staff is paramount, and infection control practices need to be emphasized. Trauma surgery for COVID-19 patients can be done safely. Adaptations to the preoperative, intraoperative, and postoperative phases of care are necessary to achieve the best patient outcomes.

References

1. John Hopkins University. Coronavirus resource center Malaysia: overview, 2022. Available from: https://coronavirus.jhu.edu/region/malaysia (assessed 5 July 2022)

2. Ministry of Health Malaysia. Annex 1: case definitions, 2022. Available from: https://covid-19.moh.gov.my/garis-panduan/garis-panduan-kkm/ANNEX-01-COVID-19-Case-Definition-23052022.pdf (assessed 5 July 2022)

3. Ministry of Health Malaysia. Annex 8: Guidelines on infection prevention and control measures in managing person under surveillance, suspected, probable or confirmed coronavirus disease (Covid-19), 2022. Available from: https://covid-19.moh.gov.my/garis-panduan/garis-panduan-kkm/ANNEX-8-IPC-MEASURES-IN-MANAGING-PUS-SUSPECTED-PROBABLE-CONFIRMED-COVID-19-09032022.pdf (assessed 5 July 2022)

4. Okoye O. Implementing trauma resuscitation protocol in COVID-19 era: our modifications at the National Trauma Centre, Abuja, Nigeria. *Nigerian Journal of Clinical Practice* 2021;**24**:138-141

5. Sawhney C, Singh Y, Jain K, Sawhney R, Trikha A. Trauma care and COVID-19 pandemic. *Journal of Anaesthesiology Clinical Pharmacology* 2020;**36**:S115

6. Li Y, Zeng L, Li Z, Mao Q, Liu D, Zhang L, Zhang H, Xie Y, Liu G, Gan X. Emergency trauma care during the outbreak of corona virus disease 2019 (COVID-19) in China. *World Journal of Emergency Surgery* 2020;**15**:1-10

7. Gong Y, Cao X, Mei W, Wang J, Shen L, Wang S, Lu Z, Yu C, Che L, Xu X. Anesthesia considerations and infection precautions for trauma and acute care cases during the Coronavirus Disease 2019 pandemic: recommendations from a task force of the Chinese Society of Anesthesiology. *Anesthesia and Analgesia* 2020;**131**:326-34

8. Cook T, El-Boghdadly K, McGuire B, McNarry A, Patel A, Higgs A. Consensus guidelines for managing the airway in patients with COVID-19: Guidelines from the Difficult Airway Society, the Association of Anaesthetists, the Intensive Care Society, the Faculty of Intensive Care Medicine and the Royal College of Anaesthetists. *Anaesthesia* 2020;**75**:785-99

9. Ministry of Health Malaysia. Annex 40: Guidelines on resuscitation during Covid-19 pandemic version 4/2021, 2020. Available from: https://covid-19.moh.gov.my/garis-panduan/garis-panduan-kkm/ANNEX_40_GUIDELINES_ON_RESUSCITATION_DURING_COVID19_PANDEMIC_17062021.pdf (assessed 5 July 2022)

10. Awad ME, Rumley JCL, Vazquez JA, Devine JG. Perioperative considerations in urgent surgical care of suspected and confirmed COVID-19 orthopaedic patients: operating room protocols and recommendations in the current COVID-19 pandemic. *Journal of the American Academy of Orthopaedic Surgeons* 2020;**28**:451-63

11. Dutton RP, Grissom TE, Herbstreit F. COVID-19 and trauma care: improvise, adapt, and overcome! *Anesthesia and Analgesia* 2020;**131**:323-5

12. Kander T. Coagulation disorder in COVID-19. *The Lancet Haematology* 2020;**7**:e630-e2

13. Spahn DR, Bouillon B, Cerny V, Duranteau J, Filipescu D, Hunt BJ, Komadina R, Maegele M, Nardi G, Riddez L. The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. *Critical Care* 2019;**23**:1-74

14. Semple JW, Rebetz J, Kapur R. Transfusion-associated circulatory overload and transfusion-related acute lung injury. *Blood* 2019;**133**:1840-53

15. Young CC, Harris EM, Vacchiano C, Bodnar S, Bukowy B, Elliott RRD, Migliarese J, Ragains C, Trethewey B, Woodward A. Lung-protective ventilation for the surgical patient: international expert panel-based consensus recommendations. *British Journal of Anaesthesia* 2019;**123**:898-913

16. Nho J-S, Lee S-Y, Kang J-M, Kim M-C, Choi Y-K, Shin O-Y, Kim D-S, Kwon M-I. Effects of maintaining a remifentanil infusion on the recovery profiles during emergence from anaesthesia and tracheal extubation. *British Journal of Anaesthesia* 2009;**103**:817-21

17. Schulman S, Hu Y, Konstantinides S. Venous thromboembolism in COVID-19. *Thrombosis and Haemostasis* 2020;**120**:1642-53

18. Khadabadi NA, Logan PC, Handford C, Parekh K, Shah M. Impact of COVID-19 pandemic on trauma theatre efficiency. *Cureus* 2020;**12**:e11637

19. Tsan SEH, Kamalanathan A, Lee CK, Zakaria SA, Wang CY. A survey on burnout and depression risk among anaesthetists during COVID-19: the tip of an iceberg? *Anaesthesia* 2021;**76**:8-10

Transfusions in Trauma

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"Full activation in Red Zone. A 40-year-old gentleman high impact motor vehicle accident (motorbike versus car). Hemodynamic unstable, FAST scan positive for intraabdominal free fluids."

This is not an unfamiliar referral we would receive on a busy weekend night. On average, there are 17 deaths per day due to traffic accidents, making it the fourth most common cause of death in Malaysia in 2021.[1] Since 2012 to 2019, there has been a steady increase in the number of road traffic accidents, but there has been a slight reduction in the Road Fatalities Index over the same time period.[1]

A study carried out in the United Kingdom estimated that the incidence of major haemorrhage in trauma patients to be about 33%, with a mortality rate of 1 in 4 patients with major haemorrhage, which increased to 1 in 3 patients with massive haemorrhage.[2] Major haemorrhage was defined as patients requiring more than 4 units of packed red blood cells (PRBC) within 24 hours of admission, and massive haemorrhage was defined as requiring more than 10 PRBC within 24 hours of admission. Another important finding from this study was that 62.2% of deaths occurred within the first 24 hours of admission. The high mortality rate was attributed to the inability to stabilize and match the blood loss in a rapidly exsanguinating patient.[2]

This review will focus on the management of transfusion in trauma patients, evaluating the evidence of prehospital and in-hospital transfusion strategies, as well as looking to the future of transfusions in trauma.

