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Abdominal Trauma

New Solutions to Old Problems

Edited by Dmitry Victorovich Garbuzenko

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Published in London, United Kingdom

Abdominal Trauma - New Solutions to Old Problems
http://dx.doi.org/10.5772/intechopen.100982
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First published in London, United Kingdom, 2023 by IntechOpen
IntechOpen is the global imprint of INTECHOPEN LIMITED, registered in England and Wales, registration number: 11086078, 5 Princes Gate Court, London, SW7 2QJ, United Kingdom

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

Additional hard and PDF copies can be obtained from orders@intechopen.com

Abdominal Trauma - New Solutions to Old Problems
Edited by Dmitry Victorovich Garbuzenko
p. cm.
Print ISBN 978-1-80355-810-3
Online ISBN 978-1-80355-811-0
eBook (PDF) ISBN 978-1-80355-812-7

Meet the editor

Dmitry Victorovich Garbuzenko graduated from Chelyabinsk State Medical Institute in 1985. From 1985 to 1987, he was a clinical intern. From 1987 to 1990, he was a post-graduate student at the Department of Hospital Surgery, Chelyabinsk State Medical Academy, Russia. After obtaining his Ph.D. in 1991, Dr. Garbuzenko served as an assistant professor at the same institution until 1996. Since 1996, he has been an assistant professor, associate professor (2003), and full professor (2006) in the Department of Faculty Surgery, South Ural State Medical University, Russia. He obtained his DMedSc in 2008. Dr. Garbuzenko is a member of the Russian Society of Surgeons. His practical activities involve emergency abdominal surgery. He is the author of nearly 200 publications.

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Preface

Diagnosing and treating abdominal trauma is dangerous and complex. Injury to the abdomen can be isolated or combined with other types of trauma. It can cause damage to internal organs accompanied by life-threatening bleeding, the development of peritonitis, purulent-septic complications, and loss of functions of organs and systems. Abdominal trauma accounts for 5% of all injuries and ranks third among the most common traumas in emergency medicine, after acute appendicitis and acute cholecystitis. Among peacetime injuries, that is, injuries sustained outside of military operations, isolated abdominal trauma accounts for 15%–20% of injuries; however, abdominal trauma is more often combined with injuries to other anatomical areas. The frequency of diagnostic errors in combined injuries ranges from 7% to 25%. The frequency of unjustified laparotomies in closed abdominal trauma ranges from 28% to 46%. The frequency of intestinal damage occurring with a closed abdominal trauma ranges from 6.3% to 38.5%; the mortality rate in these cases is 12%–15%. With ruptures of the mesentery of the intestine and the intestinal wall with peritonitis, the mortality rate is 19%–24%. The frequency of intestinal damage in gunshot wounds of the abdomen is 37.2%–84.3%. In 66%–82% of cases, several organs are damaged simultaneously. The liver is second only to the intestines in terms of the frequency of damage caused by abdominal trauma. The mortality rate in patients with a closed abdominal trauma is 21.7%–68%. Those who die from liver injuries account for 15%–20% of all those who die from injuries. Many victims die at the scene or during transportation. About 15.2%–23.4% of the victims die shortly after hospitalization due to the extreme severity of the condition and the complexity of diagnosis against the background of an intra-abdominal catastrophe. The frequency of gunshot wounds to the liver with penetrating abdominal wounds is 25.3%–73.3%. The mortality rate for stab wounds of the liver is 9.2%–35.3%. The spleen is one of the most life-threatening injured organs in abdominal trauma because of its high vascularity and vulnerable anatomical location. Spleen injury occurs in 16%–50% of closed abdominal trauma cases. Pancreatic injuries are observed in 1%–22% of closed abdominal trauma and penetrating abdominal wound cases. They are characterized by a severe course with the development of post-traumatic pancreatitis. The frequency of pancreatic injury with abdominal trauma is as high as 87.7%, the rate of complications can reach 77%, and the mortality rate is 10%–72%. Pancreatic injury is often combined with damage to the liver, stomach, spleen, intestines, and large vessels. The clinical picture depends on the localization of injuries, their severity, and developing complications. Characteristic features of modern abdominal trauma are the multiplicity and severity of injuries accompanied by gross violations of homeostasis and disorders of vital functions of the body. This circumstance requires urgent actions, the primary goals of which are to restore the functions of the body and determine the indications for emergency surgery. It should be noted that in the last decade there have been many reports about the use of minimally invasive technologies in the diagnosis and treatment of abdominal trauma. To improve the outcomes of the most severe polytrauma, the “damage control” principle

was proposed. “Damage control” surgery is a series of operations performed to accomplish definitive repair of abdominal injuries in accordance with the patient’s physiologic tolerance. Trauma surgeons focus more on the physiological reserve of the patient rather than the anatomy of the lesions. Surgical techniques are focused on hemorrhage and contamination control to stop bleeding and control intestinal, biliary, or urinary leakage into the abdominal cavity. Literature data confirm the effectiveness of this method, demonstrating a reduction in mortality and immediate postoperative complications.

Written by an international team of highly qualified specialists, this book will be of interest to anyone who has engaged in emergency abdominal surgery.

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Chapter 1

Introductory Chapter: Abdominal Trauma – An Update

Dmitry Victorovich Garbuzenko

1. Introduction

"The first doctor invited to the victim should remember that he has three tasks: (1) take measures against shock; (2) recognize damage to the internal dense organ—the cause of internal bleeding; and (3) recognize damage to the hollow organ—the cause of hyperacute peritonitis. He should also know that all injuries, without any exception, are subject to the competence of the surgeon and require extreme urgency. Whether it is a perforation of the intestine and infection of the peritoneum, or a rupture of a dense internal organ and bleeding—it doesn't matter, in either case, the victim is in mortal danger and the minutes are counted" [1].

Closed injuries and abdominal wounds have always been a difficult surgical problem. The presence of many vital organs in the abdominal cavity, the specifics of their anatomical structure, vascular architectonics and innervation, the immediate proximity of intestinal contents rich in pathogenic flora, the presence of organs producing extremely active enzymes—all this leads to massive internal bleeding, rapid development of peritonitis, and the occurrence of irreversible changes in organs and tissues.

As with no other injury, abdominal trauma requires accurate and rapid diagnosis, thoughtful and adequate surgical tactics, and the ability to predict the dynamics of the development of pathological changes occurring in parenchymal organs and the gastrointestinal tract [2].

As a rule, abdominal trauma differ in the severity of the general condition, internal bleeding, the development of shock, the distinct dependence of treatment outcomes on the timing of surgery, the complexity, complexity of the operation, and the need for particularly careful management of the patient in the postoperative period. Even in peacetime, they are accompanied by a significant frequency of complications and adverse outcomes.

Abdominal trauma account for up to 1/3 of peacetime injuries, and their frequency and severity, despite the downward trend, remain high. The main part of the victims is men of working age, which makes the problem particularly relevant [3].

Over the past 20 years, serious changes have taken place in the structure of abdominal trauma due to the steady increase in the number of road accidents, falls from heights, man-made disasters, natural disasters, and local military conflicts. The characteristic features of modern abdominal trauma are the multiplicity and severity of injuries accompanied by gross violations of homeostasis and disorders of vital functions of the body, which causes a high, nondecreasing mortality rate—6.1–26% and a high frequency of postoperative complications—10–27% [4].

Meanwhile, most of the victims with abdominal trauma are hospitalized in general surgical departments, whose doctors do not always have sufficient experience in providing care to such patients. The outcomes are negatively affected by errors in diagnosis and treatment, most of which are allowed due to the lack of uniform tactical settings on the nodal issues of the problem.

Despite the availability of a wide range of classical and modern diagnostic, resuscitation and anesthesiological aids, many issues of surgical tactics in abdominal trauma still remain unresolved to the end. The unfavorable factors should also include unjustified highly traumatic surgical interventions carried out due to diagnostic errors made in determining the leading damage in victims with combined trauma [5].

The proportion of unjustified laparotomies in a wide range of surgical approaches for abdominal trauma remains unreasonably high today. Until recently, with an abdominal wounds, as well as when it was impossible to exclude damage to the abdominal organs with a closed abdominal injury, a wide laparotomy was an unshakable axiom. However, in the last decade there have been many reports about the use of minimally invasive technologies in the diagnosis and treatment of abdominal trauma [6].

Thus, the arguments given indicate that the problem of modern diagnostic and therapeutic approaches to abdominal trauma is very relevant and requires detailed coverage.

2. Diagnostic algorithm for abdominal trauma

Blunt abdominal trauma requires a thoughtful diagnostic approach and interpretation of the results taking into account the overall condition of the patient. Laboratory tests, such as blood gas analysis, determination of pH, base excess/deficit, hemoglobin and hematocrit levels, and INR, are mandatory for diagnosis as allow to quickly assess the physiological condition of the patient. All patients with blunt abdominal trauma should undergo an urgent focused assessment with sonography for trauma (FAST), since this method is simple and commonly, and since 1999 has been used for evaluating not only the abdomen but also the cardiac and thoracic regions. It should be borne in mind that FAST has limitations in the detection of bowel and mesenteric injuries [7].

The gold standard for the diagnosis of blunt abdominal trauma is multi-slice computed tomography (MSCT). Hemodynamically stable patients with abdominal pain and direct or indirect signs of abdominal trauma with MSCT should undergo diagnostic laparoscopy. All patients with blunt abdominal trauma, including those with negative MSCT data, should be admitted for dynamic observation and, if necessary, re-examination for at least 24 hours, since negative MSCT data cannot reliably rule out intra-abdominal injuries. In case of persistent pain or clinical signs of peritonitis, unclear or abnormal findings in FAST and/or MSCT, the next step is diagnostic laparoscopy, which should be performed within the first 24–36 h after trauma [8].

3. General principles of management of abdominal trauma

The main task that a physician solves when helping a patient with abdominal trauma is to determine the indications for surgery, the timing of its implementation,

and the possibilities of conservative therapy. There is a difference in determining indications for surgical treatment in patients with open (wounds) and blunt abdominal trauma.

Most patients with abdominal wounds, both penetrating and non-penetrating, are subject to surgical treatment. Surgical treatment should be understood as the debridement, and in the case of the penetrating wound—the performance of median diagnostic laparotomy. If there are obvious signs of penetrating abdominal wounds, the operation immediately begins with a median laparotomy. Signs of intra-abdominal bleeding or peritonitis in patients with an abdominal wall wounds are also an indication for urgent laparotomy. In all other cases, the debridement is performed, the task of which is not only the removal of nonviable tissues, hemostasis and suturing, but also the final determination of the nature of the wound: whether it is penetrating or not. The presence of a peritoneal defect is an indication for median laparotomy. It should also be remembered that with abdominal wounds, any doubt is resolved in favor of surgery.

It should be noted that in recent years, there have been reports of nonsurgical treatment of patients with penetrating abdominal wounds.

With a blunt abdominal trauma, tactics are more differentiated. The presence of obvious signs of intra-abdominal bleeding, as well as peritonitis, serves as an absolute indication for immediate surgery, regardless of the severity of the condition and hemodynamic parameters. Conservative treatment is subject to patients with abdominal wall bruises, with intra-organ hematomas of parenchymal organs that do not tend to increase, with small and stable subcapsular hematomas. The complex of conservative measures for blunt abdominal trauma includes the creation of rest, the appointment of respiratory analeptics, and therapy aimed at the prevention and treatment of organ failure. Of great importance is the replenishment of blood loss, anti-shock measures, the introduction of hemostatic agents, and cardiotropic drugs.

4. Conclusions

For a physician who is faced with a patient with an abdominal trauma, the hemodynamic status and the mechanism of injury are keys to choosing appropriate diagnostic approach and management. Most hemodynamically, unstable patients require immediate laparotomy, but in hemodynamically stable patients, two important issues need to be clarified: (1) Is there an intra-abdominal injury? and (2) If there is an intra-abdominal injury, which organ is involved and how serious is its damage? The answers to them can help make the right decision [9].

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Chapter 2

Complications and Avoidance of the Complications Associated with Management of Abdominal Trauma

Janvier Nzayikorera

Abstract

Despite decades of dramatic advance in treatment and prevention of trauma, globally trauma continues to be a major public health problem. More than 5 million individuals perish every year as a consequence of injuries. This is responsible for about 9% of the world's deaths, approximately 1.7 times the number of mortalities that result from HIV/AIDS, tuberculosis and malaria combined. Abdominal trauma continues to be the leading cause of mortality and morbidity in all age groups. A comprehensive management of traumatic abdominal patient with various approaches is of proven value in terms of mitigating the burden associated with abdominal trauma. However, all available approaches used to manage traumatic abdominal patient are potentially associated with development of various complications. Practical to mitigate these complications, various measures should be considered all the time while managing any traumatic abdominal patient. The goal of this chapter is to describe systematic approaches for avoiding the complications associated with management of abdominal trauma. Moreover, it describes the common and some rare complications associated with the management of traumatic abdominal patient.

Keywords: abdomen, abdominal trauma, penetrating abdominal trauma, blunt abdominal trauma, traumatic abdominal patient, management of abdominal trauma

1. Introduction

Etymologically the term complication originates from (Latin complicationem, past participle; complicare which means to fold together). Various experts of surgery have defined the term complication. Some authors have defined complication as an occurrence which is avoidable. Moreover, other authors have devised criteria of complication in surgical practice; in certain book of neurosurgery complication has been regarded as an occurrence which fulfills three criteria namely, unwanted, unplanned and does not commonly occur. Management of abdominal trauma is complex and remains a problematic in surgical practice due to notable occurrence of numerous complications [1]. Failure to recognize and treat these complications earlier increases the mortality and morbidity. Planning and uniting more efforts to predict and prevent the occurrence of complications associated with management of traumatic abdominal

patient is fundamentally essential. The main goal of this chapter is to describe systematic approaches for avoiding the complications associated with management of traumatic abdominal patient. Risk factors leading to the occurrence of complications, commonly occurring complications and some rare complications but with higher potential to cause mortality and morbidity are also described. The contents of this chapter are arranged as follows:

1. Introduction
2. General consideration
3. Risk factors leading to the occurrence of complications associated with the management of abdominal trauma
4. Complications associated with non-operative management of traumatic abdominal patient
5. Complications associated with operative management of traumatic abdominal patient
6. Systematic approaches for avoiding the complications associated with the management of abdominal trauma
7. Discussion
8. Conclusion
9. Future prospectus

2. General consideration

The mortality and morbidity associated with abdominal trauma can be attributed to the disturbance of anatomical and functional integrity of abdominal structures. Based on understanding the anatomy and physiological processes performed by abdominal organs, it is possible to plan and enhance measures designed to avoid the occurrence of the complications associated with the management of abdominal trauma. To achieve such tasks more efforts should be directed to avoiding all possible risk factors leading to the occurrence of abdominal trauma, try as much as possible to avoid the removal of any injured abdominal organ, and ensure as quick as possible to restore functions of any injured abdominal organ.

2.1 Anatomical and functional consideration of abdominal organs

Knowledge of anatomy and physiological processes of abdominal organs is paramount for understanding and avoiding complications which occur secondary to abdominal trauma and those associated with chosen management approach. Abdomen is flexible and dynamic part of the body which lies between diaphragm and pelvis. Abdominal cavity houses all structures that involve in gastrointestinal and genitourinary system. Some abdominal structures are intra-peritoneal while others are

Divisions	Components/abdominal organs		
Abdominal wall	A) Boundaries of abdominal wall		
	Superior: Xiphoid, Costal arch, X II rib	***Inferior:*** Pubis symphisis, inguinal groove, Iliac crest	***Lateral:*** Posterior axillary line
	B) Layers of anterolateral abdominal wall		
	• Skin • Subcutaneous tissues • Superficial fatty layer- camper's fascia • Deep membranous layer-Scarpa's fascia • Muscles (external oblique abdominal muscle, internal oblique abdominal muscle and transverse abdominal muscle)		• Transversalis fascia • Extraperitoneal fat • Parietal peritoneum
Intraperitoneal Organs	• Liver • Spleen • Stomach		• Small bowel • Transverse colon • Mesentery
Extraperitoneal organs	Solid and hollow organs	Genito-urinary tract	Blood vesells
	• Pancreas (except tail) • Suprarenal glands • Duodenum • Ascending and descending colon • Esophagus • Rectum	• Kidneys • Ureters • Bladder • Urethra	• Abdominal aorta • Inferior vena cava

Table 1.
Components of abdominal wall and classification of abdominal organs which can assist to make diagnosis.

retroperitoneal. Shown in **Table 1** are the components of abdominal wall and the classification of abdominal organs. The fact that, abdominal organs have minimal bony protection they are frequently injured during trauma event [2]. Like any other injuries following abdominal trauma two responses happen namely: (1) biological adaptation to condition of external stress (injury and starvation), and (2) maintenance of internal constancy. These responses are useful for increasing the chance of survival for traumatic abdominal victim. However, in certain instances these responses can be dangerous; for instance if they occur in uncontrolled manners, in excessive and for prolonged time and when there is removal or failure multiple organs. The primary function of abdominal organs is to maintain homeostatic process. Thus, while managing traumatic abdominal patient, it is crucial to restore the functions of abdominal organs as quick as possible and as well as to avoid the removal of any abdominal organ as much as possible.

2.1.1 Liver

Liver is a solid and the largest organ of the body, located in the right upper quadrant of the abdomen under the right lower rib cage against the diaphragm [3]. It receives dual blood via: (1) hepatic arteries which deliver about 20% blood oxygen rich, and (2) portal vein which carries about 80% blood nutrient rich from stomach, intestine, pancreas and spleen via portal vein. Moreover, at rest liver receives about 25% of cardiac output and has the capacity to reserve about 450 ml of blood in healthy person and up to 1 liter for congestive heart failure patient. Liver is the most commonly injured organ during trauma due to its big size and because of its high vascularity, hemorrhage is the most frequent complication to associate with liver injury.

Liver serves as a hub of metabolic processes of which life depends. Eight main metabolic processes taking place in the liver are: (1) bile formation and excretion, (2) carbohydrate metabolism, (3) protein metabolism, (4) fat metabolism, (5) blood coagulation, (6) vitamin metabolism, (7) detoxification and (8) phagocytosis and immunity. It is very unlikely for human being to survive without liver. One of the events which can lead to the loss of liver is severe injury of which hepatectomy would be warranted. In such case liver transplant would be only possible solution. However, liver transplant is too expensive, not available as an emergency treatment and it is associated with other numerous complications. Evidence has shown that liver cells have the capacity to regenerate. This regeneration is mainly achieved with the support of portal blood; because portal blood contains hepatotrophic portal blood factor (HPBF) which supports hepatic cells to regenerate [4]. Given this evidence it is very crucial for the physician to ensure enough portal blood supply to any injured liver. No hepatectomy should be done at all unless there is immediate liver transplant.

2.1.2 Spleen

Spleen is situated in the left upper quadrant of the abdomen. Spleen is encircled superiorly and laterally by diaphragm and left lower rib cage, inferiorly by the colon, medially by stomach and posteriorly by the kidney. Spleen is highly vascularized organ. Spleen also receives dual blood supply via splenic artery and short gastric artery, and it receives about 5% of cardiac output. Though, it seems that, the spleen is protected by ribs and muscular parieties, the spleen is commonly injured during abdominal trauma because, it is friable, and it has suspended ligaments that are attached to an adherent capsule. Thus, even relatively minor trauma can lead to avulsion of splenic substances or tearing of the blood vessels that are present within its suspensory ligaments which result into abundant bleeding.

Spleen has a number of functions in the body including: (1) filtering blood elements and foreign material, (2) production of lymphocytes and antibodies. Human being can survive without spleen indicating that functions that are carried out by the spleen can be performed by other organs elsewhere in the boy. However, it has been confirmed that, loss of spleen is associated with overwhelming infectious complications caused by encapsulated bacteria (e.g., *Haemophilus influenzae*, *Streptococcus pneumoniae*, *and Neisseria meningitidis*) [5]. The recognition of high rates of infections after spleenectomy led to the shift of paradigm of management of splenic injury from mandatory operative to selective conservative management, and then to non-operative management and splenic artery embolization, etc. Studies have shown that more than 60% of splenic injury can be managed with non-operative approach.