PHYSIOLOGY OF COAGULOPATHY IN TRAUMA

After trauma, the human body responds by activating the haemostatic response to stop the bleeding and begin the process of wound healing. Haemostasis is a dynamic process which balances the pro- and anti-coagulation systems as well as the fibrinolytic and fibrinolysis-inhibitory pathways. In normal circumstances, the interplay between the endothelial cells, platelets and clotting factors lead to the formation of a fibrin mesh, trapping platelets and securing the damaged tissue from further blood loss.[3]

However, in major trauma, this process is disrupted leading to a dysregulated response of coagulopathy and thrombosis. This dysregulation has been termed trauma-induced coagulopathy (TIC). In the past, this coagulopathy was thought to be caused by the lethal triad of trauma, namely hypothermia, acidosis and dilution of clothing factors. However, as we begin to understand more about the pathophysiology of TIC, it is now known that the mechanism is much more complex than initially thought. Figure 1 outlines the pathophysiology of TIC.

Trauma Associated Factors

During a trauma, tissue injury and haemorrhage occurs. The extent of the injury and haemorrhage may influence the degree of response from the body. The more severe the trauma and the blood loss, the greater the consumption of coagulation factors to stem the bleeding as well as the greater the loss of coagulation factors. The presence of coagulopathy at presentation was associated with greater mortality.[4]

Dysregulation of Haemostasis with Systemic Endotheliopathy

After trauma has occurred, the resultant tissue damage exposes subendothelial collagen and activates tissue factors (Factor VII) which would then begin the coagulation cascade and activate the haemostatic system.[3] In severe trauma it is postulated that the depletion of pro-coagulatory factors like Factors I, II, V, VII, VIII, IX and X and the activation of the protein C system leads to the dysregulated haemostasis. Activated protein C is an anticoagulant, which inactivates Factors Va and VIIIa (which are procoagulants) and enhances fibrinolysis by inhibiting plasminogen activator inhibitor-1

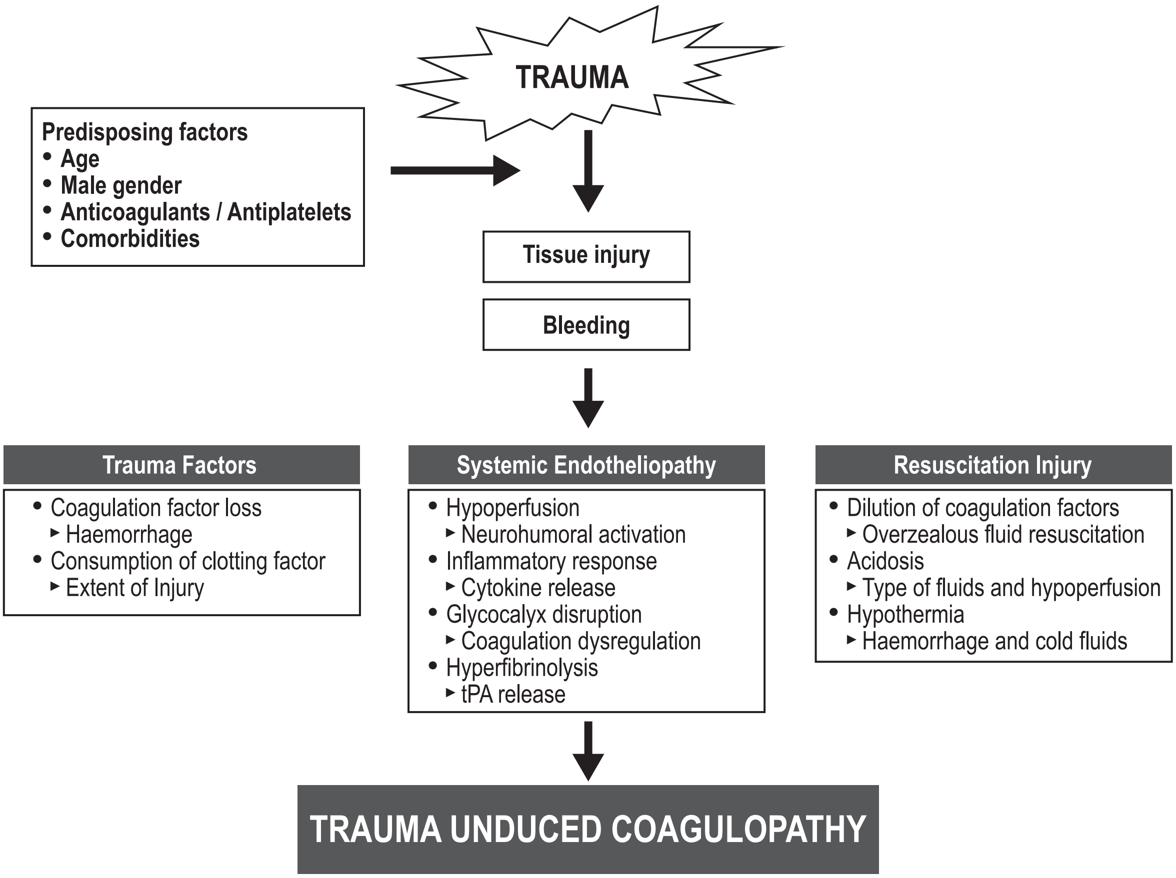

Figure 1: Summary of the factors affecting trauma induced coagulopathy (TIC). (tPA - Tissue plasminogen activator). Adapted from Savioli et.al (2021)[3]

(PAI-1).[5] The study by Cohen et. al. also showed that there was an increased risk for nosocomial infections in patients with early TIC.[5]

Another haemostatic pathway is the activation of the neurohumoral system after trauma. The activation of the sympathetic nervous system leads to the secretion of adrenaline and vasopressin, as well as the secretion of inflammatory cytokines.[6] This in turn stimulates the release of tissue plasminogen activator (tPA) and Weibel-Palade bodies (which contain von Willebrand Factor (VWF).[3] The release of tPA would lead to the activation of plasmin, and the breakdown of fibrin and clot lysis.[7] However, the concomitant release of VWF via the Weibel-Palade bodies leads to platelet activation and adhesion. These two opposing systems are in balance, however in severe trauma the balance is loss, leading to endotheliopathy. Another contributor to endotheliopathy is the glycocalyx degradation that occurs with the catecholamine surge, which also can cause capillary leakage following trauma.[6] The increased consumption and breakdown of fibrinogen leads to hypofibrinogenaemia which are indicators of poorer outcomes.[8,9]

Resuscitation Injury

Resuscitation injury occurs due to overaggressive resuscitation practices that were common place in yesteryears. This practice has since become less popular as the focus has shifted towards more targeted fluid resuscitation, with judicious use of crystalloids. Overzealous crystalloid resuscitation leads to the lethal triad of trauma, namely dilution of coagulation factors, acidosis from hyperchloraemia and hypoperfusion, and lastly hypothermia from the large volumes of cold fluids infused. The improvements seen by the use of damage control or targeted resuscitation was examined by Cole et. al. (2021), and found that there was a reduction in mortality as well as reduction in number of packed cells transfused.[10] This coupled with the endothelial injury due to neurohumoral stimulation leads to interstitial leakage of fluids and, worse still, colloids, causing interstitial oedema and worsening the microcirculation.[6] The cycle then is perpetuated as the worsening microcirculation leads to anaerobic metabolism in peripheral tissues, with lactic acidosis as a result, which in turn may trigger more fluid resuscitation in an attempt to correct the acidosis.

The link between hypothermia and coagulopathy is also well established, with evidence pointing to reductions in platelet aggregation and adhesion as the main reasons for the coagulopathy.[11] In summary, hypothermia predominantly inhibits the early stages of coagulation, while acidosis inhibits the propagation and thrombin generation phases. However, if core body temperature is normalised, there is also concomitant improvements in coagulation if acidosis is not present.[11] Acidosis impairs coagulation by the impairment of enzymatic activity crucial to the coagulation cascade. Contrary to hypothermia, a review of studies attempting to correct the coagulopathy by correcting the acidosis revealed that improvements in the pH did not lead to immediate improvements in coagulation.[12] The presence of both hypothermia and acidosis is synergistic in its effect to impair coagulation.[13]

Other Contributory Factors

Other factors that have been shown to impact coagulation in trauma include age, male gender, comorbidities like hypertension and diabetes, presence of traumatic brain injury as well as concomitant treatment with antiplatelets and anticoagulants.[3]

DIAGNOSIS

The accurate diagnosis and recognition of patients at risk for TIC is a challenge. Traditionally, the use of conventional coagulation tests (CCT) like Prothrombin Time (PT) and Activated Partial Thromboplastin Time (aPTT), fibrinogen levels and platelet counts has been standard, but the limitations of these assays are the delayed time to results and the difficulty to pinpoint the components that are deficient. Viscoelastic Haemostatic Assays (VHA) like Thromboelastography (TEG) and Rotational Thromboelastometry (ROTEM) have been suggested as alternatives to improve the detection of coagulopathy. Viscoelastic haemostatic assays allow for point of care testing, with more rapid results as the clot evolves, and a guide to decide which blood components would be needed to correct the assay and improve haemostasis.

A previous systematic review on VHA use in major haemorrhage revealed that VHA reduced transfusions of blood and blood products, but the quality of evidence was poor.[14] A recent randomised control trial, the ITACTIC trial[15] showed that there was no difference when VHA was compared to CCT in transfusion related outcomes and mortality in patients receiving massive haemorrhage protocol management. This trial enrolled 396 patients across 7 trauma centres in 5 countries in Europe. One positive finding from this trial was that in traumatic brain injury (TBI) patients, there was a reduction in 28-day mortality (44% vs 74%, OR 0.28 [95% CI 0.10 - 0.74]).[15]

MANAGEMENT

The management of the bleeding trauma patient is summarised in Figure 2 and is based on the European guideline on management of major bleeding and coagulopathy following trauma.[16] The guideline is part of the *"STOP the Bleeding"* launched in 2013, and is in its 5th edition. The working group recommended a series of bundles to be implemented at the prehospital, inhospital and coagulation levels.

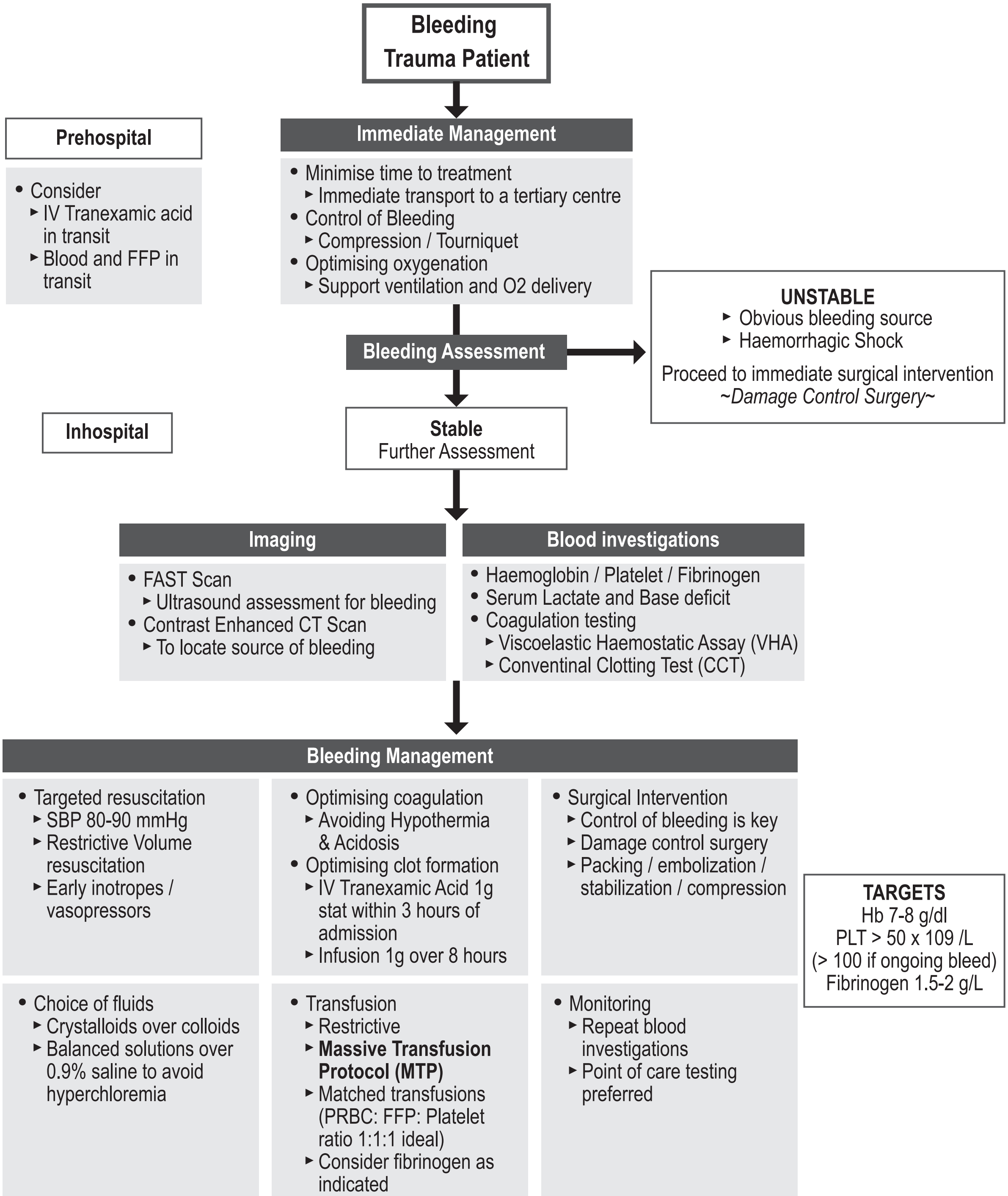

Figure 2: Management of a bleeding trauma patient, showing the prehospital, inhospital and bleeding bundles. (PRBC - Packed Red Blood Cells, FFP - Fresh Frozen Plasma) Adapted from the European Guideline on Management of Major Bleeding and Coagulopathy Following Trauma: Fifth edition

Prehospital Bundle

The management of the bleeding trauma patient begins at the scene of the trauma and during the transport. The first recommendation was to minimise the elapsed time to treatment from the scene of trauma. A systematic review in 2015 showed that the odds of mortality were reduced when response-time or transfer-time was shorter, especially in patients with penetrating injuries and hypotension as well as traumatic brain injury patients.[17] There were three other important trials for prehospital management of trauma patients which were the Resuscitation with blood products in patients with trauma-related haemorrhagic shock receiving prehospital care (RePHILL),[18] Prehospital Air Medical Plasma (PAMPer)[19] and Control of Major Bleeding After Trauma (COMBAT)[20] trials.