2.1.3 Pancreas

Pancreas is not commonly injured during abdominal trauma [6]. However, greater considerations should be taken while managing any abdominal trauma involving the pancreas because of its intimate relationship with vital vascular structures. While in its transverse course, pancreas passes immediately anterior to inferior vena cava, the aorta, superior mesenteric artery and vein. It also lies anterior or slightly to the splenic artery and vein. The common serious danger for both penetrating and blunt injury to the pancreas is the risk of injury to these great vessels. The pancreas may obscure the site of bleeding and as such extensive mobilization or transection of the pancreas may be required in order to control the bleeding vessel. Early mortality related to

pancreatic injury is due to massive hemorrhage whereas late mortality can result from the consequence of infections and multiple organ failure. Moreover, the neglected pancreatic injury may result into complications such as: pseudocysts, fistulas, sepsis and secondary hemorrhage [6].

2.1.4 Gastrointestinal tract (GIT)

The components of gastrointestinal tract (GIT) to consider with regard to abdominal trauma include stomach, small intestine and large intestine. GIT assists in digestion, absorption, assimilation of nutrients, and secretion and excretion of waste products. Absorptive and propulsive actions of GIT are reduced after trauma anywhere in the body. There is profound and prolonged reduction of GIT actions when peritoneal cavity is involved. The disturbed GIT actions leads to the accumulation of fluid within the abdominal cavity causing increased intra-abdominal pressure, abdominal distention and increased risks of aspiration as one of the complications. Moreover, fluid accumulation into the GIT and possibly bleeding causes the reduction of cardiac output. Following this instance the body compensates by transferring adequate blood to vital organs (brain and heart), leaving other organs such as GIT, skin etc. This compensation takes place because brain and heart are vital organs with high metabolic rates and their capacity to store substrates for energy production is very low, as such they need adequate constant blood supply. Reduction of blood supply to GIT causes the development of ischemia which is a common complication to associate with abdominal trauma.

2.1.5 Other abdominal organs

An appreciation of anatomy and functional physiology of other abdominal organs such as kidneys and bladder, blood vessels, nerves, uterus and ovaries (in female) is also important. These organs have substantial functions in various physiological processes including regulation of homeostasis. During abdominal trauma these organs can also be damaged and some of them are hard to treat. Readers are advised to revise anatomy and physiology of these organs.

2.2 Approach to the patient with abdominal trauma

2.2.1 General consideration and primary survey

The patient with abdominal trauma can present with multiple injuries with higher likelihood to compromise functions of vital organs. As such, all traumatic abdominal patients should be managed holistically. Management of traumatic abdominal patient is complex, challenging and typically encompasses all possible interventions to offer to the patient during the course of management. In approaching traumatic abdominal patient the clinician should be prepared to provide various interventions at any of the three phases of trauma care, namely: (1) primary phase that encompasses initial assessment and provision of certain actions to correct any impairment of airway, breathing and circulation, disability and exposure, (2) secondary phase which progresses with resuscitation and full assessment of the patient), and (3) tertiary phase which involves the provision of definitive treatment to specific injuries.

Death is certainly a powerful dependent variable but unwanted one, which is ever seen in all kinds of trauma. All kinds of trauma have the potential to cause death to the

victim either directly or by any complications that occur in the trajectory of management. Ideally, in order to avoid such death, the basic principles of advanced and trauma life support (ATLS) protocols are the forefront interventions to offer to any trauma patient and should be started at the scene. The core components of ATLS protocol, namely: (1) Airway management, (2) Breathing, (3) Circulation, (4) Disability or Damage, and (5) Environment/Exposure (ABCDE) are of the first priority [5] in order to secure the functions of vital organs.

2.2.1.1 Airway

The most common cause of death for traumatic patient is asphyxia. To avoid this tragedy to happen an immediate goal of management should be to clear and keep the airway open to ensure adequate ventilation. Shown in **Table 2** are the strategies used for recognizing the compromised airway and actions to do as early as possible to ensure adequate ventilation.

Assessment	**Important actions to be done as early as possible in order to ensure adequate ventilation**
1. Call the patient; if able to reply appropriately indicates that, airway is patently open. 2. Look in the mouth to ascertain the presence of blood, vomits or broken teeth that may obstruct airway or be aspirated. 3. Perform a quick brief respiratory physical examination: • Listen properly to the nature of breathing; the positive noisy breathing indicate upper airway obstructions • Auscultate for the breath sounds • Check for the presence of: (1) asymmetric chest wall movement, and (2) open wounds or flail segments	1. Take away the secretions from the airway with suction. 2. Perform chin lift and jaw thrust if there is no evidence of neck injury and position the patient properly, conscious patient should be kept in sit up posture in order to support drainage of secretion by gravity and reduce the risks of aspiration. 3. Insert oral-pharyngeal airway. Remember that unconscious patients are at high risks of airway obstruction and aspiration due to: • Loss of tone for the muscles of pharynx, jaw and tongue leads to fallback of the tongue when the patient is kept in supine position causing airway obstruction. • These patients also have depressed laryngeal reflexes and do not cough out or swallow. As such secretions worsen their obstructed airway and increase the risks of aspiration. • Airway of any traumatic unconscious patient should be secured meticulously; inserting oral airway, putting the patient in coma position and be frequently turned would suffice the control of their airway. 4. Intubating the patient should be done: • If airway is not clear • If there is bleeding into the pharynx • When the patient has aspirated 5. Execute tracheostomy in case upper airway is injured and when intubation is impossible. 6. Execute cricothyroid stab if there is no time for tracheostomy.

Table 2.
Recognition of the compromised airway and the important actions to do as early as possible to ensure adequate ventilation.

2.2.1.2 Breathing

Impaired breathing is a common cause of respiratory failure, perhaps the common cause of death among traumatic patients. Quick recognition and correction of impaired breathing is crucial. Shown in **Table 3** are the potential findings indicating impaired breathing and actions to perform in order to correct impaired breathing.

Findings of compromised breathing	Important actions to correct impaired breathing
• Cyanosis • Tachycardia • Unsatisfactory breathing • Poor respiratory pattern • Paradoxical movement	• Oxygen therapy to maintain oxygen saturation between 94 and 98% • Intubation • Ventilation

Table 3.
Potential findings indicating impaired breathing and actions to perform to correct the impaired breathing.

2.2.1.3 Circulation

Shock secondary to trauma is largely caused by bleeding and perhaps the common cause of circulatory failure and a leading cause of deaths among traumatic patients. The dangerous effect of shock is that all body organs are affected. The hypovolemic shock secondary to bleeding affects all body organs regardless the location of the bleeding. Lack of the capacity to maintain systolic blood pressure at ≥90 mmHg after trauma provokes hypovolemia which is associated with mortality of about 50%. The direct goal of management is to prevent further blood loss and determine the degree of circulatory derangement. Directly identify the site of bleeding, feel central (carotid) and peripheral (radial pulses) and start resuscitative interventions. Shown in **Table 4** are signs of shock and prompt stepwise interventions to execute in order to correct hypovolemic shock in primary phase of trauma management. Despite the control of bleeding, the patient may continue to manifest signs and symptoms of shock as consequences of loss of plasma

Signs of hypovolemic shock	Stepwise interventions to treat hypovolemic shock
Mild hypovolemic (<20% blood volume) • Cold and clammy on the face and hands • Droplets of sweat on the face and hands • Restlessness, anxiety and confusion, • Increased capillary refill time Moderate hypovolemic (20–40%blood volume) Above signs plus: • Tachycardia • Tachypnea • Postural changes • Oliguria Severe hypovolemic (>40% blood volume) Above signs plus: • Hypotension • Marked Tachycardia • Hemodynamic instability • Loss of consciousness	• Begin resuscitation with a goal of rapid re-expansion of the circulating intravascular blood volume along with other actions to stop ongoing bleeding. • Insert two largest bore intravenous cannulas (preferably 14 gauge in adult) • Start volume resuscitation with isotonic saline (take a care to avoid hyperchloremia) or balance salt solution such as ringer's lactate (take a care to avoid hyperkalemia) • Classically infusion of 2–3 L of salt solution should restore normal volume in about 20–30 minutes. Failure of these interventions suggests that shock has not been reversed or persistent blood loss. • Evidence of persistent blood loss and declining hemoglobin ≤10 g/dL implies initiation of blood products. Do blood grouping and cross matching. • Coagulopathy due to deficient of clotting factors is a common clinical state for the patient resuscitated with crystalloid or banked packed red blood cells. Evidence has shown that early administration of component therapy during massive transfusion (fresh frozen plasma and platelets) appears to improve survival. • For severe or prolonged hypovolemia, after restoration of blood volume inotropic support with epinephrine, vasopressin or dopamine may be vital to maintain ventricular performance. • Insert urinary catheter to monitor response of resuscitation.

Table 4.
Signs of shock to look for and prompt interventions for correcting hypovolemic shock during the primary phase of trauma management.

volume into the interstium, and this effect is compounded by injury induced inflammatory responses. The physician should put this into consideration and give maintenance fluids to the patient after resuscitation phase.

2.2.2 History and physical examination

Ascertaining the type of abdominal trauma that has occurred is essential in terms of choosing diagnostic approach, selecting appropriate therapy, and providing potential vital information regarding the prognosis; this task is achieved in secondary survey. Typically, two types of abdominal trauma, namely: blunt and penetrating abdominal injuries have been recognized. In secondary survey assessment, the mechanism of injury, time and place of injury, whether the patient had consumed some substances (e.g. alcohol) and other clinical manifestations implying abdominal organ injuries should be elicited. Clinical presentations of traumatic abdominal patient are diverse and depend on the type of abdominal injury sustained.

2.2.2.1 Clinical presentation for penetrating abdominal injury

Patient with penetrating abdominal injury can present with stab or gunshot wounds. Gunshot wounds are much more difficult injuries to treat. The type of gun used should be determined. The severity associated with gunshot wounds depends on the kinetic energy of the bullet used.

$$\mathrm{MV} = {}^{\mathrm{MV}^2}\!/_{2\mathrm{g}}, \tag{1}$$

where KE = kinetic energy, M = mass of the bullet, V = velocity of the bullet, g = gravitational acceleration. As it can be seen KE is directly proportional to mass and squared velocity. As such, multiple visceral damage should be ascertained when the bullet of high velocity or great mass has been used and the exit wound may be noted. Exploratory laparotomy must be performed for all gunshot wounds. Surrounding injury warrants extensive debridement of tissues that have been destroyed by concussive forces. Low velocity bullet mostly remains within the abdominal cavity and sometimes can be handled as knife stab wounds. The fact that, some bullets move in different directions while coursing within the body, multiple organ damage should always be anticipated. Abdominal trauma surgeon should perform meticulous assessment to any bullet wounds to avoid missing an injury.

The patient with penetrating stab wounds can present with diverse entities and they should be assessed thoroughly. Assessment of stab abdominal wounds should be done under local anesthesia. If posterior rectus sheath has been penetrated it is wise to perform laparotomy. It is vital to remember that intact peritoneum may be misleading because the perforated peritoneum retracts with abdominal rigidity. Omental protrusion through the stab wounds warrants laparotomy. The patient may present with knife in the abdomen, which should not be pulled out immediately; it should be removed by surgeon via an operation [5].

2.2.2.2 Clinical presentation for blunt abdominal trauma

The common mechanism of blunt abdominal trauma include: road traffic accident, physical violence. Abdominal pain is usually the presenting complaint of blunt

abdominal trauma. The common signs include: abdominal distention, rigidity, and tenderness which implies peritonism. Bowel sounds can be absent and abdomen moves poorly with respiration. Tachycardia, hypotension and other signs of shock are frequently present which infers laparotomy. Other important signs to look for in case of blunt abdominal trauma include: (1) Seat belt sign (diagonal and lower abdominal abrasion) if positive points to bladder, bowel perforation and fracture of lumbar spine, (2) balance sign (immovable mass or immovable area of dullness in the left upper quadrant) its positivity implies splenic sub-capsular or extra-capsular hematoma, (3) Ker's sign (presence of left shoulder/ neck pain) if positive it is associated with splenic injury, and (4) Cullen's signs (presence of periumblical ecchymosis) in case it is positive it implies hemorrhage in the peritoneum.

2.2.3 Investigations

History and physical examination findings are essential but most of the time not enough for complete assessment of traumatic abdominal patient. To appreciate thoroughly abdominal organ injuries certain investigations should be performed to compliment the findings of history and physical examination. The available modalities to use for the assessment of traumatic abdominal patient include: computer tomography (CT), focused assessment sonography for trauma (FAST), laparoscopy, diagnostic peritoneal lavage (DPL) and other basic investigations such as complete blood count (CBC). The key points related to these investigations with respect to the management of abdominal trauma are provided in **Table 5**.

Investigation	Key significant points with respect to abdominal trauma management	Disadvantages
CT	• CT is the gold standard investigation to use for assessing stable traumatic abdominal patient • Compared to other investigations such as DPL, CT has higher predictive ability for lesions to be operated • CT is useful to guide angiographic interventions for determining the source of bleeding • CT has a capacity to visualize retroperitoneal space and vertebral column • It is useful for assessing genitourinary and renal arteries • CT is effective for avoiding needless surgery	• The patients must leave emergency department • CT can potentially delay laparoscopy or laparotomy • There are risks of radiations • It is expensive investigation which is not available and affordable for most patients especially in developing countries
Ultrasound FAST For blunt Penetrating Extended-FAST	• Ultrasound has profound advantages for both blunt and penetrating abdominal trauma patient assessment. • It is portable, fast and serial examinations can be performed • It is non-invasive, safe and no risks of radiations • E-FAST has the capacity to detect small amounts of hemoperitoneum with good specificity and can support to determine concurrent injuries located in thorax	• Lack of the capacity for imaging solid parenchymal damage and retroperitoneal and diaphragmatic injuries • Nature of the patient e.g. obesity, agitated, and gas in the bowel may limit its usability • It is user dependent • It has no capacity to detect hollow viscus injury
Laparoscopy	• Laparoscopy is used for investigational and therapeutic purpose. • Laparoscopy is powerful for detecting diaphragmatic injuries	• Complications associated with insertion • Missing solid organ, stomach, small bowel

Investigation	Key significant points with respect to abdominal trauma management	Disadvantages
	• It also reduces the rate of nontherapeutic laparotomy. • Numerous investigators have reported higher sensitivity and specificity	injury, retroperitoneal injuries • It requires higher level of expertise prior to its use.
DPL	• It is useful for triaging unstable patients with uncertain FASTs • It can be used when FAST is not available (e.g. in most hospital of developing countries)	• Risk of infections (very low) • Intraperitoneal injury (low) • Failure to perform DPL can lead to unnecessary laparotomy for the patient who is stable and with self-limiting injury
Others • x ray • MRI • Hematologic investigations	• X ray can be used to detect chest injuries • MRI can be useful to detect spinal cord injuries • Hematological investigations such as complete blood count (CBC)	• Increased white blood cells especially neutrophils, and left shift, toxic granulation may indicate bacterial infections

Table 5.
Key points related to stated investigations with respect to the management of abdominal trauma.

3. Risk factors leading to the occurrence of complications associated with management of abdominal trauma

In addition to understanding anatomy, physiology of abdominal organs and the framework of management for traumatic abdominal patient, it is essential to know other risk factors leading to complications associated with the management of abdominal trauma. Recognizing these predisposing factors can support in planning and enhancing designed measures which aim to avoid the occurrence of the complications associated with abdominal trauma.

3.1 Individual and community related risk factors

Certain complications associated with the management of abdominal trauma are highly common because of individual and community influence. The common known fact is that, life is made at home and repaired at the hospital. The violation of this fact is seen for individuals who sustain abdominal trauma for whatever the cause and delay to present to the health facility.

For one or more reason (s) some traumatic abdominal patients do not seek immediate medical care for their injury. Ignorance is among the factors stopping some individuals and communities from seeking immediate medical care after trauma event. This is commonly seen in developing countries. In developing countries there are still remarkable dual management approaches for traumatic patients [7]. Some traumatic abdominal patients are first seen by traditional healers. The traditional healers have insufficient knowledge and capacity to support quick restoration of functions of injured abdominal organs. Due to failure of the treatment started by traditional healers, traumatic abdominal patients are further referred to the health facility in delayed time. However, due to the delay the standard of management is compromised, which is a major factor leading to complications associated with management of abdominal trauma.

Furthermore, all individuals and communities of the World are suspected to maintain peace which is one of the 17 sustainable development goals (SDG) maximally all the time. With the current ambitions of various countries to achieve SDGs, peace (SDGs 16) is highly needed. All 17 SDGs integrate each other. Specifically integrating SDGs 3 (good health and wellbeing) and SDGs 16 (peace and justice) would favor the mitigation of injuries in various communities; in fact one of the targets of SDGs 3 is to halt number of global deaths and injuries from road traffic accident by 2020. However, evidences indicate that, wars, conflicts [8, 9] and road traffic accident continue to affect many individuals and communities in many parts of the world. Inflicting various types of injuries including abdominal injuries is among the common worst outcomes of un-peaceful communities. Intentional abdominal injuries are likely to be penetrating. Evidences have shown that penetrating abdominal injuries are associated with many complications such as infections, bleeding etc. Thus, high incidence of penetrating abdominal trauma in a community associates with occurrence of many complications that occur during its management.

3.2 Weak health system and trauma care system related risk factors

Weak health system of various countries is among the profound factors leading to complications of various diseases or event. Many countries continue to lack strong health system. Weak health system is profoundly found in most of developing countries [9] yet majority of the diseases and events including abdominal trauma happen in these countries. One of the indicators of a weak health system is continuous occurrence of high mortality and morbidity related to trauma ever reported in these counties. Weak health system seemingly marks the negligence of various countries to their populations. For instance, evidence has shown that the spectrum of trauma has increased due to: (1) increased urbanization, (2) use of automobiles, (3) use of firearms. These factors have also led to higher prevalence of abdominal trauma. As of such high prevalence of trauma, one would suspect strong health system (with standard trauma care as component) to be available all the time. However, in many countries this element has been ignored, thus, complications continue to occur among traumatic abdominal patients at any stage of their management.

Likely in developing countries majority of traumatic abdominal patients are still managed at the substandard centers due to weak trauma care system and due to this instance complications develop. Weak trauma care system can be marked by: (1) Inadequate trained trauma care providers to manage abdominal trauma, (2) Lack of pre-hospital services for traumatic abdominal patients, (3) Absence of appropriate referral system for traumatic abdominal patient, (4) lack of inter-professional collaboration while managing traumatic abdominal patient, (5) Negative attitudes of trauma care providers towards traumatic abdominal patients, and (6) Lack of equipments and infrastructure to use while managing traumatic abdominal patients.

3.2.1 Inadequate trained trauma care providers to manage abdominal trauma

Traumatic abdominal patient should be managed by trained health workers whose knowledge is enough to help to make rational decision regarding management approach. As mentioned earlier the main goal of management of traumatic abdominal patient should be to restore the function of abdominal organs as quick as possible. Lack of trained trauma care providers to provide timely interventions at any stage of

management reduces the chance of survival and those who survive are likely to remain with permanent disabilities.

3.2.2 Lack of pre-hospital care services for traumatic abdominal patient

For many years trauma has been a neglected epidemic worldwide. The history marks increased mortality and morbidity related to trauma because of such neglect [10]. With the recognition of such neglect in 2000 WHO affirmed the use of prehospital care interventions as one way for mitigating the mortality and morbidity associated with any kind of trauma. However, many countries especially developing countries have not adopted the principles of prehospital care optimally yet majority of trauma cases happen in these countries as such poor outcomes including: deaths, prolonged hospital stay and development of complications are still reported at unacceptable level.

Three levels of deaths associated with trauma have been recognized; level 1 (immediate deaths encompass deaths which occur quickly due to overwhelming injuries, level 2 (intermediate deaths encompass deaths which occur within several hours after trauma event and notably result from treatable conditions) and level 3 (delayed deaths encompass deaths which occur within days or weeks after trauma event). Evidences have shown that most of these deaths can be prevented by providing timely prehospital care interventions. Trauma care provider should know conditions which are likely to kill the patient and appropriate tasks to perform in order to prevent such deaths at any of these levels. Traumatic abdominal patient may die at any of these stages due to lack of prehospital care interventions. Examples of conditions which can cause death to abdominal trauma victim at any of these stages are shown in **Table 6**.