The RePHILL trial was carried out in the United Kingdom, involving 432 patients randomised to receive either 1 litre of 0.9% saline or 2 units of packed red blood cells (PRBC) and 2 units of lyophilised plasma (LyoPlas - freeze dried plasma) in the prehospital setting.[18] There was no difference between groups for primary outcome of inpatient mortality or lactate clearance. A Bayesian analysis was also done and showed that it was highly unlikely that there was any significant difference between groups.

The PAMPer trial was a multicentre, cluster-randomised trial done in the United States of America, involving patients requiring air transport to 9 trauma centres participating in the study. A total of 501 patients were enrolled in the study, with a primary outcome looking at 30-day mortality.[19] The intervention was the transfusion of either 2 units of fresh frozen plasma (FFP) or 0.9% saline as resuscitation fluid during the transfer. The results indicated that the 30-day mortality was significantly lower in the plasma group compared to control (23% vs. 33.0%, 95% CI -18.6 to -1.0; p = 0.03).[19]

The COMBAT trial on the other hand, was a randomised control trial conducted in a single centre involving ground transfer of trauma patients involving 144 patients. The average transport time was less than 20 minutes, and the study was stopped early due to futility, as there was consistently no difference between interventions for primary and secondary outcomes.[20] Further post-hoc analysis of both trials looking at the survival rate in transports which took longer than 20 minutes revealed that there was an increased mortality at 28 days in the standard care group (0.9% saline resuscitation) with a hazard ratio (HR) of 2.12 (95% CI, 1.05-4.30; p = 0.04).[21]

Other interventions that were recommended include local control of bleeding by compression or application of a tourniquet and the application of damage-control resuscitation principles. Another aspect that was recommended was the recommendation to control ventilation, to ensure adequate oxygenation and avoiding hyper and hypocarbia.[22] Data for this recommendation was mostly from closely related studies and widely heterogenous.[16,22] The targets for ventilation were maintaining a normal $PaCO_2$ while avoiding hyperoxia with PaO_2 > 120 mmHg,[22] where a cohort study by Page et. al. (2018) showed that hyperoxia in the Emergency Department was an independent predictor of hospital mortality (adjusted OR 1.95 (1.34-2.85)).[23]

Inhospital Bundle

Upon arrival in the hospital, the patient should be rapidly assessed by the attending emergency physician for stability and ongoing bleeding. Hemodynamic markers of stability like inability to sustain blood pressure and tachycardia, coupled with a dropping haemoglobin level despite blood transfusions are suggestive of ongoing bleeding. Imaging modalities using the Focused Assessment with Sonography in Trauma (FAST) scan and a contrast enhanced whole body CT were recommended to rapidly diagnose the source of bleeding.[16]

The first pharmacological intervention would be to administer intravenous tranexamic acid. The use of tranexamic acid was shown to reduce death by exsanguination at 24-hour and reduce all-cause mortality by 1.5%. This landmark trial was the Clinical Randomisation of Antifibrinolytic therapy in Significant Haemorrhage (CRASH-2) trial which randomised 20211 patients to receive either IV tranexamic acid 1g bolus followed by a further 1g over 8 hours or a matching placebo.[24] There are suggestions that the administration of IV tranexamic acid be given even earlier on-site, and this is being studied in the Pre-hospital Anti-fibrinolytics for Traumatic Coagulopathy and Haemorrhage (The PATCH-Trauma study) which is still ongoing.[25]

If ongoing massive bleeding is suspected, activation of the massive transfusion protocol (MTP) should be done. The transfusion strategy for massive trauma would be the use of matched PRBC: FFP: Platelet ratios of 1:1:1 as per the findings of the PROPPR trial.[26] The Pragmatic, Randomized Optima Platelet and Plasma Ratios (PROPPR) trial showed that there were no differences in 24-hour and 30-day mortality for patients receiving 1:1:1 or 2:1:1 ratios of PRBC: FFP: Platelets transfusions. However, it was reported that the group receiving 1:1:1 ratio transfusion was more likely to achieve haemostasis and less likely to die from exsanguination. The MTP differs from institution to institution but generally involves the supply of 4 units of PRBC with either 4 units of FFP and 4 units of platelets together or in alternating cycles until the MTP is deactivated.[26]

The initial resuscitation should be guided by clinical assessment, but clinical coagulation testing should also be sent. Viscoelastic haemostatic assays (VHA) offer an interesting option in point-of-care testing as discussed earlier. These tests ideally should be repeated after administration of transfusion to guide further transfusion decisions as VHA guidance has been shown to reduce blood product transfusions in severe trauma.[27]

The other strategies that are equally important are the maintenance of normothermia and the prevention of acidosis. The guidelines recommend the usage of crystalloids over colloids, and balanced solutions over 0.9% saline to reduce the leakage and subsequent tissue oedema as well as reduce the incidence of hyperchloraemic acidosis.[6,16]

Factor concentrate usage, like prothrombin complex concentrate (PCC) and fibrinogen concentrate have been recommended for use in the European guidelines.[16] Factor concentrates have the advantage of being easier to store and reconstitute, reduce volume load and with a reduced risk of allergic and infective reactions.[28] However, it is more expensive and at the moment limited in its availability in Malaysia. At the moment, immediate reversal of vitamin K antagonist (VKA) overdose is the main indication for PCC use, but it has been shown that PCC can be used in massive haemorrhage where the coagulopathy is the main reason for persistent bleeding.

FUTURE OF TRANSFUSION IN TRAUMA

The current trends in transfusion are:

- *Use of factor concentrates*
  The results from the Fibrinogen Early in Severe Trauma (FEISTY) pilot study showed that fibrinogen concentrate can be given early (<30 mins) and quickly (duration of 4 minutes to completion) in severe trauma when compared to cryoprecipitate. Other interesting results from this trial was the improvement in VHA fibrinogen parameters was superior in the fibrinogen concentrate group compared to the control group.[29]

- *Earlier administration of blood and blood products*
  The CRYOSTAT-2 trial has completed recruitment and will be reporting 1500 patients randomised to receive early cryoprecipitate therapy (<3 hours) and standard care. The results should indicate if there is a role for early replacement for fibrinogen in patients with severe trauma.[30] The evidence for out of hospital on site transfusions are still lacking and this would be an area for future research.