Level	Likely cause of death	Actions to prevent the occurrence of death
Immediate deaths	• Airway obstruction • Hypoxia • Hemorrhage • Abdominal trauma with other severe injury (severe traumatic brain injury, severe cardiac injury)	• Immediate aids • Immediate ATLS interventions • Followed by other standard trauma care interventions
Intermediate deaths	• Airway obstruction • Hypoxia • Hemorrhage	• High benefits of prehospital interventions are noted at this level. • Timely ATLS interventions can mitigate or stop the cascades of events that lead to deaths or lifelong disability. • Followed by other standard trauma care interventions
Delayed deaths	• Airway obstruction Hypoxia • Hemorrhage • Infections • Multiple organ failure • Abdominal trauma with other injuries (e.g. spinal cord injury, fractures etc.) • Other complications	• Prehospital intervention can mitigate deaths which occur at this phase by ensuring: ◦ Proper wound care ◦ Adequate immobilization of fracture ◦ Early initiation of other measures which reduce the likelihood for the development of complications • Other standard trauma care interventions

Table 6.
Levels of deaths associated with trauma and likely interventions which can prevent the occurrence of such deaths.

3.2.3 Absence of appropriate referral system for traumatic abdominal patient

The transfer of traumatic abdominal patient may encompass transportation from the scene to health facility or inter-facilities transfer. Depending on the severity of abdominal injury, the patient might need management interventions at different levels of trauma centers. To accomplish such task, an appropriate referral system should be available all the time. Lack of appropriate referral system disturbs the standard of management which is among the prominent factors leading to complications and even sometimes death of abdominal trauma victim.

3.2.4 Insufficient inter-professional collaboration while managing traumatic abdominal patient

Insufficient inter-professional collaboration while managing abdominal trauma patient may increase the occurrence of complications due to: lack of proper communication, increased rates of errors, insufficient assessment of the patient etc.

3.2.5 Negative attitudes of traumatic health care providers towards a traumatic abdominal patient

Saving lives and avoidance of the occurrence of complications for traumatic abdominal patients would be achieved if all trauma care providers approach to them with good attitude. Negative attitude of trauma care providers towards a traumatic abdominal patient can be marked by various factors. For instance, neglecting the patient, failure to follow standards of trauma care, abusive language etc. as per observation of an author working in one of developing countries, negative attitudes of health workers towards patients is real fact. As such many innocent traumatic patients (including those with abdominal trauma) continue to die and some survival patients develop numerous complications.

3.2.6 Lack of equipments and infrastructure to use while managing traumatic abdominal patients

The evidence is clear management of any traumatic abdominal patient should be done at standard trauma center which should have adequate equipments and good infrastructures. Lack of standard trauma care is a major factor leading to the occurrence of complications. Evidence has confirmed that, findings of history and physical examination are unreliable for deciding management approach. Many studies have shown that, CT, FAST, and laparoscopy support to make correct decision regarding the management approach to utilize for traumatic abdominal patients. Due to shortage of equipments and infrastructures many traumatic abdominal patients continue to undergo non-therapeutic laparotomy which is ever associated with numerous complications. Markedly, unacceptable shortage of equipments and infrastructures is found in developing countries where most trauma incidence, mortality and morbidity happen.

3.3 Mechanisms of abdominal trauma related risk factors

All mechanisms leading to abdominal trauma have the potential to associate with a certain complications which may occur during the trajectory of management.

However, the variability in terms of how dangerous they provoke complications exist. For instance Gunshot as one of the mechanisms of penetrating abdominal injury is associated with many complications [1]. If the bullet of high velocity and large mass was used, many complications develop because of the damage of multiple abdominal organs. Classically, penetrating abdominal trauma is associated with many complications and deaths compared to blunt abdominal trauma. However, in terms of making diagnosis, blunt abdominal trauma poses more challenges to diagnose compared to penetrating abdominal injuries. As such, astute clinician should thoroughly assess all traumatic patients and perform certain investigations in order to remove such confusions, make appropriate diagnosis and institute timely treatment interventions.

3.4 Abdominal trauma with concurrent and multiple injuries related risk factors

Concurrent and multiple injuries profoundly increase the occurrence of complications associated with the management of traumatic abdominal patient. Shown in **Table 7** are possible injuries which increase complications associated with management abdominal trauma. In fact evidences have shown that these injuries are the leading cause of deaths among traumatic abdominal patients. The way these injuries cause complications vary from one another. For instance, patient with abdominal trauma together with traumatic brain injury and who are unconscious are at higher risk of aspiration and asphyxia. Unconsciousness impairs the contraction of pharyngeal muscles and muscles of the tongue, thus the tongue fall back when the patient is in supine position, causing airway obstruction that culminate into aspiration and asphyxia. Moreover, injuries to the central respiratory centers may be present and are among the cause of impaired breathing.

• Retroperitoneal hemorrhage	• Traumatic brain injury
• Tears of the aorta or inferior vena cava	• Cardiac injury
• Fractured ribs (Lower ribs fractures)	• Pulmonary injury
• Pelvic and vertebrae injury	• Spinal injuries
• Diaphragmatic injury	• Fracture of extremities

Table 7.
Possible injuries which increase complications associated with management abdominal trauma.

3.5 Treatment approach related risk factors

Classically, in order to lessen complications and burden associated with the management of abdominal trauma, astute clinician should manage any traumatic abdominal patient using principles of medical management. There are five principles of medical management namely: (1) identify and treat the cause, (2) identify and treat complications which have occurred or as they occur, (3) communication, (4) consultation, and (5) continuous management. The causes of abdominal trauma include road traffic accident, assaults, wars etc. It is impossible for the clinician to directly stop the causes of abdominal trauma. However, in the hospital clinician should teach patients, attendants, and community measures designed to stop the occurrence of injuries all the time, but also clinician should teach them other health promotion and preventive measures.

There are numerous complications such as airway obstruction, hypoxia, hemorrhage, infections, and multiple organs failure which are likely to occur during management of traumatic abdominal patient. It is necessary for practitioners caring

traumatic abdominal patient to have optimal understanding factors which favor the development of these complications at any stage of management. In broadly speaking three factors can contribute to the occurrence of complications to the hospitalized traumatic abdominal patient. These factors are: (1) Lack of information, incorrect information or confusion in data regarding to choosing, and planning management approach, (2) Incorrect judgment in choosing and planning management approach, and (3) incorrect execution of management approach. Shown in **Table 8** are factors and examples of conditions which are likely to increase the occurrence of complications.

Furthermore, treatment of abdominal trauma should be comprehensive and should be done via multidisplinary approach. Appropriate communication (between the patient and clinician, and between clinicians), consultation and continuous management are highly crucial in terms of mitigating the burden associated with the management of abdominal trauma.

Risk factor	Examples of situations leading to complications
I) Lack of information, incorrect information or confusion regarding data in choosing, and planning management approach	A) Incorrect or confused data • Management of wrong patient • Management of wrong abdominal organ (operated) • Administration of wrong medications, unnecessary blood and fluids B) Complications due to failure to treat other medical conditions • Bleeding disorders • Diabetes mellitus • Electrolyte imbalance • Endocrinopathies • Cardiovascular disorders • Pulmonary disorders
II) Incorrect judgment in choosing and planning management approach	• Failure to start timely ATLS interventions • Failure to triage the patients • Failure to choose appropriate management approach (non-operative or operative) due to insufficient assessment of the patient • Failure to consider and treat other medical conditions • Failure to adhere to infection control measures • Failure to adhere to World Health Organization surgical checklist (if the patient is to be operated) • Misdiagnosis • Use and misuse of instruments (urinary catheters, intravenous cannula, ventilators and nasal-gastric tube), use of contaminated instruments • Failure or delay to refer the patient at higher trauma centers for continuous management • Prolonged hospitalization of traumatic abdominal patient
III) Incorrect execution of management approach	• Prolonged operation for traumatic abdominal patient • Failure to treat other concurrent injuries • Missing injured abdominal organs • Excessive retraction of abdominal organs • Removing abdominal organ unnecessary • Inserting unnecessary drains • Creating unnecessary stoma

Table 8.
Factors and examples of conditions leading to complications associated with the management of abdominal trauma within the hospital.

4. Complications associated with non-operative management of abdominal trauma

Many investigators have confirmed profound benefits of Non-Operative Management (NOM) approach for the management of traumatic abdominal patients. The main indicators NOM include: hemodynamic stability of the patient, absence of peritoneal signs and negative findings of certain imaging modalities. Studies have shown that NOM is useful for the management of majority of blunt and few penetrating abdominal injuries. With the use of NOM most patients progress smoothly to complete recovery without complications. However, in certain number of instances complications develop. Shown **Table 9** are some of the possible complications to associate with non-operative management of abdominal trauma. There are shortages of literature written on some of these complications; probably because of the fact that, some of these complications develop in delayed phase of management.

4.1 Infectious complications associated with non-operative management of abdominal trauma

4.1.1 General consideration

Both of the useful and dangerous microorganisms have been with human beings for many years. Human body is ever colonized by useful microorganisms so called normal flora. Evidences have shown that these organisms play substantial role in defense mechanism for normal human being. However, due to certain circumstances such as injuries, and compromised immunity these microorganisms escape their usual habitants and reach sterile site of the body which eventually results into infections. Typically infections can be defined as an invasion and destruction of tissues by microorganisms. Various factors influence the occurrence of infections to humans. For hospitalized non-operated traumatic abdominal patients, among the factors which influence infectious complications include: (1) presence of superficial lacerations, (2) missed and unrepaired hollow viscus injuries, (3) Overcrowded wards of which abdominal trauma patients are mixed with other patients who have other surgical

Infections	• Nosocomial infections
	  ◦ Pneumonia
	  ◦ Urinary tract infections
	• Peritonitis
	• Sepsis and septic shock
	• Abscess
	  ◦ Liver abscess
	  ◦ Sub-phrenic abscess

Delayed rupture	• Delayed rupture of hematoma • Delayed rupture of a sub-capsular hematoma • Delayed rupture of pseudoaneursym • Delayed Splenic rupture • Delayed hepatic rupture
Others	• Hematoma formation • Hemobilia • Biliary stricture formation

Table 9.
Possible complications to associate with non-operative management of abdominal trauma.

conditions, (4) non-adherence to infections control measures, (5) Compromised immune status of the patient, (6) Starvation, (7) shock, and (8) prolonged hospital stay etc. These factors can influence the occurrence of principal infectious complications such as sepsis and septic shock, peritonitis and nosocomial infections for non-operated hospitalized traumatic abdominal patient.

4.1.2 Sepsis and septic shock for non-operated hospitalized traumatic abdominal patient

The initiation and progression of infection process for non-operated abdominal trauma patient occur via several routes. For instance traumatic abdominal patient with superficial wounds are at risk of developing infections due to immediate colonization of their wounds by normal flora. Usually humans mount both local and systemic responses to microorganisms that have escaped their usual habitants. Infections provoke the process of inflammation. Classic features (pain, warmth, redness, swelling and loss of functions) of inflammation may appear as signs for either local or systemic response to infections. Local metabolic effects of infections are due to tissues damage with cells deaths and buildup of proteins rich exudate of leukocyte, immuglobulins, and plasma; these are visible externally as pus.

Untreated or poorly treated local infections may result into catastrophic results that initiate systemic responses. Systemic inflammatory response syndrome (SIRS) is evident clinical when there are two or more of the following findings: (1) fever (oral temperature (>38°C), or hypothermia (< 36°C), (2) tachypnea (> 24 breaths/minutes); (3) tachycardia (heart rate > 100 beats/minute, and (4) leukocytosis (>12,000/μL) and leukopenia (400 < μL). Sepsis should be diagnosed when evidence (results of culture) shows that infections are the responsible cause of SIRS. Sepsis marks the inability of cell to use nutrients.

Untreated or poorly treated sepsis progress to septic shock. Septic shock can be in two forms namely: warm phase, and cold phase. In warm phase, there is increased peripheral circulation in attempt to deliver enough blood to the cells. High temperature marks this phase. This phase is transient and failure to treat the patient with an appropriate therapy leads to un-compensatory shock (cold phase). The dangerous outcome of septic shock include: low flow state (volume reduction), tissue injury, pump failure (heart) and more infections. The diagnosis of septic shock is made if there is sepsis and hypotension (arterial blood pressure < 90 mmHg systolic or 40 mmHg less than patient's normal blood pressure) for at least 1 hour regardless of satisfactory fluid resuscitation. Early recognition of septic shock and institution of appropriate therapies can be useful in terms of saving the life of the patient.

4.1.3 Peritonitis

4.1.3.1 Description

Peritonitis is life threatening condition which is associated with abdominal trauma. The association between NOM and peritonitis depends on the fact of missing perforation of hollow viscous organ. "Injuries to the stomach, duodenum, small intestine, and colon are common in penetrating trauma and relatively rare in blunt trauma. Violation of the peritoneum occurs in between 20 and 80% of patients with penetrating trauma, depending on the type of weapon used" [11]. Both of the pillage of abdominal contents and blood into the peritoneal cavity irritates peritoneal membrane. Persistent non-repaired perforation of hollow viscus abdominal organ

exacerbates the process of inflammation due to continuous spillage of GIT contents into the peritoneal cavity. Moreover, severity of peritonitis can depend on perforated hollow organ. For instance, when stomach or duodenum has been perforated, the severity is high because of the spillage of contents of low PH and some microorganisms.

4.1.3.2 Clinical manifestation and treatment

The clinical manifestations of peritonitis may include, fever, rigidity, guarding, signs of toxemia and shock etc. Early recognition and institution of treatment approach is lifesaving. Firstly, stabilize the patient; ensure adequate ventilation, breathing and circulation. Administer fluids and antibiotics. Secondary proceed to the repair of perforated viscus organ. And finally provide postoperative and long term care in order to detect and treat any complications which can occur after an operation.

4.2 Hematoma formation

4.2.1 Description

Hematoma formation is a common outcome to occur following abdominal trauma. Hematoma can form within the tissue or outside the tissue due to damage of blood vessels. Blood that has accumulated coagulate and results into hematoma. The association between NOM of abdominal trauma and hematoma formation as a complication lies on the fact of making a wrong decision. Certain imaging modalities can assist to stage hematoma and support to make best choice regarding management approach. Evidence has shown that stage 1 and 2 of hematoma resolve spontaneously in contrast to stage three and above which should be managed via operative approach. Lack of imaging modalities to decide which stage of hematoma the patient has developed is a common factor leading to the use of wrong management approach. When a certain unrepaired blood vessel continues to bleed more blood accumulate and hematoma continue to form. Untreated hematoma may serve as culture medium for microorganisms because accumulated blood lyses and release cellular contents such as iron which is good nutrients of microbes. As such hematoma can be a focus of infections which may turn into sepsis. The use of antibiotic as prophylaxis for infections associated with hematoma seems not to be effective because hematoma does not allow the entrance of antibiotics.

4.2.2 Clinical features

Manifestations of hematoma depend on its location, size and whether it has ruptured or infected by microbes. History of abdominal trauma and left upper quadrant pain and positive balance sign (immovable mass or immovable area of dullness in the left upper quadrant) point to splenic sub-capsular or extra-capsular hematoma. The pain may occur due to big size of hematoma which compresses nerves, capsule and other tissues to result into ischemia. Signs of hemodynamic instability may be present if hematoma has undergone rupture. Moreover, if hematoma has been infected by microorganisms, signs of infections may be apparent; evidence of infections should infer quick interventions because untreated infections may turn into sepsis, septic shock; perhaps death.

4.2.3 Treatment approach

Evacuation is treatment of choice for hematoma. Evacuation of hematoma diminishes successive inflammatory reactions to the initial insult. But also, diminish damage associated molecular patterns (DAMPs) and successive diffuse organ injury. Operating on hematoma is challenging due to risk of bleeding. While managing patient with abdominal hematoma, physician should remember to treat other complications which would have occurred or as they occur. Treatment or prevention of hypovolemic shock and infections is highly needed.

5. Complications associated with operative management of abdominal trauma

Both of the penetrating and blunt abdominal traumas can be managed with operative approach. The main indicators for an operation are hemodynamic instability and evidence of peritonitis. Penetrating abdominal trauma especially those caused by bullets should be treated operatively. Like non-operative approach most patients undergoing operative management recover smoothly without complications. However, in certain instances complications develop. Notably, to avoid the occurrence of these complications, the management should be performed holistically via five steps namely: (1) preoperative interaction with and evaluation of the patient, (2) choice and planning of the operation, (3) execution of the operation, (4) formulating of the correct diagnosis, and (5) post-operative and long-term care. Certain actions should be performed at each of these steps in order to avoid the occurrence of complications. Shown in **Table 10** are some the tasks to perform in order to favor good operative outcome for abdominal trauma patients. Failure to perform one or more of these tasks at any of these steps increases risks of complications. The principle complications to associate with operative management of abdominal trauma are listed in **Table 11**.

5.1 Hypothermia, coagulopathy and metabolic acidosis

Hypothermia, coagulopathy and metabolic acidosis form the triad of complications associated with operative management of abdominal trauma. These complications are associated with higher morbidity and mortality. Opening abdominal cavity and prolonged operation for abdominal organs leads to loss of temperature via evaporation. The reduced temperature reduces the rate of blood clotting and coagulation catalytic enzymes. Thus, impaired blood clotting and coagulation process leads to excessive bleeding which eventually results into hypovolemic shock. Hypo-perfusion leads to anaerobic respiration with the release of lactic acid which is the hallmark of metabolic acidosis.

5.2 Hypovolemic shock

Hypovolemic shock is the common complication to associate with operative management of traumatic abdominal patient. The association between hypovolemic shock and operative management of abdominal trauma can be explained in several ways for instance: (1) the fact that, most abdominal organs are highly vascularized; injuries to either organ can cause severe bleeding and shock. Surgery on abdominal organs such as liver, spleen is a problematic as there can often be a large amount of blood loss

Step	Example of tasks to perform to improve outcome of an operation
I) Preoperative interaction with and assessment of the patient	• Firstly, triage the patients and offer ATLS interventions • If possible involve patient in the decision making concerning their surgery • Ensure that the patient and attendant (family member) understand the goal of operation; tell them the benefits of an operation, and risks and the possible complications to encounter while performing an operation. • Tell the patient other alternative treatment approach; the benefits and risk of such approach should be discussed. • Obtain informed consent
II) Selection and preparation of the operation	• Choose appropriate management approach (non-operative, operative, damage control, embolization, laparoscopy or • Each operation should be individualized • Involve anesthetic team in planning of the operation. Traumatic abdominal trauma patients are at high risk of aspiration and anesthetic agents can exacerbate such risks. Anesthetic team can plan ahead strategies for minimizing these risks prior to an operation. • Start pre-medications • Book blood if excessive bleeding is anticipated. • Consider and normalize other medical conditions prior to an operation if possible • Ensure appropriate temperature in operating room
III) Execution of the operation	• Follow infections control measures • Follow WHO surgical checklist • Avoid the removal and resecting abdominal organs needlessly • Ensure optimal communication between all members of the operating team during an operation • Avoid prolonged operation
IV) Formulation of the correct diagnosis	• To avoid misdiagnosis, surgeon should perform adequate assessment of the patient during preoperative and intraoperative period. • Adequate light is highly required
V) Postoperative and long-term care	• Meticulous monitor of vital signs and patient recovery from anesthesia should be done properly after an operation. • Advice the patient about the appropriate time to resume eating; early resumption should be favored in order to avoid negative nitrogen balance if not possible total parenteral nutrition should be offered to the patient. • Ensure long term care to detect delayed complications. • When complication happens during intraoperative or postoperative, operating team should support the patient to overcome the burden of such complication.

Table 10.
Some of tasks to perform in order to maximize the operative outcome for abdominal trauma patient.

associated with operations, and increase the morbidity and mortality, (2) in case of prolonged operation more fluids evaporate and this compound hypovolemia state, and (3) fluid loss into the interstium as result of inflammation also take place during surgery and complexes hypovolemic state.