- Expanding the use of point-of-care testing to guide transfusions
  As the use of VHA grows and the availability increases, the usage of point-of-care testing would be an invaluable tool in helping to guide transfusions. The ideal would be for personalised transfusion plans based on real time clotting assays and individual genetics / profiles which would use artificial intelligence to determine the optimal dosage of blood and blood products for the management of severe trauma haemorrhage.

CONCLUSION

Transfusion management for patients with trauma and haemorrhage is a challenging and emerging field. The practice has progressed further than just the prevention of the lethal triad of trauma, with early recognition and intervention with matched transfusions as key. Matched transfusions guided by viscoelastic haemostatic assays would be the management of choice, with the use of factor concentrates becoming more mainstream in the future.

References

1. Azhari, A.H., Zaidi, F. A. M., Anuar, M. H. A., & Othman, J, A Statistical Analysis of Road Accident Fatalities in Malaysia. *International Journal of Academic Research in Business and Social Sciences* 2022;**12**(5):p.1224-1230

2. Stanworth, S.J., et al., Mortality from trauma haemorrhage and opportunities for improvement in transfusion practice. *Br J Surg* 2016;**103**(4):p.357-65

3. Savioli, G., et al., Trauma-Induced Coagulopathy: Overview of an Emerging Medical Problem from Pathophysiology to Outcomes. Medicines 2021;8(4)

4. MacLeod, J.B., et al., Early coagulopathy predicts mortality in trauma. *J Trauma* 2003;**55**(1):p.39-44

5. Cohen, M.J., et al., Critical Role of Activated Protein C in Early Coagulopathy and Later Organ Failure, Infection and Death in Trauma Patients. Annals of Surgery 2012;255(2)

6. Ostrowski, S.R., et al., Sympathoadrenal activation and endotheliopathy are drivers of hypocoagulability and hyperfibrinolysis in trauma: A prospective observational study of 404 severely injured patients. Journal of Trauma and Acute Care Surgery 2017;82(2)

7. Chapman, M.P., et al., Overwhelming tPA release, not PAI-1 degradation, is responsible for hyperfibrinolysis in severely injured trauma patients. *J Trauma Acute Care Surg* 2016;**80**(1):p.16-23; discussion 23-5

8. McQuilten, Z.K., et al., Fibrinogen is an independent predictor of mortality in major trauma patients: A five-year statewide cohort study. *Injury* 2017;**48**(5):p.1074-1081

9. Paydar, S., et al., Early Predictive Factors of Hypofibrinogenemia in Acute Trauma Patients. *J Emerg Trauma Shock* 2018;**11**(1):p.38-41

10. Cole, E., et al., A Decade of Damage Control Resuscitation: New Transfusion Practice, New Survivors, New Directions. Annals of Surgery 2021;273(6)

11. Wolberg, A.S., et al., A systematic evaluation of the effect of temperature on coagulation enzyme activity and platelet function. *J Trauma* 2004;**56**(6):p.1221-8

12. Martini, W.Z., Coagulopathy by hypothermia and acidosis: mechanisms of thrombin generation and fibrinogen availability. *J Trauma* 2009;**67**(1):p.202-8; discussion 208-9

13. De Robertis, E., et al., Coagulopathy induced by acidosis, hypothermia and hypocalcaemia in severe bleeding. *Minerva Anestesiol* 2015;**81**(1):p.65-75

14. Wikkelsø, A., et al., Thromboelastography (TEG) or thromboelastometry (ROTEM) to monitor haemostatic treatment versus usual care in adults or children with bleeding. *Cochrane Database Syst Rev* 2016;**2016**(8): p.Cd007871

15. Baksaas-Aasen, K., et al., Viscoelastic haemostatic assay augmented protocols for major trauma haemorrhage (ITACTIC): a randomized, controlled trial. *Intensive Care Med* 2021;**47**(1):p.49-59

16. Spahn, D.R., et al., The European guideline on management of major bleeding and coagulopathy following trauma: fifth edition. *Crit Care* 2019;**23**(1):p.98

17. Harmsen, A.M., et al., The influence of prehospital time on trauma patients outcome: a systematic review. *Injury* 2015;**46**(4):p.602-9

18. Crombie, N., et al., Resuscitation with blood products in patients with trauma-related haemorrhagic shock receiving prehospital care (RePHILL): a multicentre, open-label, randomised, controlled, phase 3 trial. *Lancet Haematol* 2022;**9**(4):p.e250-e261

19. Sperry, J.L., et al., Prehospital Plasma during Air Medical Transport in Trauma Patients at Risk for Hemorrhagic Shock. *New England Journal of Medicine* 2018;**379**(4):p.315-326

20. Moore, H.B., et al., Plasma-first resuscitation to treat haemorrhagic shock during emergency ground transportation in an urban area: a randomised trial. *Lancet* 2018;**392**(10144):p.283-291

21. Minutes: A Post Hoc Analysis of the PAMPer and COMBAT Clinical Trials. *JAMA Surg* 2020;**155**(2):p.e195085

22. Damiani, E., et al., Arterial hyperoxia and mortality in critically ill patients: a systematic review and meta-analysis. *Crit Care* 2014;**18**(6):p.711

23. Page, D., et al., Emergency department hyperoxia is associated with increased mortality in mechanically ventilated patients: a cohort study. *Crit Care* 2018;**22**(1):p.9

24. Shakur, H., et al., Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant haemorrhage (CRASH-2): a randomised, placebo-controlled trial. *Lancet* 2010;**376**(9734):p.23-32

25. Mitra, B., et al., Protocol for a multicentre prehospital randomised controlled trial investigating tranexamic acid in severe trauma: the PATCH-Trauma trial. *BMJ Open* 2021;**11**(3):p.e046522

26. Holcomb, J.B., et al., Transfusion of Plasma, Platelets, and Red Blood Cells in a 1:1:1 vs a 1:1:2 Ratio and Mortality in Patients With Severe Trauma: The PROPPR Randomized Clinical Trial. *JAMA* 2015;**313**(5):p.471-482

27. Gonzalez, E., et al., Goal-directed Hemostatic Resuscitation of Trauma-induced Coagulopathy: A Pragmatic Randomized Clinical Trial Comparing a Viscoelastic Assay to Conventional Coagulation Assays. *Ann Surg* 2016;**263**(6):p.1051-9

28. Brekelmans, M.P.A., et al., Benefits and harms of 4-factor prothrombin complex concentrate for reversal of vitamin K antagonist associated bleeding: a systematic review and meta-analysis. *J Thromb Thrombolysis* 2017;**44**(1):p.118-129

29. Winearls, J., Wullschleger, M., Wake, E., McQuilten, Z., Reade, M., Hurn, C., Ryan, G., Trout, M., Walsham, J., Holley, A., George, S., Dyer, W., McCullough, J., Keijzers, G., Fraser, J., Presneill, J., & Campbell, D. , Fibrinogen early in severe trauma study (Feisty): Results from an australian multicentre randomised controlled pilot trial. *Critical Care and Resuscitation* 2021;**23**(1):p.32-46

30. ISRCTN Registry. Early cryoprecipitate in major trauma haemorrhage: CRYOSTAT-2. 2019

Nutrition in Traumatic Brain Injury

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INTRODUCTION

Traumatic brain injury (TBI) is the commonest cause of morbidity and disability following road traffic accidents. The global incidence of all causes of TBI is estimated at 939 cases per 100,000 people in 2019. Thus, an estimated 69.0 million people worldwide will suffer TBI each year. The Southeast Asia Region had the highest annual volume of TBI, estimated at 18.3 million.[1] Some often refer to this condition as a "silent epidemic," which gives great challenges and burdens to our health care system.[2]

The aim of management in patients with TBI is to prevent secondary brain injury following the primary insult. These include maintaining adequate cerebral perfusion pressure, preventing hypoxia and aiming for normothermia, normoglycemia and normocarbia. Following traumatic brain injury, the body undergoes hypermetabolic and hypercatabolic states as a result of hypersecretion of endogenous catabolic hormones such as corticosteroids, catecholamines, and glucagon together with proinflammatory cytokines (e.g. tumour necrosis factor-α, interleukin-1 and interleukin-6) which cause an increase in systemic and cerebral energy requirements. Following an insult, molecular disruption has profound consequences for neuronal function. Brain-derived neurotrophic factor (BDNF) is a protein encoded by the BDNF gene. This protein promotes neurogenesis, synaptogenesis and cognitive function in learning and memory.[3,4]

Nutritional intake is a crucial way to affect brain function. The type of diet determines levels of BDNF and directly affects neuronal and behavioural plasticity. In an experimental model, the high fat sucrose diet reduces the level of BDNF and the capacity of the brain to compensate for insults.[4] Apart from that, diets that are high in sugar or fat can also increase free radical formation, which leads to oxidative stress. The presence of large amounts of circulating unsaturated fatty acids and oxygen in the brain makes it susceptible to oxidative stress following lipid peroxidation.[5] β-oxidation of free fatty acids in mitochondria involves reduction of cofactors Flavin Adenine Dinucleotide (FAD) and Nicotinamide Adenine Dinucleotide (NAD+). During the process of reoxidation, electrons from NADH and FADH2 together with cytochrome C oxidase, oxygen and protons form water. Interaction with oxygen at this point produces reactive oxygen species (ROS) and superoxide anion radicals.[6] ROS can trigger and activate proinflammatory factors such as interferon-γ, tumour necrosis factor TNF-α, and inducible nitric oxide synthase (iNOS). Activation of iNOS mediated nitric oxide production causes the accumulation of reactive nitrogen species. The presence of these free radicals causes oxidative damage at the molecular level, leading to neuronal death.[7,8] These are a few but not all the mechanisms by which dietary intake can directly affect brain recovery following trauma.

Besides that, it may be difficult for TBI patients to achieve the target calorie intake due to pain and discomfort, and other co-injuries such as dental fractures, facial fractures and oral injuries. The need for prolonged cervical immobilisation with a hard-cervical collar may delay the initiation of an oral diet.[9] Additionally, they may experience eating behaviour changes including loss of appetite, secondary to psychological impairment, especially post-traumatic depression.[10] TBI patients are at risk of malnutrition as a result of feeding interruptions, such as fasting for surgery or procedure, or for other patient-related reasons.[11]

TIMING OF FEEDING

Initiation of early medical nutrition therapy (MNT) is associated with better outcomes. MNT is a term that encompasses oral nutritional supplements, enteral nutrition (EN) and parenteral nutrition (PN) in accordance with the European Society for Clinical Nutrition and Metabolism (ESPEN) terminology recommendations.[12]

The timing of mortality reduces with early feeding.[13] The definition of early and delayed nutrition differs across the literature. Some define early feeding as within 24 hours post trauma and some describe it as within 5 days.[13,14] Both the American Society for Parenteral and Enteral Nutrition-Society of Critical Care Medicine (ASPEN-SCCM) and ESPEN guidelines recommend initiating early EN (within 24-48 hours) instead of delaying EN in critically ill adult patients.[12,15] Other benefits of early nutrition in TBI patients include improved endocrinologic factors, reduced inflammatory responses, and improvement of Glasgow Outcome Scale (GOS) at three months. Achieving an early enteral feeding is protective and associated with a lower risk of infectious complications which includes early onset ventilator associated pneumonia, central nervous system infection, bloodstream infection, and urinary tract infection and subsequent reduction in length of ICU stay. [14,16,17]

Early initiation of enteral nutrition after TBI emerges as an independent factor affecting mortality. Feeding within first five days of insult is associated with a significant reduction in two-week mortality. A 2- and 4-fold increase in mortality expected if patients were not fed within 5 and 7days, respectively.[13,14,16,18]

METHODS OF FEEDING

Early medical nutrition therapy in TBI patients can be achieved either via enteral (gastric, jejunal) or parenteral methods. Chiang et. al. in his study reported data from medical records of TBI patients with GCS 4-8 from 18 hospitals in Taiwan from 2002-2010. Patients who received EN had a greater survival rate and GCS score on Day 7 intensive care unit (ICU) admission and a better outcome at one month post injury.[19] Based on available data, two review articles agreed that EN is the preferred approach to nutrition therapy in patients with TBI due to reduced risk of hyperglycaemia, infection, cost effectiveness and reduced incidence of catheter related complications.[20,21] The updated Guidelines for the Management of Severe TBI from the Brain Trauma Foundation (BTF) state that early transgastric jejunal feeding is recommended to reduce the incidence of ventilator-associated pneumonia[22] as it reduces gastric residual volume. Altered gastric emptying following brain injury could be the explanation. EN can be administered at lower rates to avoid overfeeding and able to support the gut mass and barrier function.[17] EN stimulates gastrointestinal GI post-prandial hyperaemia, enhancing mucosal blood flow, which counterbalances the alterations in GI blood flow due to situations of increased intrathoracic pressure during vasopressor use, leading to an increase gut-associated lymphoid tissue (GALT) expression. Furthermore, EN provides a better quality of macro- and micronutrients such as medium-chain triglycerides and fibre, leading to the production of short-chain fatty acids.[3,9,17] ESPEN recommends the use of continuous rather than bolus EN.[12] In a retrospective cohort study that was carried out in a neurosurgical ICU, continuous feeding was found to be better tolerated than bolus feeding among patients with acute brain injuries.[23] Based on this rationale and the data available, we agree that early EN is the best approach to nutrition therapy in patients with severe TBI.