Like any other type of shock, hypovolemic shock leads to tissue hypoperfusion, followed by deprivation of nutrients and oxygen to tissues and provoke anaerobic respiration with the release of lactic acid as hallmark of metabolic acidosis. The cellular damage provoked by insufficient delivery of oxygen and substrates induces the formation and releases of damage associated molecular patterns (DAMPs, also called danger signals) and inflammatory mediators which further compromise tissue hypo-perfusion. Typically body's responses to any kind of shock are too complex, and

The triad of:	• Hypothermia, • Coagulopathy • Metabolic acidosis
Shock	• Hypovolemic shock secondary to: ○ Hemorrhage ○ Evaporation ○ Loss of fluid into the interstium
Infectious complications	• Surgical site infections ○ Superficial surgical infections ○ Deep surgical infections, • Sepsis and septic shock • Secondary peritonitis • Nosocomial infections
Others	• Fistula formation

Table 11.
Examples of complications to associate with operative management of abdominal trauma.

can be useful and dangerous. Stimulation of dramatic network of inflammatory mediators by innate immune system is the most dangerous responses to occur after shock. These inflammatory responses contribute to the progression of shock, development of multiple organs injury, multiple organs dysfunction and multiple organs failure and finally death.

5.3 Infectious complications

Infections remain the most dreaded complications in surgical practice. Typically infection refers to the presence of microorganisms in a normal sterile site with subclinical or symptomatic. In surgical practice infections associated with operative management can be described in terms of cleanliness of surgery performed. The type and incidence of infections include: (1) clean surgery ($\leq 5\%$), (2) clean -contaminated surgery (5–15%), (3) contaminated surgery (10–25%), and (4) dirty surgery (30–80%). Operation to penetrating abdominal injury is an example of dirty surgery. Operative management for an abdominal trauma and infections are frequently associated. The major determinants for infectious complications include: (1) the infecting organisms, (2) patient and his disease, (3) environments, equipments and medical personnel, and (4) conduct of an operation. To better understanding these determinants, the following formulas can be used to describe the relations ship between certain variables.

$$\text{Infections and their severity } \alpha \frac{\textit{the dose (number of infections) times virulence}}{\textit{immunity of the patient}} \quad (2)$$

$$\text{Or infections and its complications } \alpha \frac{\textit{microbiology times epidemilogy}}{\textit{anatomy times immunology}} \quad (3)$$

Given the significance of these expressions in terms of understanding infectious complications associated with abdominal trauma and operative management deserves comments. Firstly, for any infection to occur the pathogen and host must encounter each other. It is clear that, Infections and their severity is directly proportional to dose and virulence of microbes but inversely proportional to immunity of the patient.

Factors which increase numerator and reduce the denominator of this expression increase the burden of infections. Among traumatic abdominal patients, factors that are likely to increase numerator include: penetrating abdominal injury (open wounds), use of contaminated instruments, and spillage of abdominal contents into the peritoneal cavity, whereas factors that can reduce denominator include any conditions which can reduce immunity such as HIV/AIDS, immunosuppressive drugs, undernutrition etc. Otherwise second expression also indicates that, increased microbiology and epidemiology and impaired anatomy and immunology also increase the burden of infections. Further, emphasis for understanding these expressions can be made by using spleenectomy as an example. Spleen has significant immunological functions; overwhelming infectious complications caused by encapsulated bacteria (e.g., *H. influenzae*, *S. pneumoniae*, *and N. meningitidis*) [5] have been reported after spleenectomy.

5.4 Sepsis and septic shock

Sepsis and septic shock is dangerous bomb which kill human body cells. The hall mark of sepsis is presence of clinical evidence of infection plus systemic response to infection. Various mechanisms can lead to infections which may further progress to sepsis and septic shock. Contamination by penetrating injuries, hematogenous spread, local inoculation, and iatrogenic introduction of microbes into the sterile site are examples of portal of entry for microbes which result into infections. If infections are not recognized and treated promptly further progression to sepsis and septic shock develop. Septic shock can be in two forms namely warm phase, and cold phase. Warm phase is marked by higher peripheral circulation as the compensatory mechanism. This phase is transient and failure to treat the patient with an appropriate therapy leads to un-compensatory shock (cold phase). The dangerous outcome of septic shock include: low flow state (volume reduction), tissue injury, pump failure and more infections.

The cause of death for septic shock patient is multiple organs failure. Evidence has shown that, failure of four body systems leads to death 100%. Only possible way for avoiding this tragedy to happen is to avoid the occurrence of infections and in case infections have occurred early institution of appropriate therapy (with antimicrobial agents, remove the source of infections and supportive care such as oxygen and fluids to correct circulation and respiratory compromise) would favor the rescue to the patient.

6. Systematic approaches for avoiding the complications associated with management of abdominal trauma

The twentieth and twenty first centuries have been the time of great changes. In medical field remarkable changes have been noted and mainly changes have focused on finding new solutions to old problems. In overall, trauma continues to be a serious global problem of which new solutions are needed. In fact, evidences have confirmed that, trauma is a worldwide epidemic which is ever becoming worse due to many factors for instance: increased unstandardized urbanization in many countries (especially developing countries), increased use of unstandardized automobiles and roads, increased firearms in many communities, unreasonable violence and wars in many parts of the world etc. As mentioned earlier death is certainly a powerful dependent

variable but unwanted one which is ever seen in all kinds of trauma. However, mortality and morbidity associated with most of trauma cases can be prevented. Thus, it is wise to direct more efforts to avoiding the occurrence of abdominal trauma and complications which occur during the trajectory of its management.

6.1 The role of individual and community participation in avoiding the occurrence of abdominal trauma and its complications

Historically, curative measures have occupied greater place in all fields of medicine. However, from 1960s–1970s up to now evidences have shown that, curative measures are not enough for optimizing health status of the populations [9, 12, 13]. As such health promotion and preventive measures are of the greater significance in terms of tackling various medical problems. Health promotion and prevention measures focus on avoiding the occurrence of a certain disease or event. The philosophy for optimizing the use health promotion and preventive measures lies on empowering individual and community to participate in all designed actions which aim to stop the occurrence of certain disease or event.

With regard to abdominal trauma which is the persistent old problem to be solved with new solutions various ambitions are to be emphasized. Redesigning and optimizing the strategies which aim to empower individual and communities to stop all factors leading to the occurrence of abdominal trauma is an effective way which can stop all complications related to abdominal trauma. All causes of abdominal trauma and factors that increase the complications associated with it are known and are preventable. Road traffic accidents, physical violence are marked as common cause of abdominal trauma, however, these are preventable. Thus, mentoring individuals and communities to optimize the use of measures designed to prevent trauma is one of the effective ways to reverse the burden caused by abdominal trauma and its complications.

6.2 The role of countries' health system in avoiding the occurrence of abdominal trauma and its complications

Evidences are clear all countries should opt to maximize health status of their populations. Through health system which is defined as all organizations, people, and actions whose primary intents are to promote or restore or maintain health; countries can optimize health status of their population without leaving any one behind. From 2015 all worlds' countries opted to achieve sustainable development goals (which are the extension of millennium development goals) by 2030 [14]. With regard to surgical practice, in 2015 global lancet commission on surgery was established upon recognizing the fact that, globally about 5 billion people had no easy access to surgical care services [14, 15]. This commission is in line to support countries to achieve sustainable development goals through ensuring easy access to surgical services at any time.

Intuitively, by looking on the coverage of various countries towards achieving this commission, many are still needed to be done. Worldwide (especially in developing countries) equitable access to affordable surgical services, safe anesthesia remains a serious problem for many surgical patients including those who sustain abdominal trauma. As such poor outcomes are ever reported for these patients. The World is advancing solving old problems with new solutions is an effective and efficient way for mitigating various problems of Worlds' populations. In the province of abdominal trauma care, scientists have devised various approaches designed to mitigate the burden caused by abdominal trauma. Among those approaches include: (1) use of

Management approach	Some essential aspects related to this approach
Non-operative management	Indications • Hemodynamic stable patient • Absence of peritoneal signs (Guarding, rigidity) Complications that can be reduced if this approach is used suitably • Non-therapeutic laparotomy • Bleeding (shock) • Infections Key remarks • Non operative management has become the most preferred approach to adopt for stable abdominal trauma patients • It can be used for both blunt and penetrating abdominal trauma.
Operative management	Indications Indications for emergency laparotomy following: A) For penetrating abdominal trauma • Hemodynamic instability • Peritonism • Evisceration • Diaphragmatic injury • Gastrointestinal hemorrhage • Intraperitoneal air • Gunshot wounds traversing peritoneum B) For blunt abdominal trauma • Unstable vital signs with strongly suspected abdominal injury • Unequivocal peritoneal irritation • If there is evidence of pneumoperitoneum • If there is evidence of diaphragmatic injury • If there are signs of significant gastrointestinal bleeding • Hypotension and positive FAST scan or DPL Complications that can be reduced if this approach is used suitably • Infections • Bleeding
Laparoscopy	Indications • Stable penetrating abdominal trauma • Few stable blunt abdominal injuries Complications that can be reduced if this approach is used suitably • Missing an injury • Infections • Bleeding Key remarks • Laparoscopy is essential for both therapeutic and diagnostic purpose [16]
Damage control Strategy	Indications Damage control surgery is warranted if there is positive findings of: • Acidosis: pH ≤ 7.2 • Hypothermia: core temperature ≤ 34°C • Coagulopathy: transfusion of ≥5000 mL or total fluid infusion ≥1200 mL • Injuries that would otherwise require overly time-consuming surgery (> 90 min) • Intra-abdominal tissue edema preventing formal closure of the abdominal wall Source: [17] Complications that can be reduced if this approach is used suitably • Shock • Infections • Abdominal compartment syndrome Key remarks • Damage control primarily focus on the normalization of:

Management approach	Some essential aspects related to this approach
	1. Physiological 2. Biochemical stabilization over the full anatomical repair of all injuries • Damage control surgeries are useful for a subcategory of traumatic abdominal patients as such not suitable in all cases. • Guiding criteria for damage control management may comprise the mechanism of injury and the degree of physiological derangement
Embolization strategy	Complications that can be reduced if this approach is used suitably • Hypovolemic shock • No removal of injured organ • Infections
Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA)	Complications that can be reduced if this approach is used suitably • Hypovolemic shock • No removal of injured organ • Infections Key remarks • REBOA is essential for the control for enormous hemorrhage • It has delivered auspicious results in the trauma victims • It is recognized as a slightly invasive and lower risk technique • Complications associated to usage of REBOA are infrequent in case used properly

Table 12.
Highlights of some aspects of some available management approaches for abdominal trauma.

damage control strategy, (2) use of laparoscopy for therapeutic and diagnostic purpose, (3) use of embolization strategy to control bleeding, (4) reducing the rate of operative management for traumatic abdominal injuries, and (5) enhancing health promotion and preventive measures designed to reduce risk factors leading to the occurrence of trauma. The purpose of this chapter is not describing in details these approaches, only few highlights about the significance of these approaches are shown in **Table 12**.

These strategies have been of greater significance in terms of reducing the burden of abdominal trauma in some countries. However, some countries have not utilized these measures optimally due to weak health system. As such unacceptable poor outcomes for traumatic abdominal patients are ever noted. Strengthening trauma care system can support to stop the burden of abdominal trauma. The components of standard trauma care system which should be given the first priority include: prehospital care services, appropriate referral system for traumatic abdominal patients, adequate infrastructure and equipments, practice goal oriented approaches. Shown in **Table 13** are some of the remarks related to these components in terms of avoiding the complications associated with abdominal trauma management.

6.3 Approaches for avoiding infectious complications associated with abdominal trauma management

With the advent of antimicrobial agents, various famous of medical fields believed that infectious diseases would soon disappear. However, currently infections are still marked among the contributors leading to mortality and morbidity worldwide. Infections are still marked as dreaded complications to associate with surgical care and cause unacceptable mortality and morbidity among all kinds of surgical patient. The

Component	Some of the remarks related to standard trauma care in terms of avoiding complications associated with abdominal trauma management

Pre-hospital care	• Pre-hospital interventions have valuable role in terms of avoiding the complications associated with management of traumatic abdominal patient. Classically prehospital care can support for:
	  ◦ Early initiation of ATLS protocol
	  ◦ Early transportation of traumatic abdominal patients to the hospital,
	  ◦ Enhance communication process among trauma team members caring traumatic abdominal patient.

Practice goal oriented approaches	• The primary goal of traumatic management is to prevent deaths • The second goal of management is to restore functions of abdominal organs or the whole patient as quick as possible. • The third goal is to provide definitive management and to teach the patient health promotion and preventive measures designed to mitigate burden of any trauma and other medical conditions. • Astute clinician should optimally practice these goal oriented approaches, in order to support his/her clients and various communities to achieve optimal health status.
Ensure correct management approach to be done at an appropriate trauma center	• Correctly choose management approach (Non-operative versus operative). • Operative management has been marked to associate with many complications compared to non-operative management. • Many countries have issued essential protocol to support abdominal trauma providers to make appropriate decision regarding to whether to operate or not. • Availability of equipments such as CT, FAST has advanced abdominal trauma care with best outcomes. However, marked disparities continue to exist between developing and developed countries regarding to the availability of these investigational modalities. Non-therapeutic laparotomies are still being performed and are associated with high morbidity and mortality. • To mitigate these tragedies countries should opt to ensure the availability of these investigational modalities in their hospitals (trauma care centers)
Ensure correct execution of management approach	• Various complications associated with management of abdominal trauma would be avoided if correct execution of the management approach. • To ensure that happen, all traumatic abdominal patients should be managed by appropriate trained medical personnel at standard trauma center in order to provide correct execution of management approaches.
Appropriate monitoring of traumatic abdominal patients	• Physiological derangement associated with abdominal trauma happens in dynamic fashion. • As such continuous monitoring (vital signs, response to treatment etc.) of the patient is very essential at any stage of management

The role of inter-professional collaboration (IPC) in avoiding the complications associated with management abdominal trauma patients	• Inter-professional collaboration is valuable approach to adopt in order to optimize the standard of care for any patient.
	• The emphasis has been made that, “inter-professional collaboration is of global interest for addressing the complex health care needs and improving patient safety in health care” [18].
	• Inter-professional collaboration (IPC) can support to avoid the complications associated with the management of abdominal trauma as follows:
	  a. IPC can empower members of trauma team who routinely involve in management of traumatic abdominal patient
	  b. IPC can close the communication gaps among the team members managing traumatic abdominal patient
	  c. IPC can favor traumatic abdominal patient to receive comprehensive care

Component	Some of the remarks related to standard trauma care in terms of avoiding complications associated with abdominal trauma management
	d. IPC can support to minimize days of hospital stay and readmission rates for traumatic abdominal patients as IPC supports to reduce errors during the course of management e. IPC can promote team mentality f. IPC can promote centered care to traumatic abdominal patients

Table 13.
Significances of availability of standard care in terms of avoiding the complications associated with abdominal trauma management.

fact that infections continue to infect patients seeking surgical care warrants the continuous search for the strategies and new technology that can prevent their occurrence. The correct use of antiseptics and of antimicrobial prophylaxis can support to reduce infectious complications associated with the management of abdominal trauma. "Prophylactic antibiotics for patients sustaining penetrating abdominal injuries with intestinal contamination have a role for reducing the rate of incisional wound infection subjected to gastrointestinal soiling" [19]. Moreover, in hospitals where infections are a problematic an infection controls committee may design guideline to follow to protect the patients and trauma care providers from spreading infections and prevent the occurrence of infections and their impacts.

In overall, use of various antimicrobial agents have played a significant role in reduction the burden caused by microorganisms. However, resistance, virulence and unavailability of these agents have been reported as factor limiting the usability of some of these agents. As such scientists continue their discoveries in order to discover agents to use for fighting infections. The recent renewed light based technology (air flow of ultraviolet (UV-C) germicidal emitters, open UV-C germicidal lamps, ozone generators, professional disinfection devises based on UVC radiation and ozone, or the combination of technologies) is being given greater consideration in many countries for fighting infections.

The postulated mechanism of which UV-C radiation inactivates a microorganism is by damaging deoxyribonucleic acid (DNA). Examples of microbes that are killed by UVC include: *Pseudomonas aeruginosa, Staphylococcal aureus*, *Methillicin-resistant Staphylococcus aureus* (MRSa), *Staphylococcus epidermidis, Mycobacterium tuberculosis*, *Serratia marcescens, Corynebacterium diptheriae, Legionella pneumophilia Adeno virus type III*, *Coxsackie A2*, *Influenza etc.* Some of these microbes are encountered in traumatic abdominal patients; perhaps some are more resistant to antimicrobials and cause significant mortality among surgical patients. There have been noted success of the use of air disinfection by UVC in surgical rooms and stimulated an expansion of UVC application in hospitals [20]. Evidence indicates that infections continue to be a serious problem in many hospitals. However, there is promising evidence that, light based technology can destroy microorganisms effectively compared to other agents. Shown in **Table 14** are advantages of light over alternative disinfectants, biocides, and anti-infectives [20]. Designing and adopting the use light based technology in surgical field would favor the reduction of infectious complications among traumatic abdominal patient, indeed for all patients and people who interact daily with patients.

7. Discussion

Globally, injuries are increasing and cause significant health problems worldwide. The greater burden of trauma is reported in middle- and low-income countries and approximately 90% of injury-related deaths happen in these countries [21]. This is a painful fact, as there is published evidence that "if injury mortality rates in low- and middle-income countries were reduced to rates in high-income countries, 2,117,500 lives could be saved per year" [22]. All body organs are vulnerable to the impacts of trauma. However, some body regions are more susceptible than others. Abdominal injuries are the most common type of injuries sustained during trauma event. Development of various complications during the course of management has been documented as a major driver leading to mortality and morbidity among traumatic abdominal patients. However, strategies for avoiding the occurrence of these complications have not been described. In this chapter we discussed systematic approaches for avoiding the complications associated with management of traumatic abdominal patient. Moreover, risk factors leading to the occurrence of these complications, and commonly occurring complications and some rare complications but with higher potential to cause mortality and morbidity have been discussed. We defined complication as an occurrence which is avoidable.

In order to avoid complications associated with the management of abdominal trauma, it is crucial to have maximal knowledge of anatomy and physiological processes of abdominal organs. We have highlighted essential points regarding to the anatomy and physiological process of liver, spleen and GIT because they are mostly injured organs during abdominal trauma. Moreover, anatomy of pancreas has been described because of its intimate relationship with vital vascular structures and common serious danger for both penetrating and blunt injury to the pancreas is the risk of injury to these great vessels. As it was asserted pancreas may obscure the site of bleeding and extensive mobilization or transection of the pancreas may be required in order to control the bleeding vessel.

The comprehensive management of abdominal trauma is a major determinant for the survival of abdominal trauma victim. The framework (primary phase, secondary phase and tertiary phase) of trauma management should be applied to the management of abdominal trauma. In principle all trauma patients should be managed by following the accident and trauma life support (ATLS) protocols. These protocols are also of the first priority while managing traumatic abdominal patient. These protocols contain all interventions aimed to prevent deaths. But also, these interventions influence all other steps of the traumatic abdominal management. Most importantly in this chapter we described ATLS interventions to offer to traumatic abdominal patients as shown in **Tables 2–4**. Evidence has shown that prehospital care services can optimizes ATLS interventions and improves patient outcomes [23]. However, most of the developing countries do not have formal prehospital care. And possibly this contribute to reported unacceptable mortality and morbidity associated with trauma in these countries. More studies are needed in order to determine barriers stopping developing countries to have formal prehospital care services.

Classically, as shown in this chapter there are various complications associated with the management of abdominal trauma and contribute to poor outcomes. Numerous risk factors leading to the occurrence of these complications have been discussed. In broadly speaking, risk factors discussed are: (1) *Individual and community related risk factors, (2) Weak health system and trauma care system related risk factors, (3) mechanisms of abdominal trauma related risk factors, (4) Abdominal trauma*

with concurrent and multiple injuries related risk factors, and (5) treatment approach related risk factors. By closer look at these factors, it appears that most of them are preventable, suggesting that, multiple tiers and more integrative processes are needed in order to avoid the occurrence of complications associated with the management of abdominal trauma.

Apparent of individual and community related risk factors as factors contributing to the occurrence of complications associated with abdominal trauma indicate that more efforts are needed to in order to enhance the prevention strategies at the individual and community level. "Human beings are regarded as rational decision makers whose knowledge informs their actions. The knowledge regarding health promotion and disease prevention is mostly insufficient or not well perceived by many world's people" [9]. Mentoring and educating various individuals and communities positively about the strategies designed to prevent the occurrence of abdominal trauma and to have peaceful community is an effective way for mitigating all burden associated with abdominal trauma. Such mentorship would bring the best outcomes by changing unhealthy behaviors leading to physical violence and this in turn would leads to the reduction of abdominal trauma and complications associated with its management.