OPTIMUM CALORIE AND PROTEIN PROVISION

Hypercatabolism is a state involving excessive metabolic breakdown of muscle and adipose tissue, leading to weight loss and wasting as a result of trauma, surgery or sepsis. Following traumatic brain injury, the patient will be in a hypermetabolic and hypercatabolic state. Glycogen stores are quickly depleted during the initial acute phase, resulting in the need for muscle proteins as a source of energy. Significant lean body mass and negative nitrogen balance ensue.[24-26] Non stressed individuals can lose approximately 200-300g of muscles per day while TBI patients can lose up to 1000g. Release of chemical mediators (cortisol, glucagon, catecholamines and cytokines) post trauma causes this high catabolic state and leads to the breakdown of muscle rather than fat for energy.[27] In brain injured patients, a hypermetabolic state causes an increase in energy expenditure of up to 40-200% for a given individual with similar gender, age, height, weight, and activity level. The highest energy expenditures are observed in patients with decerebrate or decorticate activity.[28]

As per ESPEN recommendation, in critically ill mechanically ventilated patients, energy expenditure (EE) should be determined by using indirect calorimetry (IC). The use of IC to measure resting energy expenditure (REE) and its application to achieve nutritional requirements or monitor nutritional support is established.[12,20] Maxwell et. al. postulated that in the absence of IC, patients with severe TBI undergoing enteral nutrition based on the REE estimated with the Harris-Benedict Equation may be at risk of underfeeding, leading to a negative nitrogen balance by Day 7.[29] ASPEN-SCCM and many clinicians recommend that IC is the current "gold standard" to measure energy requirements in patients with TBI. If indirect calorimetry is not available, a published predictive equation or a basic weight-based equation (25-30kcal/kg/d) can be used to determine energy requirements.[20,26] Permissive underfeeding of 50-80% of estimated energy needs may be acceptable for acute TBI in the ICU setting in first 24 to 72 hours. A higher percentage of energy needs in the acute phase has been shown to be detrimental, especially in TBI patients where blood sugar control is important. Beyond 72 hours, achieving full energy needs should be the target. Higher protein intake reaching 1.5 to 2g/kg/day may be considered in this population, since there are large protein losses (20-30g/L).[12] Most TBI patients are not malnourished on admission but may become malnourished during the ICU stay, especially with other injuries. These patients at risk may be missed by the NUTRIC score since a significant loss of muscle mass occurs and is correlated with the length of hospitalisation and three-month function level. Most of the patients are underfed, receiving 58% of the energy requirements and 53% of the protein requirements. After discharge, the nutrition deficit persists.[30]

Several studies in general ICU patients demonstrated that the control of hyperglycaemia using exogenous insulin can lead to significant improvements in outcomes of critically ill patients. On the other hand, the use of intensive insulin therapy with tight glycemic control could have overall deleterious effects for the patients, especially for those with severe TBI.[31,32] Use of intensive insulin therapy in enterally fed patient has substantial risk of hypoglycaemia due to interruptions in normal feeding in conjunction with constant levels of insulin and variations in the rate of food absorption from the gut.[25] The goal for blood glucose level remains controversial in patients with TBI and recommended levels may vary with severity and stage of TBI.[33,34] Generally keeping glucose levels between 6-10mmol/L would be a reasonable approach as in all other critically ill patients.

IMMUNONUTRITION

Following primary insult, as explained earlier, a phase of neuroinflammation, free radical formation, and oxidative stress takes place. Immunonutrition therapy allows the provision of immune modulating nutrients to improve immune responses and modulate inflammatory responses in TBI patients, which helps in promoting brain tissue recovery. These immune enhancing feeding may contain arginine, glutamine, omega-3-fatty acids, nucleotides and antioxidants: copper, selenium, zinc, vitamins B, C and E.[20] Immunonutrition among TBI patients causes a reduction in cytokine, IL-6 serum levels and higher glutathione, which suggests increased antioxidant defence as well as decreased inflammation and modulation of systemic inflammatory response syndrome (SIRS).[19,35] They are also more likely to have higher prealbumin levels, reflecting improved nutritional status during hospitalisation.[15] However, further multicentre randomised controlled trials need to be carried out to determine overall outcomes and clinical benefits for this type of feeding.

NUTRITION MONITORING & PREVENTION OF COMPLICATIONS

To provide an ideal medical nutrition therapy for patients with TBI, the clinician should aim at monitoring and maintaining body mass consumption, preserving adequate brain metabolism and homeostasis, and avoiding complications related to feeding. Clinical conditions such as feeding intolerance, over or underfeeding, hyper or hypoglycaemia, electrolyte imbalance, and ileus are common among TBI patients.[20] Feeding intolerance include high gastric residual volume, abdominal distension, vomiting, diarrhoea or reduced passage of stools. These complications occur because they are comatose, intubated or mechanically ventilated, with malfunctioning parasympathetic and sympathetic system, disturbed hypothalamic-pituitary axis, elevated intracranial pressure, increasing endogenous opioids and endorphins, and widespread prescription of narcotics. All these unfavourable factors may contribute to impaired gastrointestinal function, delayed gastric emptying, and increased risk of feeding intolerance.[9,17] Evaluation of nutrition regime with IC can prevent over or under feeding. In patients with diarrhoea, prokinetic agents should be avoided, consider the addition of soluble fibre supplement into standard feeds or the use of small peptide semi-elemental formula. In patients with abdominal distension, gastric paresis or high gastric residual volume not solved with prokinetic agents, post pyloric feeding should be used.[12,20] Enteral naloxone and intravenous neostigmine have been shown to be successful in treating paralytic ileus especially if opioid induced. Electrolytes (potassium, magnesium, phosphate) should be monitored at least once daily for the first week. In patients with refeeding syndrome, electrolytes should be measured 2-3 times a day and supplemented if needed.[12]

CONCLUSION

In the critical care setting, feeding should be initiated as soon as possible once patient is hemodynamically stable with a functional gastrointestinal tract. Enteral nutrition is recommended over parenteral nutrition whenever feasible. Calorie requirement should be individualised based on patient's demographic, comorbidities, severity of trauma and phase of illness. TBI related educational efforts should be aimed at both health care providers and patients/families for a better outcome.

References

1. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M, et al. Estimating the global incidence of traumatic brain injury. J Neurosurg. 2018 Apr 1:1-18
2. Rusnak M. Traumatic brain injury: giving voice to a silent epidemic. *Nature Reviews Neurology* 2013;**9**:186-187
3. Bistrian BR, Askew W, Erdman JW Jr, et al. Nutrition and traumatic brain injury: a perspective from the Institute of Medicine report. *JPEN J. Parenter Enteral. Nutr* 2011;**35**:556-559
4. Wu A, Molteni R, Ying Z, Gomez-Pinilla F. A saturated-fat diet aggravates the outcome of traumatic brain injury on hippocampal plasticity and cognitive function by reducing brain-derived neurotrophic factor. *Neuroscience* 2003;**119**:365-375
5. Cobley JN, Fiorello ML, Bailey DM. 13 reasons why the brain is susceptible to oxidative stress. *Redox Biol* 2018;**15**:490-503
6. Matsuzawa-Nagata N, Takamura T, Ando H, Nakamura S, Kurita S, Misu H, et al. Increased oxidative stress precedes the onset of high-fat diet-induced insulin resistance and obesity. *Metabolism* 2008;**57**:1071-1077
7. Dalvi PS, Chalmers JA, Luo V, Han DYD, Wellhauser L, Liu Y, et al. High fat induces acute and chronic inflammation in the hypothalamus: Effect of high-fat diet, palmitate and TNF- on appetite-regulating NPY neurons. *Int. J. Obes* 2017;**41**:149-158
8. Tapias V, Hu X, Luk KC, Sanders LH, Lee VM, Timothy Greenamyre J. Synthetic alpha-synuclein fibrils cause mitochondrial impairment and selective dopamine neurodegeneration in part via iNOS-mediated nitric oxide production. *Cell. Mol. Life Sci* 2017;**74**:2851-2874
9. Cook AM, Peppard A, Magnuson B. Nutrition Considerations in Traumatic Brain Injury. *Nutr Clin Pract* 2008;**23**:608-620
10. Gouick J, Gentleman D. The emotional and behavioural consequences of traumatic brain injury. *Trauma* 2004;**6**(4):285-292
11. Chapple LAS, Deane AM, Heyland DK, et al. Energy and protein deficits throughout hospitalization in patients admitted with traumatic brain injury. *Clin Nut* 2016;**35**:13
12. Singer P, Blaser AR, Berger MM, et al. ESPEN guideline on clinical nutrition in the intensive care unit. *Clin Nutr* 2019;**38**:48-79

13. Hartl R, Gerber LM, Ni Q, Ghajar J. Effect of early nutrition on deaths due to severe traumatic brain injury. *J Neurosurg* Jul 2008;**109**(1):50-56. PMID: 18590432

14. Chourdakis M, Kraus MM, Tzellos T, et al. Effect of early compared with delayed enteral nutrition on endocrine function in patients with traumatic brain injury: an open-labeled randomized trial. *J Parenter Enteral Nutr* 2012;**36**(1):108-116. PMID: 21965459

15. Painter TJ, Rickerds J, and Alban RF. Immune enhancing nutrition in traumatic brain injury - A preliminary study. *Int. J. Surg* 2015;**21**:70-74

16. Lepelletier D, Roquilly A, Demeure dit latte D, et al. Retrospective analysis of the risk factors and pathogens associated with early-onset ventilator-associated pneumonia in surgical-ICU head-trauma patients. *J Neurosurg Anesthesiol* Jan 2010;**22**(1):32-37. PMID: 20027012

17. Wang X, Dong Y, Han X, Qi XQ, Huang CG, Hou LJ. Nutritional support for patients sustaining traumatic brain injury: a systematic review and meta-analysis of prospective studies. PLoS One. 2013;8(3). PMID: 23527035

18. Dhandapani S, Dhandapani M, Agarwal M, et al. The prognostic significance of the timing of total enteral feeding in traumatic brain injury. *Surg Neurol Int* 2012;**3**:31

19. Chiang YH, Chao DP, Chu SF, et al. Early enteral nutrition and clinical outcomes of severe traumatic brain injury patients in acute stage: a multi-center cohort study. *Journal of Neurotrauma* 2012 Jan;**29**(1):75-80. PMID: 21534720

20. Kurtz P and Rocha EEM. Nutrition Therapy, Glucose Control, and Brain Metabolism in Traumatic Brain Injury: A Multimodal Monitoring Approach. *Front. Neurosci* 2020;**14**:190

21. Ashok Mahapatra. "Role of Nutrition in Head Injury Patient". Acta Scientific Nutritional Health 3.9 (2019):111-114

22. Carney N, Totten AM, O'Reilly C, Ullman JS, Hawryluk GW, Bell MJ, et al. Guidelines for the management of severe traumatic brain injury. *Neurosurgery* 2017;**80**(4):6-15

23. Rhoney DH, Parker Jr D, Formea CM, Yap C, Coplin WM. Tolerability of bolus versus continuous gastric feeding in brain-injured patients. *Neurol Res* 2002;**24**:613-20

24. Berg ABM, Bellander M, Wanecek L, Gamrin A, Elving O, Rooyackers U, et al. Intravenous glutamine supplementation to head trauma patients leaves cerebral glutamate concentration unaffected. *Intensive Care Medicine* 2006;**32**(11):1741-1746

25. Erdman J, Oria M, Pillsbury L. Nutrition and Traumatic Brain Injury: Improving Acute and Subacute Health Outcomes in Military Personnel. Institute of Medicine (US) Committee on Nutrition, Trauma, and the Brain. Washington (DC), National Academies Press (US), 2011. PMID: 24983072

26. McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, et al. Society of Critical Care Medicine; American Society for Parenteral and Enteral Nutrition. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). *JPEN J Parenter Enteral Nutr* 2016;**40**:159-211

27. Loan T. Metabolic/nutritional alterations of traumatic brain injury. *Nutrition* 1999;**15**(10):809-812

28. Young B, Ott L, Yingling B, McClain CJ. Nutrition and brain injury. *J Neurotrauma* 1992;**9**(suppl 1): S375

29. Maxwell J, Gwardschaladse C, Lombardo G, Petrone P, Policastro A, Karev D, et al. The impact of measurement of respiratory quotient by indirect calorimetry on the achievement of nitrogen balance in patients with severe traumatic brain injury. *Eur J Trauma Emerg Surg* 2017 Dec;**43**(6):775-782. PMID: 27658944

30. Chapple LAS, Deane AM, Williams LT, Strickland R, Schultz C, Lange K, et al. Longitudinal changes in anthropometrics and impact on self-reported physical function after traumatic brain injury.Critical Care and Resuscitation.2017;19(1)

31. Investigators NSS, Finfer S, Chittock DR, Su SY, Blair D, Foster D, et al. Intensive versus conventional glucose control in critically ill patients. *N. Engl. J. Med* 2009;**360**:1283-1297

32. Investigator NSS, Finfer S, Chittock DR, Li Y, Foster D, et al. Intensive versus conventional glucose control in critically ill patients with traumatic brain injury: long-term follow-up of a subgroup of patients from the NICE-SUGAR study. *Intensive Care Med* 2015;**41**:1037-1047

33. Bilotta F, Rosa G. Glycemia management in critical care patients. *World J Diabetes* 2012 Jul 15;**3**(7):130-4. PMID: 22816025

34. Meier R, Béchir M, Ludwig S, Sommerfeld J, Keel M, Steiger P, et al. Differential temporal profile of lowered blood glucose levels (3.5 to 6.5 mmol/l versus 5 to 8 mmol/l) in patients with severe traumatic brain injury. *Critical Care* 2008;**12**:R98

35. Rai VRH, Phang LF, Sia SF, et al. Effects of immunonutrition on biomarkers in traumatic brain injury patients in Malaysia: a prospective randomized controlled trial. *BMC Anesthesiol* 2017;**17**(1):81