Moreover, in this chapter weak health system is considered among the most profound factors leading to the occurrence of complications associated with the management of abdominal trauma. Weak health system is mainly found in developing countries where a greater burden of trauma is reported. In overall, "to ensure optimal health status of the people in developing countries, we need a strong health system, we shall surely have it if all health concerned stakeholders understand and put into the consideration the fact that achieving optimal good health status is an important and primary goal to be primarily considered in all planned actions" [9]. Strong health system can lead to the fruition of existence of standard trauma care system of which abdominal trauma patients can also profit.

Certain complications develop as consequence of chosen management approach. Numerous investigators have favored the use of non-operative approach for any stable traumatic abdominal patients regardless the types of abdominal injuries sustained. Probably, this is a good approach in developed countries because of the fact that, the decision for using NOM is made with the support of findings of certain advanced imaging modalities. This is contrary to developing countries where there are shortages of imaging modalities. In developing countries the decision for using NOM is mainly based on clinical findings. This is very dangerous because numerous traumatic abdominal patients present with no external features of intra-abdominal organs injuries. Negative abdominal examination findings do not warrant absence intraabdominal injuries. Evidence has shown that, about half of the bleeding in the peritoneal cavity or retroperitoneum manifests itself with few or no symptoms and that about 31% of cases of abdominal trauma deaths occur when there are no external features indicating intraabdominal injuries [24].

As asserted in this chapter, both penetrating and blunt abdominal trauma can be managed either by nonoperative or operative approach. In past it used to be mandatory to perform laparotomy for all Gunshot wounds however; evidence has shown that some Gunshot wound's patient can be managed nonoperatively [25]. Other main indicators for operation regardless the types of injuries sustained include hemodynamic instability and presence peritonism and positive finding of certain imaging modalities. Studies have confirmed that various imaging modalities can support to detect intraabdominal organs injuries after trauma.

Specifically FAST is essential for assessing blunt abdominal trauma and about 93% sensitive and 99% specificity have been reported [24]. Otherwise CT scan is gold standard investigation for detecting various abdominal organs injuries. According to the study done in Iran of which 100 patients were enrolled and it was confirmed that CT scan has highest sensitivity for detecting various abdominal injuries. Typically the results of CT in detecting various abdominal injuries in this study are as follows: liver (100%) and spleen (86.6%), specificity for detecting retroperitoneal hematoma (100%) and injuries to kidney (93.5%) [26]. Additionally the accuracy of CT images for detecting injuries of spleen, liver, kidney and retroperitoneal hematoma were reported to be 96.1, 94.4, 91.6, and 91.6% respectively. Imaging modalities assist to make rational decision regarding the best management approach for stable blunt abdominal trauma patients. However, despite their potentials in detecting intraabdominal organs injuries they are mostly not available in most hospitals of developing countries [27] possibly because they are too expensive. Thus, in these countries blunt abdominal trauma patients are likely to be managed with wrong approach. This probably leads to poor outcome and the most dangers are likely to happen to those patients who sustain retroperitoneal injuries because without CT scan it is hard to detect these injuries.

Despite decades of dramatic advance in treatment and prevention of trauma, globally trauma continues to be a major public health problem. More than 5 million individuals perish every year as a consequence of injuries. This is responsible for about 9% of the world's deaths, approximately 1.7 times the number of mortalities that result from HIV/AIDS, tuberculosis and malaria combined. It is not clear why trauma has not been given great priorities in some countries. There has been clear stated target that "*by 2020, halve the number of global deaths and injuries from road traffic accidents*" [25]. In the context of most developing countries evidence indicates that, this goal has not been achieved. What remains to be understood is that, what caused the failure and which interventions are being taken in order to achieve this missed achievement of targeted goal? This evidence of failure indicates that, if we are in the pace of preventing and ensuring proper management of traumatic patients, we still need multiple tiers of influence of which some of them would be to solve old problems with new solutions. Road traffic accident is responsible for about 75% of blunt abdominal trauma [24]. As such mitigating road traffic accidents would favor the reduction the burden of abdominal trauma. But also, there is a need for designing new ways for avoiding the occurrence of other physical violence leading to injuries. The emphasis should be directed to designing new ways for maintaining optimal peace in many parts of the world.

As the World continues to advance solving old problems with new solutions is an effective and efficient way for mitigating various problems of Worlds' populations. Scientists have devised various approaches to use in order to mitigate the burden of abdominal trauma. In **Table 12** we highlighted essential points of various strategies devised by scientists in order to mitigate the burden of abdominal trauma. Intuitively some of stated strategies require high level of expertise and should be done with support of modern technologies. Thus, there are likely not to be available in most of developing countries. As such unacceptable poor outcomes to traumatic abdominal patients are ever reported. Thus, one would affirm the principles of preventing all factors leading to the occurrence of abdominal trauma as real solutions for avoiding the complications associated with abdominal trauma management in many countries.

More so, in this chapter we described various complications such as shock, sepsis etc. associated with the management of abdominal trauma. Infections were described

- Light is environmentally approachable and non-polluting
- Light is comparatively safe and non-toxic
- Light does not cause unwarranted injury to the material surrounding the biological agent, whether inorganic, organic, or living
- Light is relatively cheap to produce
- Light acts speedily, generally within seconds.
- Light can be pragmatic to human skin, wounds, mucosa, and other locations of contact minus initiating unnecessary injury
- There have been no reports of microbial cells evolving resistance to light-based anti-infectives

Table 14.
Advantages of light over alternative disinfectants, biocides, and anti-infectives.

as dreaded complication to associate with management abdominal trauma. Most importantly, we described strategies for preventing the occurrence of infections. We highly recognized the potential of antimicrobials in terms of mitigating infections however; due to notable resistance, high virulence of some microbes and unavailability of antimicrobial agents in some hospitals as factors limiting effectiveness and usability of antimicrobial agents; We additional described use of light based technology as new way to use for mitigating infections among traumatic abdominal patient. As shown in **Table 14** light based technology has substantial advantages over alternative disinfectants, biocides, and anti-infectives. What remains unknown is the safety and how this technology can be used effectively and efficiently to mitigate infections. The greater considerations should be given to developing countries because most of the infectious complications are reported in these countries.

8. Conclusion

In this chapter we discussed various aspects related to complications associated with management of abdominal trauma. The main goal of this chapter has been to describe strategies which can be used to avoid the occurrence of complications associated with the management of abdominal trauma. As real fact abdominal trauma is persisted old problem which must be solved with new solutions. To achieve such task a great deal of emphasis should be dedicated to preventing the occurrence of abdominal trauma. Truly, without stopping the occurrence of abdominal trauma, complications associated with its management will continue to occur. Timely initiation of evidence-based management protocols for abdominal trauma can improve patient outcomes. Evidences have shown that, management of traumatic abdominal patient at standard trauma centers coupled with optimal use of modern technology favors the benefits of decreasing mortality and morbidity associated with abdominal trauma. In fact various countries especially developed countries have endorsed the availability of standard trauma care and modern technology to be used while managing traumatic abdominal patient. Greater disparities exist between developed and developing countries in terms of tackling various cases of trauma. What remains unknown is how to eliminate these disparities? New strategies should be designed in order to eliminate such disparities. All worlds' countries have adopted the agenda to achieve sustainable development goals by 2030. It has been strongly affirmed that none should be left behind. Putting more efforts in solving abdominal trauma with new solutions is an effective way to use for supporting traumatic abdominal patient to move with others in the journey towards achieving sustainable development goals.

9. Future prospectus

Many publications have affirmed that, majority of trauma cases happen in middle and low income countries. However, data showing specifically epidemiology of trauma per body region are not available in these countries. For instance there is lack of data showing epidemiology of abdominal trauma in developing countries and as real fact it is hard to know extent of the complications associated with the management of abdominal trauma in these countries. Designing a new strategy for collecting trauma data per body region will support to develop new strategies that will be used to mitigate the burden of such certain injuries. Moreover, uses of imaging modalities are highly essential in terms of improving management outcomes for trauma patient. However, there is still shortage of these imaging modalities in most of developing countries probably due to the fact that, these imaging modalities are very expensive. Dealing with companies which manufacture equipments of imaging modalities to ensure cost effectiveness for these equipments will support in terms of availability of these imaging modalities in developing countries and this will be one of the new solutions for solving abdominal trauma plus among others.

One of the targets of SDGs 3 has been to halt number of global deaths and injuries from road traffic accidents. This target was to be achieved by 2020; however, globally a road traffic accident which is the major cause of blunt abdominal trauma continues to happen at unacceptable level. Rethinking on new strategies for achieving this designed target which aim to mitigate global deaths from injuries will support to reduce complications associated with trauma. Moreover, many communities and countries continue to lack peace, which is among the leading cause of abdominal trauma and other injuries. Various authorities from all parts of the world should look for the new ways of maintaining peace and this will reduce suffering caused by physical violence for many people.

Acknowledgements

Firstly, I would like to acknowledge my dear DIANE UMWALI, my parents JOTHAM KAMEGELI AND KESIE NYIRANGEJEJAHO, and my Elder brother GERARD NKUNZURWANDA for their profoundly constructive, supportive and inspiring ideas, and financial support given to me while preparing this chapter. Secondary, I sincerely thank the Government of RWANDA for its profoundly commitments and ambitions towards: (1) achieving sustainable development goals by 2030 and vision 2050, (2) optimizing health status of all Rwandans, (3) empowering the youths, and (4) creating strong communities which love life and development more than any other things etc. Without these commitments this work would have not come into the reality.

Conflict of interest

The author declare no conflict of interest.

DOI: http://dx.doi.org/10.5772/intechopen.106229

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Chapter 3

Life Threatening but Preventable and Treatable Medical Complications of Abdominal Trauma

Raghavi Abhilesh Bembey and Ram Babu

Abstract

Management of the patient who underwent trauma involves simultaneous interaction buy different physicians and surgeons. The physician, surgeon and anesthesiologist usually form a team, all of whom bring their different perspective and expertise for treatment of the patient. This starts a series of events that culminates in medical evaluation, anesthetic assessment, preoperative assessment, perioperative management and post operative management of the patient as a whole. The evaluation of any trauma patient begins with evaluating the airway, accessing the breathing, and managing the circulation. After deep initial management of the patient either surgical or medical, prognosis of patient depends on follow up monitoring and care, as mortality in such patients is very high due to complications as listed below, whose early diagnosis and management will be discussed in detail in our chapter: inadequate resuscitation; delays in diagnosis and treatment; intra-abdominal sepsis; deep vein thrombosis, pulmonary embolism and thromboembolic events; hematological disorders like anemias, bleeding disorders, thrombocytopenia etc.; cardiac complications like arrhythmias, stress cardiomyopathy etc.; pulmonary and gastrointestinal complications like HAP, paralytic ileus, GERD etc.; metabolic disorders like acidosis, alkalosis, dyselectrolemia etc.; trauma complicated due to pregnancy, addictions and comorbid conditions like DM, HTN etc.

Keywords: abdominal trauma, sepsis, thromboembolisim, arrhythmias, acute dialysis, post traumatic jaundice, hyperkalemia

1. Introduction

Abdominal trauma causes multi system disorder with many reasons causing morbidity and mortality. While the primary site of injury is given utmost importance, simultaneous initial resuscitation should be initiated at the earliest. Here in this

chapter we try and discuss very common, lethal complications of abdominal trauma which are commonly missed leading to bad outcome. A multidisciplinary team is needed to treat the patient as a whole and therefore need multiple referrals and consultation.

After initial evaluation and management as following a detailed survey needs to be done:-.

- Primary survey: A, B, C, D, E evaluation and stabilization of Airway, Breathing, Circulation, Disability (neurologic status), and Exposure/Environmental control.
- Secondary survey: Head-to-toe examination after initial stabilization.
- Selective use of CT and other imaging studies.

Evaluation and treatment are done simultaneously. Done as A, B, C, D, E, for Airway, Breathing, Circulation, Disability (neurologic status), and Exposure/Environmental control. All major body systems are thoroughly and rapidly examined for any serious injury or abnormalities (known as primary survey); followed by a very detailed examination (known as secondary survey), once the patient is stabilized.

The 10 Commandments for powerful consultation have been pro-posed by using Goldman and associates in 1983 [1]. 1. To determine the question and address the question. 2. To perform the consultation in a timely. 3. To perform a thorough evaluation. 4. Writing a concise and appropriate consultation report. 5. Recommendations needed should be made clear and concise. 6. To provide early and prompt communication. 7. Do not “clear for OR.” Physician should identify all risks and attempt to correct them and optimize the patient for surgery. 8. To provide detailed, routinely and appropriate follow-up. 9. Role should be known appropriately: pure consultant versus co-manager. 10. Provide treatment options and alternative approaches and teach others tactfully.

2. Preoperative assessment of patient

Regular test needed for every patient needs haemogram, liver and function test, urinalysis, sugars, electrocardiography and chest X ray.

3. Antimicrobial prophylaxis

Factors involved in the development of postoperative infections [2] (**Table 1**):

- Pathogenic bacteria present at operative site in significant numbers.
- Environment of local wound: tissue fluids, blood, necrotic tissue
- Host immune status: age, immunocopromised, diabetes mellitus, obesity and nutrition
- Surgical skills needed and length of procedure.

Type of procedure	Definition
Clean	Atraumatic; with no break; gastrointestinal, respiratory, genitourinary tracts not entered
Clean contaminated	Respiratory or gastrointestinal tract are entered but no spillage; entry into oropharynx, sterile genitourinary, or biliary tract; minor break in technique
Contaminated	Acute inflammation present; urine or bile infected; gross spillage from gastrointestinal tract
Dirty	Established infection

Table 1.
Classification of surgical procedures by degree of contamination and risk of subsequent infection [3].

- Presence of foreign body.
- Type of surgical procedure.

3.1 Non-antimicrobial interventions to decrease surgical site and related infections

- Preoperatively
    - reduce preoperative hospitalization.
    - Treatment of remote sites of infection prior to surgery.
    - Clipping of hair at site preferred, avoid shaving or delay until time of surgery.
    - Appropriate use of antibiotics preoperatively.
    - Correction of malnutrition and deficiencies.
    - Strict diabetes control.
- Intraoperatively/postoperatively
    - Skin preparation done carefully.
    - Rigorous use of aseptic technique.
    - High-flow filtered air or laminar flow use.
    - Reducing dead space.
    - Minimize the use of and duration of catheters and intravenous lines postoperatively.
    - Adequate hydration, oxygenation, and nutrition needs to be maintained postoperatively

3.2 General principles of antibiotic selection and use

See **Table 2**.

Nature of operation	Common pathogens	Recommended drugs	Adult dose before surger[#]
Cardiothoracic (including pacemaker placement)	*Staphylococcus aureus*, *Staphylococcus epidermidis*	Cefazolin Cefuroxime Vancomycin	1–2 g IV 1.5 g IV 1 g IV
Gastrointestinal			
Esophageal, gastroduodenal	Enteric gram negative bacilli, gram-positive cocci	Cefazolin	1–2 g IV
Biliary tract (including cholecystectomy)	Enteric gram-negative Bacilli, enterococci, clostridia	Cefazolin	1–2 g IV
Colorectal (including appendectomy, non-perforated)	Enteric gram-negative bacilli, anaerobes, enterococci	Oral: neomycin plus erythromycin base OR metronidazole Parenteral: ertapenem or cefotetan or cefoxitin OR cefazolin plus metronidazole[$]	1 g IV 1–2 g IV 1–2 g IV 1–2 g IV 0.5–1 g IV
Rupture of viscus	Anaerobes, Enteric gram-negative bacilli, enterococci	Ertapenem or cefoxitin or cefotetan with or without gentamicin[$]	1 g IV 1–2 g IV 1–2 g IV 1.5 mg/kg IV q8h
Genitourinary	Enterococci, enteric gram-negative bacilli	Ciprofloxacin	500 mg PO or 400 mg IV
Gynecologic and Obstetric trauma	Enteric gram-negative bacilli, anaerobes, group B streptococci, enterococci	Cefotetan or cefoxitin or cefazolin	1–2 g IV 1–2 g IV 1–2 g IV
Abortion and Dilatation and curettage	Enteric gram-negative bacilli, anaerobes, group B streptococci, enterococci	First trimester:- Aqueous penicillin G OR doxycycline Second trimester: Cefazolin	2 million units IV 300 mg PO 1–2 g IV
Vascular Arterial surgery involving a prosthesis, abdominal aorta, or groin incision	S. aureus, S. epidermidis, enteric gram-negative bacilli	Cefazolin OR Vancomycin	1–2 g IV 1 g IV

[#]Given as single dose within 60 min before operation. For prolonged operations, additional doses may be necessary. If vancomycin or a fluoroquinolone is used, give 60 to 120 min before incision.
[$]Continue for 3 to 5 days post trauma. Need to expand coverage for nosocomial pathogens in postoperative dehiscence.

Table 2.
Antimicrobial prophylaxis for prevention of specific surgical site infections [4].

3.3 Causes of post traumatic and surgical fever

- Non-infectious

  Adrenal insufficiency

  Alcohol withdrawal

  Atelectasis

  Blood (hematoma/CSF)

  Dehydration

  Drug fever (including anesthetics)

  Intravascular device infections

  Malignant hyperthermia

  Myocardial infarction

  Neoplasms, rhabdomyolysis

  Pancreatitis

  Pheochromocytoma

  Pericarditis/Dressler's syndrome

  Pulmonary embolism

  Thyrotoxicosis

  Tissue trauma

  Transfusion reaction

- Infectious causes

  Abscess

  Bloodstream infections

  Cholecystitis

  Clostridium difficile colitis

  Endocarditis

  Infusion-related infections

  Parotitis, Peritonitis

  Pneumonia

  Prostatitis

  Surgical site infections

  Superficial incisional infection

  Deep incisional/space infection

  Thrombophlebitis

Transfusion related(CMV, hepatitis)

Urinary tract infection

4. Patients AT high risk for regurgitation of gastric contents

Regurgitation of gastric contents needs to be prevented in trauma patient at it leads to multiple complications like aspiration pneumonia, ARDS, metabolic disturbances etc.

- Gastric Distention
    - preoperative fasting is inadequate
        1. gastric emptying delayed
        2. Functional
        3. Obesity
        4. Pain
        5. Sepsis
        6. Uremia
        7. Pregnancy
        8. Shock
        9. Stupor/coma
        10. Autonomic neuropathy (e.g., diabetes, Shy-Drager syndrome)
        11. Recent abdominal surgery
    - Drug-induced
        1. Anticholinergics
        2. Opioids
        3. Antiparkinsonian agents
    - Intestinal obstruction/pseudo-obstruction
        1. Alcohol ingestion
- Gastroesophageal Reflux:- drug induced, idiopathic, obesity or pregnancy related, collagen-vascular diseases

- Esophageal Disease like neoplasms, foreign body, webs or strictures

5. Risk factors for venous thromboembolism

- Surgery
- Trauma (major or lower extremity)
- Advanced age
- Obesity
- Central venous catheters
- Heart or respiratory failure
- Immobility, paresis
- Previous deep vein thrombosis or pulmonary embolism
- Varicose veins
- Inflammatory bowel disease
- Pregnancy and the postpartum period
- Estrogen-containing oral contraceptives or hormone replacement therapy, Selective estrogen-receptor modulators
- Myeloproliferative disorders, Paroxysmal nocturnal hemoglobinuria
- Smoking
- Malignant disease
- Cancer therapy (hormonal therapy, chemotherapy, or radiotherapy)
- Nephrotic syndrome
- Inherited or acquired thrombophilia

5.1 Prophylaxis for thromboembolisim

- Heparin prophylaxis
    - 5000 U subcutaneously administered 2 h before surgery.
    - 5000 U subcutaneously administered, q8h or q12h postoperatively.

This regimen is followed until the patient is discharged.

- Low-molecular-weight heparin prophlaxis

  Dalteparin: 5000 U subcutaneously administered, q24h (to be initiated on evening of surgery).

  Fondaparinux: 2.5 mg, subcutaneously administered, started 6 h after surgery followed by once daily.

  Enoxaparin: 40 mg subcutaneously administered, q24 hourly (to be initiated on evening of surgery). 30 mg administered subcutaneously q24h, if creatinine clearance of less than 30 mL/min [5].

- WARFARIN PROPHYLAXIS

1. 10 mg by mouth the evening before surgery.

   5 mg by mouth the evening of surgery

   Adjust dose daily based on an INR of 2 to 3.

   Maintain warfarin until discharge.

2. 10 mg by mouth the evening of surgery.

   No warfarin on postoperative day 1

   On postoperative day 2, begin warfarin to adjust INR to 2 to 3

   Maintain warfarin until discharge

We recommend the following regimen for prophylaxis post surgery for abdominal trauma:-

- Low-risk surgery including minor procedure, no risk factors for VTE, age > 40 years:- ambulation initiated at the earliest postoperatively.

- Moderate-risk surgery including non major procedure, age >60 years with no VTE risk factors, age 40–60 years with VTE risk factors or major procedure.

  Treatment:- Heparin: 5000 U, SC, q12 hourly.

  Enoxaparin: 40 mg, SC, started 12 h postoperatively, followed by 40 mg, SC, q24 hourly.

  Dalteparin: 5000 IU, SC, started 12 h postoperatively, followed by 5000 IU, SC, q24 hourly

- High-risk surgery including non major surgery with age > 60 yr.; VTE risk factors; major surgery, age > 40 yr., or presence of VTE risk factors

  Treatment:-Heparin: 5000 U q8 hourly.

  Enoxaparin: 40 mg, SC, started 12 hourly postoperatively, followed by 40 mg, SC, q24 hourly.

Dalteparin: 2500 IU, SC, 1–2 h preoperatively then 2500 IU, SC, 12 h postoperatively, followed by 5000 IU, SC, q24 hourly

- Very high-risk surgery including major surgery, multiple VTE risk factors present or age >60 years

  Treatment: External pneumatic compression with anticoagulant therapy including;- Heparin: 5000 U, SC, q8 hourly.

  Enoxaparin: 40 mg, SC, started 12 hours postoperatively, then 40 mg, SC, q24 hourly.

  Dalteparin: 5000 IU, SC, started 12 h postoperatively, followed by 5000 IU, SC, q24 hourly [6].

6. Evaluation of heamatological disorders

Internal bleeding is a major complication of both blunt and penetrating trauma. Signs and symptoms are Abdominal pain, distension of abdomen and these symptoms get worse as the bleeding continues. Light-headedness, fainting can cause hypotension and hypovolemic shock. A large area of skin can get deep purple stained known as ecchymosis caused as a result from bleeding into the skin or soft tissues [7] (**Figures 1** and **2**).

6.1 Indications for phlebotomy in erythrocytosis

- Relative erythrocytosis: Not indicated.
- Stress erythrocytosis: Not indicated.
- Appropriate erythrocytosis resulting from cardiopulmonary disease: To hematocrit 50–60%.
- Inappropriate primary erythrocytosis (polycythemia vera): To hematocrit <45%.
- Inappropriate secondary erythrocytosis: To hematocrit <50%.

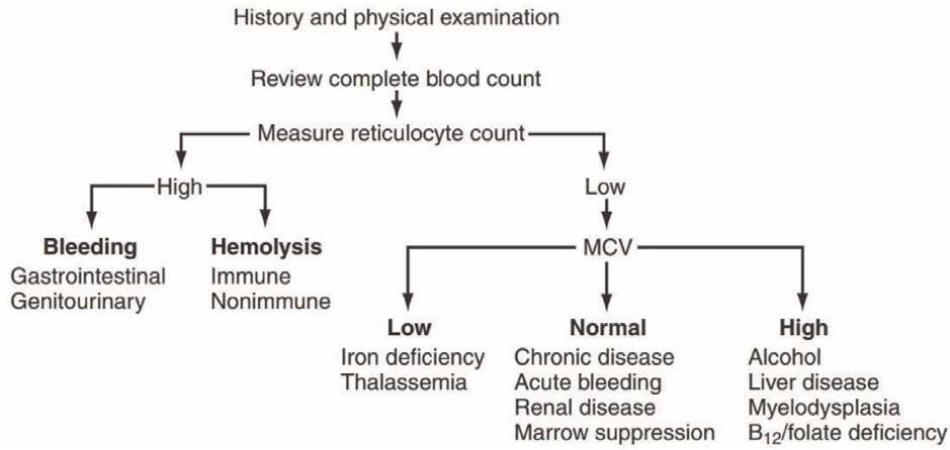

Figure 1.
Diagnostic evaluation of anemia. MCV, mean corpuscular.

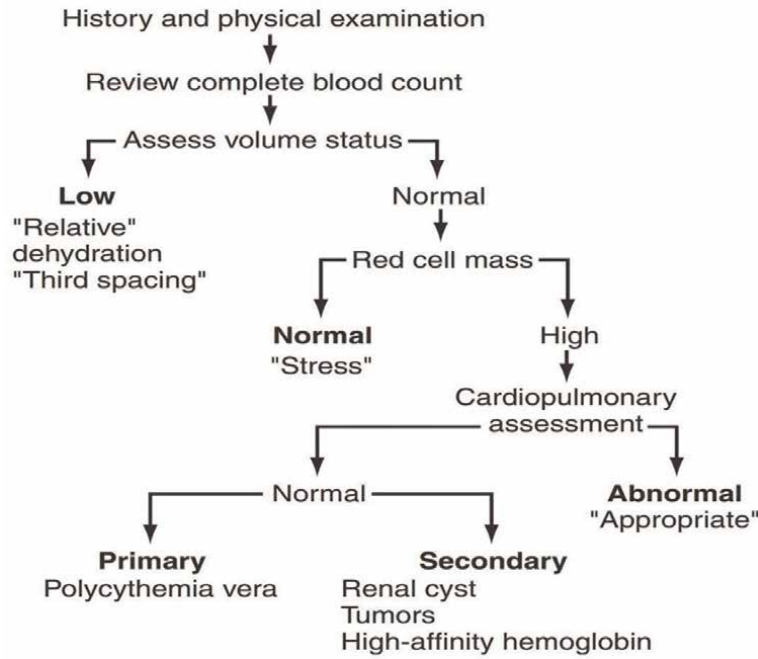

Figure 2.
Evaluation of erythrocytosis.

Other common hematological disorders needing attention:- sickle cell anemia, leukcopenia, nutritional deficiencies, bone marrow suppression, thalassemia, chronic renal failure, hemolytic anemias etc.

6.2 Steps of homeostasis

Injury to vessel wall ➔ primary vasoconstriction ➔ interaction of von Willebrand protein with sub endothelium ➔ formation of platelet plug ➔ fibrin formation ➔ clot dissolution and endothelial regeneration (**Figure 3**).

Assessment of homeostasis: careful history, bleeding time, prothrombin time, APTT, PT-INR, platelet count (**Table 3**).

Differential diagnosis for deranged coagulation test

- Prolonged bleeding time: Thrombocytopenia, von Willebrand disease, platelet function defect,
- Prolonged PT: liver disease, vitamin K deficiency, factor VII deficiency, warfarin use
- Prolonged PTT: Factor XII, XI, IX, or VIII deficiency, von Willebrand disease, heparin induced, DIC.
- Prolonged PT and PTT: Vitamin K deficiency, DIC, warfarin induced.

After diagnosis of bleeding disorder the treatment should be initiated accordingly with platelet or fresh frozen plasma infusions, corticosteroids, anti D etc [8].

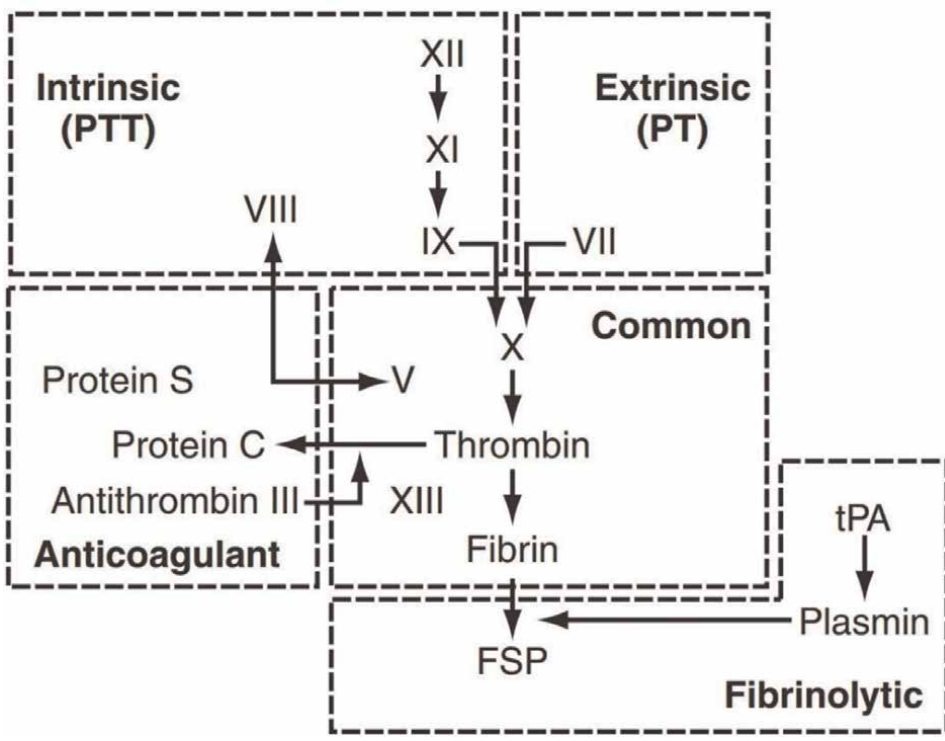

Figure 3.
Coagulation scheme with anticoagulant mechanisms. FSP:- fibrin split products; PT:-prothrombin time; PTT:- partial thromboplastin time; tPA:- tissue plasminogen activator.

Pathophysiology	Causes	Significant findings
Production decreased	Aplastic anemia	leukopenia, anemia, abnormal bone marrow, Folate deficiency abnormal, vitamin B12 low, radiotherapy or chemotherapy
Sequestration	hypersplenisim	Splenomegaly, hypercellular bone marrow, anemia, leukopenia, normal smear
Destruction increased	Idiopathic thrombocytopenic purpura, acquired immunodeficiency syndrome, drug induced, systemic lupus erythematosus	Hematocrit,white blood cell count are usually normal with normal smear, megakaryocytic hyperplasia

Table 3.
Causes of thrombocytopenia: which needed to be treated according to cause after abdominal trauma for optimal homeostasis.

7. Assessment of respiratory pathologies

See **Figures 4** and **5**.

7.1 Risk factors for post traumatic pulmonary complications

See **Table 4**.

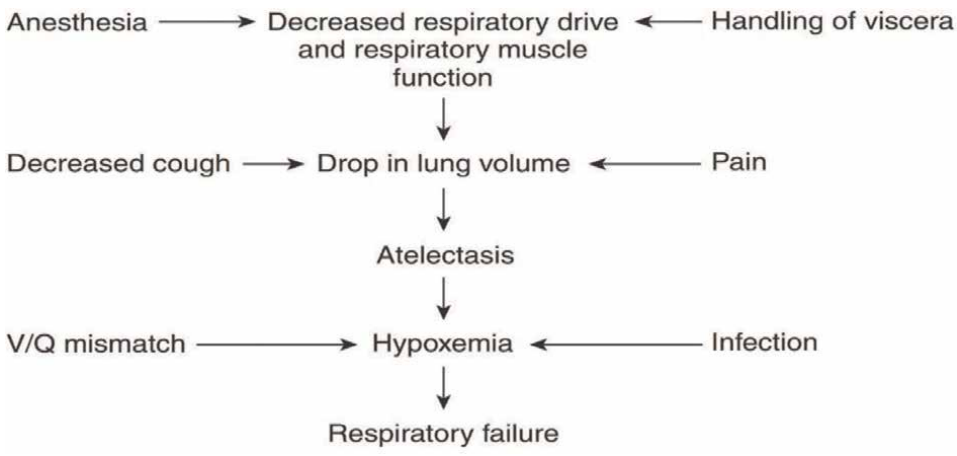

Figure 4.
Pathophysiology of the events leading to postoperative pulmonary complications. V/Q, ventilation/perfusion.

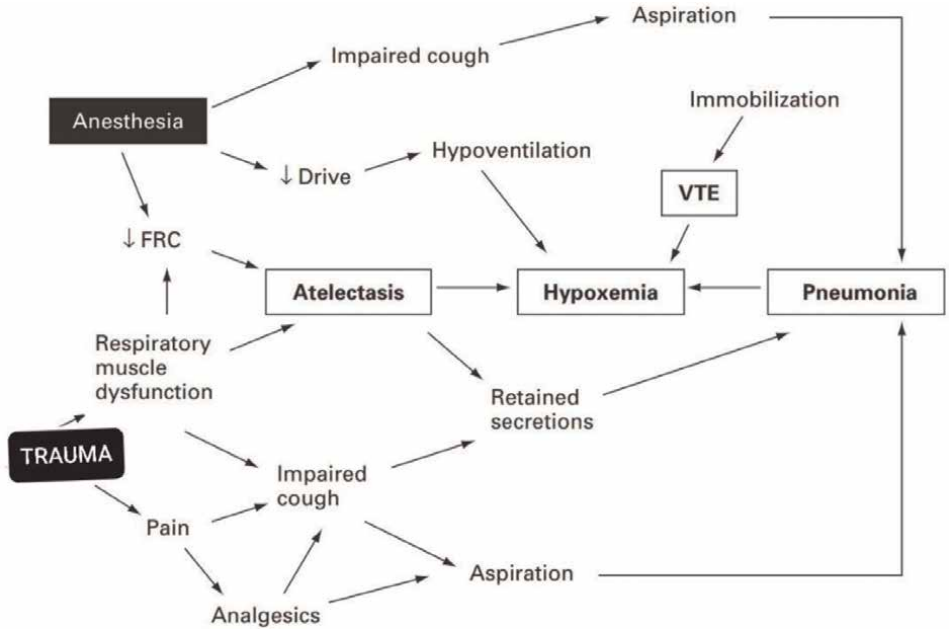

Figure 5.
Pathogenesis of major post traumatic pulmonary complications.

7.2 Causes of post traumatic pleural effusions

A) Transudate:-

- Congestive heart failure

Patient-related	Procedure-related
• General health and nutritional status	• Incision near diaphragm
Age	Thoracic surgery
Low albumin	Upper abdominal surgery
• >Functional status	AAA repair
Weight loss >10%	• Surgery technique
ASA Class	Open vs. laparoscopic
Goldman class	• Anesthesia duration >2 h
• Respiratory status	• Use of spinal/epidural anesthesia vs. general anesthesia
COPD history	• Use of long-acting neuromuscular blockade (pancuronium)
Tobacco use	• Pain control with parenteral narcotics vs. epidural analgesia
Sputum production	• Postoperative Nasogastric tube placement
Pneumonia	
Dyspnea	
OSA	
• Neurological status	
Impaired sensorium	
• CVA history	
• Fluid status	
• CHF history	
• Renal failure	
Low or high BUN	
• Preoperative blood transfusion	
• Immune status	
• Chronic steroid use	
• Alcohol use	

Table 4.
Risk factors for post traumatic pulmonary complication.

- Hypervolemia
- Ascites
- Misplaced central venous catheter
- Pulmonary embolism (rarely)
- Postpericardiotomy syndrome
- Diaphragmatic contusion

B) Exudate:-

- Pneumonia
- Pulmonary embolism
- Subphrenic abscess
- Empyema
- Atelectasis

8. Assessment of cardiovascular diseaes

8.1 Clinical predictors of increased perioperative cardiovascular risk (myocardial infarction, congestive heart failure, death)

- Major [9]
    - Unstable coronary syndromes
    - Acute MI (documented MI less than 7 days previously)
    - Recent (greater than 7 days but less than or equal to 30 days).
    - Significant arrhythmias
    - myocardial infarction with evidence of important ischemic risk by clinical symptoms or non-invasive study
    - Severe valvular disease
    - Unstable or severe angina (Canadian class III or IV)
    - High grade atrioventricular block
    - Symptomatic ventricular arrhythmias in the presence of underlying heart disease
    - Decompensated congestive heart failure
    - Supraventricular arrhythmias with uncontrolled ventricular rate
- Intermediate
    - Previous myocardial infarction by history or pathologic Q waves
    - Mild angina pectoris (Canadian class I or II)
    - congestive heart failure
    - Renal insufficiency (serum Cr > 2.0 mg/dl)
    - Diabetes mellitus
- Minor
    - Abnormal electrocardiogram (left ventricular hypertrophy, left bundle branch block, ST–T abnormalities)
    - Low functional capacity like inability to climb one flight of stairs
    - Rhythm other than sinus (e.g., atrial fibrillation)

- Advanced age
- History of cerebrovascular accident
- Uncontrolled systemic hypertension

8.2 Arrhythmias and conduction abnormalities

- Perioperative risk factors for arrythmia:
  - male sex
  - age 70 years or older
  - significant valvular disease
  - history of supraventricular arrhythmia, asthma, congestive heart failure
  - premature atrial complexes on preoperative electrocardiography
- Common arrhythmias in abdominal trauma patients
  - Sinus tachycardia:- Sinus tachycardia is a rhythm abnormality, usually benign. Heart rate is between 100 and 160 beats/min, regular rhythm with a normal P wave before each QRS complex.
  - Reflex bradycardia.
  - Atrial premature contractions, atrial flutter and fibrillation.
  - Paroxysmal supraventricular tachycardia:- characterized by the sudden onset of a rapid regular rhythm with rates between 150 and 250 beats/min.
  - Multifocal atrial tachycardia (MAT):- is an automatic arrhythmia characterized by an atrial rate greater than 100 beats/min with organized, discrete, non-sinus P-waves with at least three different forms in the same electrocardiographic lead.
  - Ventricular premature contractions and non-sustained ventricular tachycardia.
  - Sustained ventricular tachycardia and ventricular Fibrillation.
  - Long QT syndrome:- is a heterogeneous group of disorders characterized by a prolonged QT interval when corrected for heart rate, malignant ventricular arrhythmias (classically the torsades de pointes form of ventricular tachycardia), and the risk of sudden death. Causes:- Antiarrhythmic drugs (Type IA agents (e.g., quinidine), Type III agents (Amiodarone), Tricyclic antidepressants, antibiotics (e.g., erythromycin, azithromycin, ketoconazole), Metabolic and electrolyte disorders (Hypokalemia, Hypomagnesemia),

Nutritional disorders (starvation, liquid protein diets), Subarachnoid hemorrhage, Intracerebral hemorrhage, Head trauma, Encephalitis.

8.3 Indications for implantation of cardiac pacemakers

- Third-degree or advanced second-degree AV block associated with symptomatic bradycardia [10]
- Second-degree AV block with symptomatic bradycardia, bifascicular block with intermittent complete heart block with symptomatic bradycardia or symptomatic bifascicular block with intermittent type II block
- Second-degree AV block with sinus node dysfunction and symptomatic bradycardia
- After acute myocardial infarction with persistent second-degree AV block, bilateral bundle–branch block or third-degree AV block.
- Symptomatic and persistent second- or third-degree AV block.

8.4 Endocarditis prophylactic regimens for gastrointestinal injury surgery in abdominal trauma patient

Bacterial endocarditis prophylaxis is indicated for patients with specific cardiac structural abnormalities who are at risk for bacteremia resulting from the disruption of mucosal surfaces colonized with bacteria [11] (**Table 5**).

9. Assessment of gastrontestinal diseases

9.1 Factors that contribute to prolonged postoperative ileus

- Underlying medical conditions
    - Sepsis
    - Collagen vascular diseases
    - Amyloidosis
    - Diabetes mellitus
    - Thyroid disease
    - Peritonitis
    - Ischemic bowel disease
    - Electrolyte disturbances (e.g., hypokalemia)

Situation	Agent	Regimen
High-risk patients	Ampicillin and gentamicin	Adults: ampicillin 2gms intravenous or intramuscular and gentamicin 1.5 mg/kg (maximum dose 120 mg) 1st dose administered within 30 mints of initiation of Procedure followed 6 h later, ampicillin 1 g intravenous or intramuscular or oral amoxicillin 1 gms. Children: ampicillin 50 mg/kg intravenous or intramuscular (maximum dose 2gms) and gentamicin 1.5 mg/kg, 1st dose administered within 30 mints of initiation of procedure followed 6 h later with ampicillin 25 mg/kg intramuscular r intravenous or oral amoxicillin 25 mg/kg
High-risk patients with allergy to penicillin group	Vancomycin and gentamicin	Adults: vancomycin 1gm intravenous over 1–2 h with gentamicin 1.5 mg/kg, intravenous or intramuscular (maximum dose 120 mg), injection/infusion completed within 30 min of initiation of surgery Children: vancomycin 20 mg/kg, intravenous over 1–2 h with gentamicin 1.5 mg/kg, intravenous or intramuscular, injection/infusion completed within 30 min of initiation of surgery
Moderate risk patient	Amoxicillin/ampicillin	Adults: Oral amoxicillin 2gms, 1 h before sugery, or ampicillin 2gms intravenous or intramuscular, to be given with 30 min of initiation of surgery Children: Oral amoxicillin 50 mg/kg, given 1 h before surgery, or ampicillin 50 mg/kg intravenous or intramuscular, within 30 min of initiation of surgery
Moderate-risk with allergy to penicillin group	vancomycin	Adults: vancomycin 1gm, intravenous, infused over 1–2 h, within 30 min of surgery initiation Children: vancomycin 20 mg/kg, intravenous, infusion completed over 1–2 h of 30 min of surgery initiation.

Table 5.
Antibiotic prophylaxis for prevention of bacterial endocarditis in trauma patients.

- Intraoperative bowel manipulation
    - Open surgical procedure
    - Type of anesthesia
- Drugs
    - Opiates (e.g., morphine, codeine)
    - Opioids (e.g., fentanyl, pethidine, tramadol)
    - Nonsteroidal anti-inflammatory drugs (e.g., diclofenac, naproxen)
    - Phenytoin

- Anticholinergic agents (e.g., trihexyphenidyl, benztropine, amantadine)

9.2 Factors that contribute to colonic PSEUDO-obstruction

- Age
- Alcoholism
- Drugs
  - Narcotics
  - Antidepressants
  - Anticholinergics
  - Clonidine
  - Phenothiazines
- Metabolic causes
- Electrolyte imbalance
- Acid–base disturbances
- Hypothyroidism
- Diabetes mellitus
- Uremia
- Sepsis
- Inflammatory processes (e.g., pancreatitis and cholecy stitis)
- Infection
- Respiratory failure

9.3 Factors contributing to post- trauma nausea, vomiting

- Length of anesthesia
- Type of trauma (abdominal, gynecologic, urologic etc)
- Female
- Drugs

- General anesthetics
- Opiate analgesics
- Digitalis

- Postoperative ileus or pain
- Gastroparesis
- Refeeding after prolonged disuse of gastrointestinal tract
- Inflammatory processes
  - Peritonitis
  - Acute pancreatitis or cholecystitis
- Metabolic factors
  - Uremia
  - Hyperglycemia/hypoglycemia
- Electrolyte disturbances
- Dehydration
- Mechanical causes
  - Gastric outlet obstruction
  - Intestinal obstruction

Other complications which are common post trauma are gastrointestinal bleeding, gastric and stress ulcers, diarrhea, esophagitis, ischaemic collitis, pseudomembrane collitis, Mesenteric Ischemia and Infarction, Colonic Diverticulosis and angiodysplasia, intra abdominal hemorrhage [12].

9.4 Causes of post traumatic jaundice

See **Table 6**.

9.5 Local complications of abdominal trauma

Early	*Late*
Wound infection	Ulcer recurrence
Anastomotic leak	Recurrent bleeding from ulcer
Bile duct injury	Gastric outlet obstruction

Increased hepatic bilirubin load	Intrahepatic parenchymal disease
Hemolysis after Transfusions • Haematoma • Underlying hemolytic anemia	• Drugs ○ Antibiotics ○ Amoxicillin-clavulanic acid ○ Penicillins ○ Rifampin ○ Chloramphenicol ○ Sulfonamides ○ Erythromycins ○ Tetracycline ○ Isoniazid ○ Nitrofurantoin ○ Anesthetic drugs
Pre existing liver disease Gilbert's syndrome(Unconjugated hyperbilirubinemia resulting from a congenital defect in the hepatic uptake of bilirubi) Dubin-Johnson syndrome(Conjugated hyperbilirubinemia resulting from a congenital defect in secretion of bilirubin from hepatocytes)	• Other drugs • Androgens, estrogens • Phenothiazines • Phenytoin • Fluconazole • Methyldopa
Extrahepatic Obstruction • Common bile duct stone • Cholecystitis • Pancreatitis • Biliary stricture, leak, or tumor	• Other Causes Parenteral nutrition Viral hepatitis Sepsis Ischemic hepatitis

Table 6.
Post traumatic jaundice causes.

Delayed gastric emptying
Anastomotic bleeding
Anemia
Bile reflux gastritis
Postvagotomy diarrhea
Osteomalacia and osteoporosis
Post-gastrectomy carcinoma
Pancreatitis
Afferent loop syndrome
Dumping syndrome
Malabsorption

10. Assessment of renal disoders, electrolyte imbalance

10.1 Causes of perioperative renal failure

- Decreased renal perfusion
    - Intravascular volume depletion
    - Congestive heart failure
    - Sepsis
    - Cardiopulmonary bypass

- Anesthetic effects on renal blood flow
- Aortic cross-clamping
- Use of non-steroidal anti-inflammatory drugs or cycloxygenase inhibitors
- Use of angiotensin converting enzyme inhibitors/angiotensin receptor blockers

- Nephrotoxin exposure
  - Aminoglycosides
  - Radiocontrast agents
  - Anesthetic agents
  - Myoglobin/rhabdomyolysis

10.2 Indications for acute dialysis

- Symptoms and signs associated with uremia in patients with creatinine clearance <20–25 ml/min per 1.73 m^2 [13].
- Nausea, vomiting, anorexia.
- Other gastrointestinal symptoms (gastritis with hemorrhage, colitis with or without hemorrhage).
- Altered mental status (lethargy, somnolence, malaise, stupor, coma, or delirium).
- Signs of uremic encephalopathy (asterixis, multifocal clonus, or seizures).
- Pericariditis.
- Bleeding diathesis from uremic platelet dysfunction.
- Refractory or progressive fluid overload.
- Uncontrolled hyperkalemia.
- Severe metabolic acidosis, especially in an oliguric patient.
- Acute and progressive worsening of renal function with.
- Blood urea nitrogen levels >70–100 mg/dl.
- Measured creatinine clearance <15–20 ml/min.

Mechanisim	Causes
Increased potassium load	• Increased catabolism • Blood transfusion • Reabsorption of hematoma • Tissue breakdown • Red blood cell salvage • Potassium administration
Impaired transcellular potassium shift	• Fasting state (insulinopenia) • Beta blockers
Decreased potassium excretion	• Volume depletion • Constipation • Medications:-Trimethoprim-sulfamethoxazole, Potassium sparing diuretics, Angiotensin converting enzyme inhibitors, Angiotensin receptor blockers

Table 7.
Hyperkalemia in trauma patient—causes.

10.3 Causes of peritraumatic hyperkalemia

Hyperkalemia is very commonly associated with trauma reason of which are enlisted below (**Table 7**).

11. Assessment of other disorders and abdominal injury

11.1 Management of adrenal insufficiency

- Inquire about any preoperative use of glucocorticoids (systemic or inhaled) and symptoms suggestive of adrenal insufficiency.

- Administer hydrocortisone 100 mg intravenously q 8 h. Give first dose at least 1 h before induction of anesthesia.

- Once the patient is stable after operation, taper the hydrocortisone dose over 3–4 days to maintenance levels (30 mg/d in at least two divided doses) or to the patient's preoperative dose of glucocorticoid.

- Prevent volume depletion and hypoglycemia with the use of intravenous saline and glucose.

11.2 Approach to the delirious postoperative patient

- Detection is key; maintain high index of suspicion, especially for quiet, hypoactive delirious states. Consider bedside tests of memory and orientation or administration of more formal instruments such as Confusion Assessment Method (CAM).

- Review all medications, including those that the patient may have been taking prior to hospitalization. Remember that several common medications have significant anticholinergic effects.

- Focused physical examination to detect infection, comorbid conditions causing hypoxia and pain due to injury. Assess volume status and rule out fecal impaction and urinary retention. Neurological examination to detect new, focal deficits.

- Further laboratory evaluation, as clinically appropriate may include complete blood count, serum electrolytes, pulse oximetry/arterial blood gas analysis and urinalysis. Consider chest X-ray to rule out pneumonia.

- Management strategies include environmental modifications, supportive measures and pharmacological treatment [14].

Risk factor for developing delirium in trauma patient:

- Age
- Preexisting central nervous system disease (e.g., dementia, Parkinson disease)
- Type and duration of surgery
- Sensory impairment (e.g., visual and hearing deficits)
- Hypoxia
- Metabolic derangements (e.g., hyponatremia, hyperglycemia, acid–base disorders, etc.)
- Infections
- Uncontrolled pain
- Chronic alcoholism
- Benzodiazepine dependence

11.3 Delayed consequences of abdominal trauma

- Rupture of hematoma
- Intra-abdominal abscess
- Obstruction or ileus of bowel
- Biliary leakage and/or biloma
- Abdominal compartment syndrome
- Delayed incisional hernia
    - Hematomas usually resolve spontaneously over time, depending on the size and location. Splenic hematomas or hepatic hematomas may rupture,

causing significant delayed hemorrhage. Intestinal wall hematomas may perforate, typically within 48 to 72 h after injury, releasing intestinal contents and causing peritonitis, but without causing significant hemorrhage. Intestinal wall hematoma can cause intestinal stricture, typically months to years later.

- Intra-abdominal abscess is the result of undetected hollow viscus perforation but may be a complication of laparotomy.

- Bowel obstruction may develop after injury due to intestinal wall hematoma or adhesions caused by intestinal serosal or mesenteric tears. More commonly bowel obstruction is a complication of exploratory laparotomy.

- Liver injury or bile duct injury can be lead to biliary leakage or biloma. Biliary leakage cause a systemic inflammatory response, severe pain or hyperbilirubinemia.

- Abdominal compartment syndrome is similar to extremity compartment syndrome. Mesenteric and intestinal capillary leakage caused by prolonged abdominal surgical procedures, shock, systemic inflammatory response syndrome [SIRS] or systemic ischemia–reperfusion injury causing abdominal tissue edema. Peritoneal edema and ascites, increases intra-abdominal pressure (that is pressure more than 20 mm Hg), leading to pain, dysfunction of organs due to ischemia. A vicious cycle is formed where intestinal ischemia further causes edema .

- Other affected organs dysfunction including renal insufficiency, elevated abdominal pressure interfering with respiration further causing hypoxemia or hypercarbia, decreased venous return from the lower extremities leading to hypotension, intracranial pressure increases due to increased central venous pressure, inadequate venous drainage from brain, decreased cerebral perfusion, worsening intracranial injuries.

Abdominal compartment syndrome occurs when there is vascular leak and high-volume fluid resuscitation usually more than 10 l. Develops after severe abdominal injury accompanied by shock, severe burns, sepsis, and pancreatitis also.

11.4 Spleenic injury

See **Table 8**.

The diagnosis is made with CT scan, followed by observation, angio-embolization, surgical repair or splenectomy.

11.5 Hepatic injury

See **Table 9**.

Diagnosis confirmed with CT scan followed by observation and surgical intervention [15].

Grades	Injury
1	Subcapsular hematoma involving less than 10% of surface area or laceration less than1 cm.
2	Subcapsular hematoma involving 10–50% of surface area, intraparenchymal hematoma less than 5 cm n size or laceration 1–3 cm deep sparing the trabecular vessel
3	Subcapsular hematoma involving more than 50% of surface area, intraparenchymal hematoma more than or equal to 5 cm in size, ruptured or expanding hematoma or laceration more than 3 cm deep or involvement of a trabecular vessel
4	Laceration involving segmental or hilar vessels which devascularizes more than 25% of spleen
5	Completely shattered spleen Hilar vascular injury that devascularizes spleen

Table 8.
Grade of splenic injury.

Grade	Injury
1	Subcapsular hematoma involving less than 10% of surface or laceration less than 1 cm.
2	Subcapsular hematoma involving 10–50% of surface area, intra-parenchymal hematoma less than 10 cm in size or laceration 1–3 cm deep and less than 10 cm in size
3	Subcapsular hematoma involving more than 50% of surface area, intra-parenchymal hematoma more than 10 cm size or ruptured or expanding hematoma or laceration more than 3 cm deep
4	Parenchymal disruption involving 25–75% of a hepatic lobe or 1–3 Couinaud segments within a single lobe
5	Parenchymal disruption involving more than 75% of one hepatic lobe or more than 3 Couinaud segments or juxtahepatic venous injuries present involving retrohepatic vena cava or central major hepatic veins
6	Hepatic avulsion

Table 9.
Grades of hepatic injury.

11.6 Renal injury

- Renal injuries can be classified into severity of following 5 grades:
    - Grade 1: Subcapsular hematoma with or without renal contusion.
    - Grade 2: Laceration less than or equal to 1 cm in depth without any urinary extravasation.
    - Grade 3: Laceration more than 1 cm without urinary extravasation.
    - Grade 4: Laceration which involve collecting system with extravasation of urine; renal vascular injury of any segment; renal infarction; renal pelvis laceration with or without disruption of ureteropelvic.
    - Grade 5: Shattering or devascularization of kidney with active bleeding; main renal vascular avulsion or laceration.

- High-grade renal injury (significant deceleration injury, direct blow to flanks) is suspected if after blunt trauma any of the following occur;
    - Gross hematuria.
    - Microscopic hematuria with hypotension (systolic pressure < 90 mmHg).
    - Diffuse abdominal tenderness.
    - Vertebral transverse process or rib fractures [15].
- Diagnosis confirmed with clinical evaluation, CT scan, urinalysis. Treatment involves strict bed rest with close monitoring of vitals, surgical repair, angiographic intervention.

11.7 Urogenital organs

Bladder, testicular, urethral and uretral injury are common with abdominal trauma, need to be confirmed with ultrasonography, retrograde urethrography and CT scan, followed by surgical intervention and correction.

12. Discussion

The abdomen is one of the most common organs to be injured in any form of trauma. The initial resuscitation, primary and second survey, followed by FAST (focused assessment with sonography in trauma) can detect injuries. During follow up treatment detailed blood investigatins, ultasonography, CT scan of abdomen and others can detect injury of liver, spleen, pancreas, bowel alongwith common complications like intra abdominal bleeding, perforations, peritonitis etc. which can be managed surgically with laparotomy or non surgically. Also common medical conditions like uncontrolled sugars, blood pressures, rheumatological, asthma and other chronic disorders are very paticularly considered and corrected by the team of treating physicians. However, this chapter discusses the complications which very commonly occur in post trauma patients but are missed,as the main focus of treatment is limited around the trauma injury itself. In regular planned surgeries proper and stringent pre operative check up is done, optimization of patient is done, followed with srict antiseptic technique, but in trauma patient where time is the key to save the patients life these actions are often missed with lack of time to optimize the patient medically for a surgery. Sepis commonly occurs in trauma patients mostly due to primary contamination of the trauma site, but also laxity in following of antiseptic conditions, which can easily be avoided by antibiotic prophylaxis, interventions to reduce surgical site infetions as mentioned, classification of the wound, early recognition of post operative causes of fever and treatment intiation accordingly. In abdominal trauma,patient's fasting status is not known and measures to prevent gastic content aspiration should be taken which may otherwise later lead to aspiration pneumonia, sepsis, etc. These patients are usually on bed rest for prolonged periods post trauma increasing the risk of venous thromboembolic events like pulmonary embolisim, strokes etc., which can be prevented with early mobilization, physiotherapy and adequate anticoagulation therapy. The dilemma of producing bleeds in trauma patients with anticoagulations can very well be avoided with strict monitoring

and proper dosing as discussed in the chapter. Intra abdominal bleeds and hemorrhagic shock are diagnosed and treated with blood transfusions, intravenous fluids, vasopressors as and when needed, but other hematological complications like anemia, platelet disorders, coagulation disorder, erythrocytosis need attention and treatment. Assessment and attaining homeostasis helps in early recovery of wound and patient. Post traumatic lung complications are mentioned which need to be addressed as mentioned, as they can lead to prolonged need of ventilatory support and delayed healing. Cardiac abnormalities like arrhythmias and endocarditis are common in trauma patient and can lead to mortality. Acute renal injury due to pre renal and renal causes with elctrolyte imbalances can lead to early and fast deterioration of patient. Delirium in post traumatic patients is not uncommon and had multiple reasons, most of which if diagnosed timely can be treated completely, preventing any psychological sequelae. We attempt to discuss and bring into light the missed complications of abdominal trauma, so as to keep these in mind during treating an abdominal trauma patient, as the eyes see what the mind knows. The conditions mentioned above can easily be treated, significantly reducing mortality and morbidity, giving good quality of life to patient post recovery. However, treatment for each of these is beyond the scope of the chapter.

13. Conclusion

Abdominal trauma is the third organ system affected in trauma [16]. It is either blunt abdominal or penetrating abdominal trauma. While there are multiple modalities to diagnose with FAST, and other hidden trauma along with common complications. The chapter tries to cover the rare and very commonly missed complications of abdominal trauma, which are of utmost importance and can be easily diagnosed. We discuss complications like sepsis, gastric content regurgitation, ileus and obstruction, venous thrombo-embolisim, bleeding causing hemorrhagic shock, hematological complications, cardiovascular disorders like arrhythmias, endocarditis, renal and electrolyte disorders, dehydration, delirium, solid organ injuries. These in particular are addressed as these are ignored and lead to late mortality even after primary stabilization and hemodynamic correction. Timely treatment of these conditions leads to a good prognosis, significantly reducing morbidity and mortality associated with missed diagnosis of above mentioned complications. Thus, at the end we would like to conclude that treating a trauma patient as a whole is more important than just the injury.

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Chapter 4

POCUS in Abdominal Trauma: Old Gadget, New Insights

Akshaya Ramaswami and Tej Prakash Sinha

Abstract

Abdominal trauma is difficult to identify, especially in a patient with multiple injuries. Mechanism of injury can guide us to the likely organs injured, but the extent and location cannot be accurately pinpointed in most cases. Owing to the multitude of structures located in the abdomen, timely identification and appropriate intervention are crucial to ensure the good patient outcomes. Focused assessment with sonography in trauma (FAST) and its extended version (eFAST) has become the standard care as per ATLS guidelines in patient evaluation. The main goal is to identify hemoperitoneum, hemothorax, and/or pneumothorax. However, sonography can be applied to detect varying injuries to abdominal viscera, beyond the elementary eFAST examination. This includes assessment of solid organs, hollow viscus, vascular structures, and even soft tissues. Sonography, when wielded with necessary knowledge and practice, can be an incredible asset at the bedside. This chapter aims to explore these possible applications of point of care ultrasonography (POCUS) in abdominal trauma.

Keywords: POCUS, solid organ injury, bedside sonography, vascular injury, blunt trauma abdomen

1. Introduction

Abdominal trauma has varied clinical presentations, most of which are subtle, and patients may appear stable at presentation [1]. The injuries sustained are not easily identified by surface appearance or examination. Abdominal trauma is usually not found as an isolated injury, but rather as part of polytrauma cases [2]. A patient with intoxication, altered sensorium due to head injury, severe injuries over the limbs or thorax may have sustained trauma to the abdomen, which may go undetected due to the distracting nature of the other symptoms. A high index of suspicion is required in such cases. Any trauma sustained between the nipple line to the pelvis warrants a search for intraperitoneal organ injury. Point of care ultrasonography (POCUS) is a powerful tool that can aid in the search.

1.1 Relevant anatomy

Abdomen holds complex structures along with a large potential space. Knowledge of anatomy is key to identifying the possible organs involved. In general, the abdomen is divided into nine regions (**Figure 1**) for purposes of evaluation. However, this

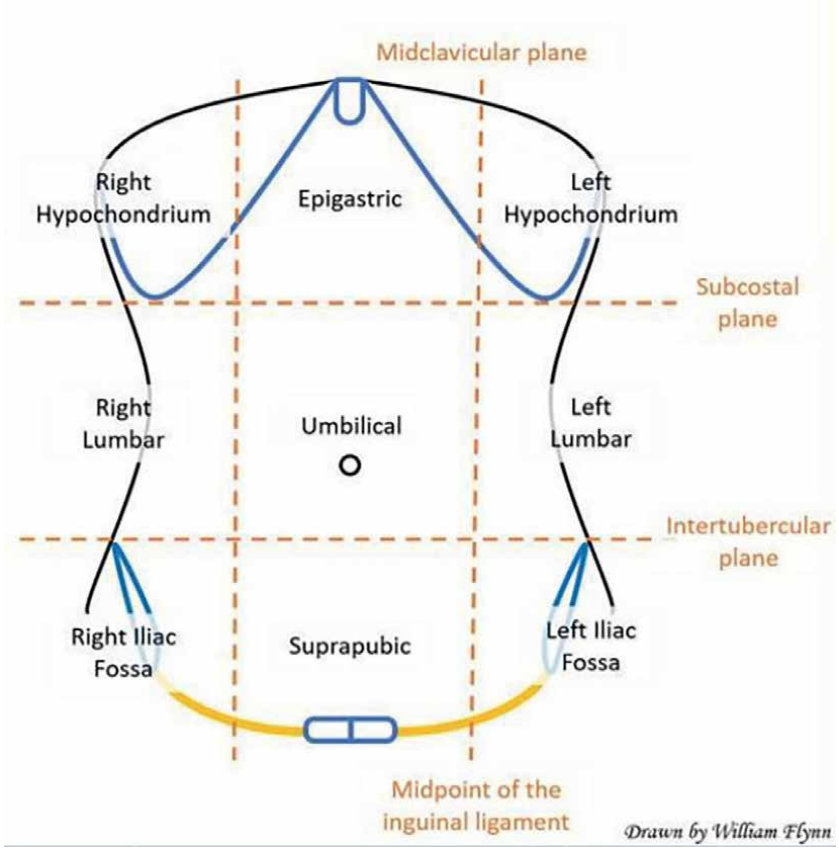

Figure 1.
Surface anatomy and regions of abdomen [3].

division studies the abdomen only from the anterior aspect. A more inclusive division of abdominal regions for trauma cases would be into four regions–lower chest, anterior abdomen, and flank and posterior abdomen. Based on the mechanism and location of the injury, the likely structures to be affected can be ascertained based on this division (**Table 1**). Retroperitoneum and pelvic structures can also be injured, however, are not well imaged by ultrasonography. POCUS can then be utilized effectively by screening these suspected structures with care, instead of performing an extensive abdominal scan that would delay the time and outcome for the patient.

Abdominal region	Extent	Suspected organs injured
Lower chest	Mid to lower thoracic cage	Liver, spleen, diaphragm, stomach
Anterior	Between anterior axillary lines	Liver, spleen, bladder, stomach, pancreas, transverse colon, ileum, jejunum
Flank	Between anterior and posterior axillary lines	Kidney, ureter, ascending and descending colon
Posterior	Between posterior axillary lines	Great vessels, duodenum, pancreas, spinal cord

Table 1.
Four abdominal regions.

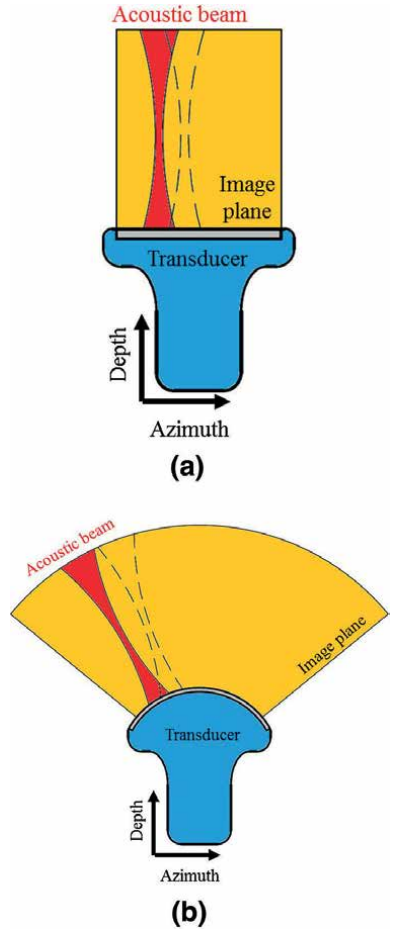

Figure 2.
Ultrasound probes – Linear (a) and curvilinear (b) [4].

The ultrasound machine is usually equipped with three basic probes - curvilinear, linear, and phased array probes (**Figure 2**). A curvilinear probe is of low frequency, allowing deeper imaging with a wide-angle view. A linear probe is of high frequency and visualizes superficial structures. By convention, the ultrasound probes when used in a sagittal or coronal plane have the pointer/marker toward the head end of the patient. In the transverse plane, the pointer is to be facing the right of the patient.

1.2 Focused assessment with sonography in trauma (FAST)

Advanced trauma life support (ATLS) guidelines have incorporated bedside sonography by non-radiologists in the evaluation of trauma patients. It is now standard of care to perform extended focused assessment with sonography in trauma (eFAST) in all cases as part of the primary survey and its adjuncts [5, 6]. eFAST serves to locate any obvious evidence of bleeding in the potential spaces of the abdominal and thorax. It can also help detect pneumothorax (**Table 2**). The abdomen is scanned in four areas (or views) – subxiphoid, right hypochondrium, left hypochondrium, and suprapubic (**Figure 3**). Both pleural cavities just above the diaphragm and pleural

Area examined	Organs visualized
Subxiphoid	Heart
Right hypochondrium	Liver, right kidney, diaphragm
Left hypochondrium	Spleen, left kidney, diaphragm
Suprapubic	Bladder, uterus/prostate
Hemithorax (each side)	Pleural line, diaphragm

Table 2.
eFAST examination.

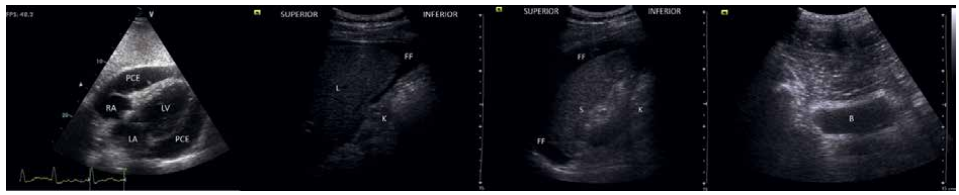

Figure 3.
FAST examination views – (from left to right) subxiphoid, right upper quadrant, left upper quadrant and suprapubic [7].

line movement on each side are also checked. FAST has even been utilized to grade the amount of intraperitoneal hemorrhage and help decide the need for laparotomy [8, 9]. Apt use of FAST has been shown to reduce time to intervention, the need for computed tomography (CT) scans, and reduce hospital stay as well as costs [10–12].

1.3 Beyond eFAST

With the advent of bedside ultrasonography, POCUS has become revolutionary in patient care. Its use in trauma settings no longer has to be limited to eFAST. Rather, this gadget can be handy in detecting several injuries within the abdomen - solid organ, hollow viscus, and even blood vessels. Timing of ultrasonography is critical so as to ensure that performing POCUS does not hinder or delay patient care. In any unstable patient with a suspected abdominal injury, the first objective is stabilization. This can include any and all measures, such as securing airway, chest drain placement, fluid resuscitation, blood transfusion, splinting, and suturing. These life-saving interventions take time, which provides the window to examine the abdomen by POCUS simultaneously without causing undue delay. As per ATLS guidelines, unstable patients who do not respond to resuscitation require transfer to the operating room (OR). POCUS-assisted identification of injuries at the bedside would guide the operating surgeons when exploratory laparotomy is underway.

In stable patients, the timing of POCUS is more complex. Patients with suspected abdominal trauma who are hemodynamically stable may be evaluated with contrast-enhanced computed tomography (CT) scans. POCUS is useful in those cases where CT scans are deferred, such as in pregnancy, intravenous contrast allergy, centers without CT capacity, and those who refuse or are uncooperative with the scan. In penetrating trauma, POCUS can be used in stable patients without the urgent need for operative intervention.

In this chapter, we will explore POCUS in abdominal trauma, which can be performed by even trained non-radiologists at the bedside.

2. Solid organ injury

POCUS for abdominal examination is usually done with the low-frequency curvilinear probe. A phased array probe may be utilized when imaging between rib spaces is required.

2.1 Liver and spleen

Liver is the most commonly injured abdominal organ in both blunt and penetrating trauma. The transducer is first positioned in the sagittal plane, pointer toward the head end of the patient and then in transverse position, and pointer toward the right of the patient. The organ to be examined is to be scanned from medial to lateral and cephalad to caudal. The liver is scanned from subxiphoid region to the left and right. Spleen is located by scanning above the left costal margin.

Hypoechoic areas within the liver parenchyma, which have no flow on color Doppler are likely lacerations or hematoma in the setting of trauma. These lesions can be measured and their extent delineated on ultrasonography. The perimeter of the organ should be scanned for anechoic collection, including sub-diaphragmatic area (**Figure 4**).

2.2 Kidney

Kidney is a retroperitoneal organ well visualized by ultrasonography. For visualizing the right kidney, the transducer is placed in the mid axillary line at the right costal margin and moved caudally till the kidney comes into view. The maximum length is identified by turning the probe obliquely and this plane marks the longitudinal axis of the kidney. The parenchyma is scanned by fanning the transducer in anterior and posterior directions. The transducer is then rotated 90 degrees to obtain a transverse view. The probe is tilted superiorly and inferiorly to examine the upper pole, hilum, and lower pole. The longitudinal view of the left kidney is visualized by placing the transducer in the posterior axillary line at the left costal margin and then moving caudally. The remaining views are obtained the same way as for the right kidney.

Major renal injury markers on ultrasonography are subcapsular hematoma, perinephric hematoma, and calyceal dilatation with internal echogenicity. Mixed echogenic material with disorganized renal architecture can be seen high-grade renal injury, such as fractured kidney with retroperitoneal hematoma (**Figure 5**). Fresh parenchymal hematoma on POCUS will be isoechoic and difficult to identify. Over

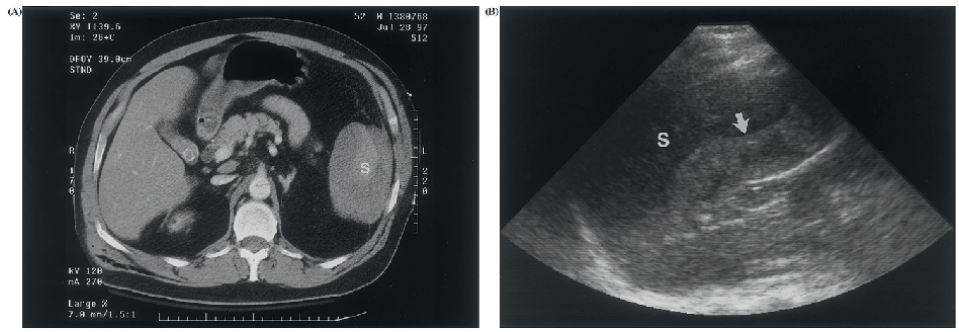

Figure 4.
Spleen injury of subcapsular hematoma as seen on CT (left) and USG (right) [13].

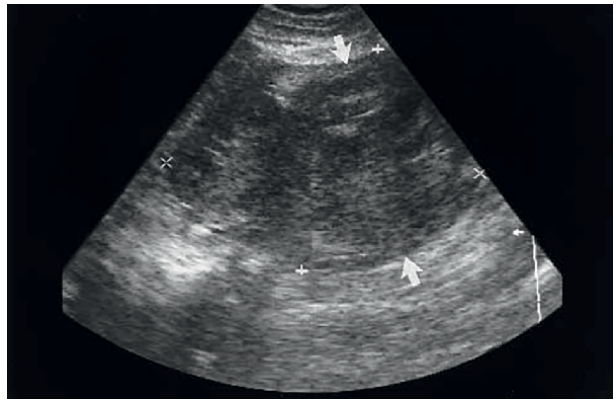

Figure 5.
High grade renal injury on USG with completely disrupted architecture [14].

time, it will become hypoechoic and easier to locate. The additional role of bedside ultrasonography includes follow-up of patients with these findings for resolution. It helps avoid repetitive radiation exposures and high costs.

Renal vascular injuries are identified by carefully scanning the hilum for abnormal Doppler flow. Segmental infarcts of the cortex are confirmed by the absence of perfusion on scanning.

2.3 Pancreas

Semierect patient position is preferred if possible to avoid interference from bowel gas. The left lobe of liver and spleen provide an acoustic window to visualize the pancreas. The transducer is placed in sagittal and transverse planes along the vascular landmarks. In the transverse plane, the pancreas is seen beneath the left lobe of the liver and crossing above the abdominal aorta and inferior vena cava and the splenic artery acts landmark as it runs along its posterior surface. In the sagittal plane, tthe tail of the pancreas is usually seen with a coronal view in a right posterior oblique position. The pancreatic duct is seen within the body of the pancreas seen as a tubular structure with reflective walls and a maximum diameter of 2 mm. Normal echotexture of the pancreas is similar to or more echoic than the adjacent liver.

When edema develops in the pancreas, the echogenicity reduces. Traumatic pancreatitis may be identified when it becomes a heterogeneous mass with an ill-defined border. There may be hypoechoic or anechoic collection around the pancreas due to bleeding or exudation. Rarely, pancreatic duct disruption can be detected (**Figure 6**).

2.4 Newer modalities/techniques

2.4.1 Contrast-enhanced ultrasonography

Solid organ injury can be detected by POCUS. Imaging can be augmented by contrast-enhanced ultrasonography. Second-generation contrast agents have been introduced that contain perflutren microbubbles that can cross the pulmonary capillaries and enter into the systemic circulation. The microbubbles vibrate with the high-frequency waves generated by ultrasonography probes, which in turn makes them more reflective than normal tissue (**Figure 7**).

Figure 6.
Pancreatic injury on USG seen as nonhomogeneous echotexture [15].

Figure 7.
Liver injury on traditional sonography (A) as hypoechoic lesion on right lobe (arrow), on contrast-enhanced USG (B) as extended liver rupture (arrows) and on CT (C), which confirmed the rupture (white arrow) [16].

In injuries to liver, spleen, and kidney, contrast-enhanced sonography images have been studied to allow better detection of injury extent compared to traditional sonography [16, 17].

2.4.2 Color Doppler in renal ultrasonography

Renal blood flow is evaluated by color Doppler to measure renal artery resistive index. It is a measure of tissue resistance to perfusion caused by vasoconstriction. This has been studied as a predictor of occult hemorrhagic shock in polytrauma patients with normal hemodynamic status in presentation. A value greater than 0.7 was studied to be predictive [18].

3. Hollow viscus injury

3.1 Pneumoperitoneum

Air is usually cited to be the enemy of ultrasonography as it obscures the view and affects image acquisition. However, this can be used to the advantage of the observer

when examining pneumoperitoneum, that is, free air in the peritoneal cavity. The patient is usually examined in a supine position with the bed elevated by 30 degrees at the head end or semilateral position with the elevation of the right flank. This is to allow the collection of free air in the peritoneal space anterior to the liver surface. Linear array probe is used in the sagittal plane with a pointer toward head end with right intercostal scanning.

The probe is placed gently over the right upper quadrant and scanned for air. Free air is visualized as a hyperechoic line with reverberation artifacts similar to that of the pleural line of the lung (**Figure 8**). When the caudal end of the probe is pressed gently over the area, the air can be displaced and the hyperechoic line will disappear and with release of pressure, the reverberation artifact will reappear. In some cases, the pleural line above the diaphragm is seen along with the pneumoperitoneum over the liver producing the pleuro-peritoneal step-off sign.

3.2 Small and large bowel

In patients with abdominal trauma, the bowel wall can be examined. However, the focused examination would be more effective than screening the entire bowel at the bedside. A high-frequency linear array probe is used to scan the bowel. It can even distinguish between the bowel wall layers. The small bowel can be differentiated from the large bowel by the size, location, and absence of haustrae. When scanning the large bowel, gentle pressure is applied with the transducer to displace bowel gas and small bowel loops from the view.

Studies have shown POCUS to be superior to plain radiography in identifying bowel obstruction. Features suggestive of obstruction include dilatation of bowel with fluid content proximal to the obstruction and collapsed distal bowel (**Figure 9**). In the case of ileus, there would be no transition point from dilated to collapsed bowel. As time progresses, the bowel wall thickens, and peritoneal

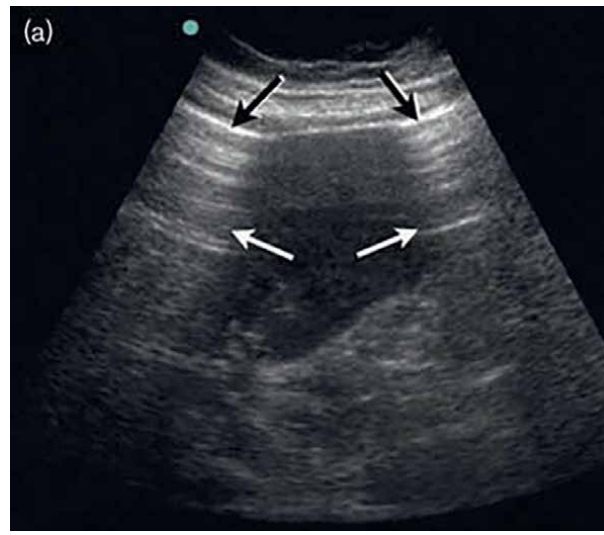

Figure 8.
Free air of pneumoperitoneum overlying liver surface with enhanced peritoneal stripe (black arrows) and reverberation artifacts (white arrows) [19].

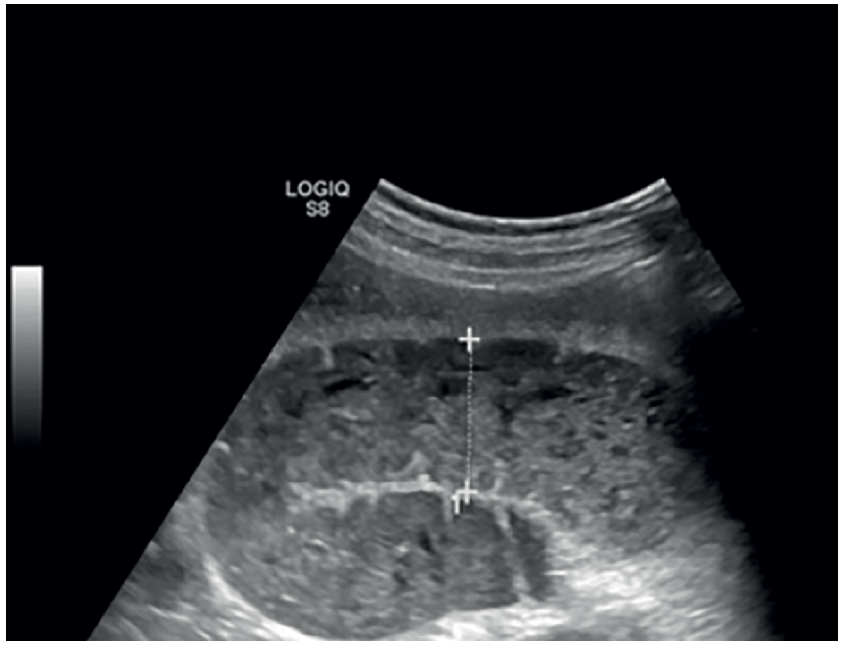

Figure 9.
Dilated bowel loops in intestinal obstruction as seen on USG [20].

free fluid develops. Peristaltic activity in the bowel can be seen as a to-and-fro movement of spot echoes within the bowel loop. Bowel strangulation can also be identified with POCUS – dilated aperistaltic proximal bowel loop with peristalsis seen in further proximal bowel, asymmetric bowel wall thickening with an accumulation of intraperitoneal fluid.

3.3 Genito-urinary tract

3.3.1 Urinary bladder

Urinary bladder is scanned by placing the transducer in the suprapubic region in sagittal and transverse planes. A moderately filled bladder is ideal for visualization, which cannot be guaranteed in a trauma patient. If not visualized, then the probe is tilted inferiorly toward the pelvis to obtain a view. In some cases, normal saline may be introduced into the bladder via a per-urethral catheter to allow better imaging of the structures.

Bladder ultrasound can help guide suprapubic catheter placement in patients with urethral injury having urinary retention.

3.3.2 Ureter

Normal ureters are not visualized by ultrasonography. However, in case of obstruction to urine outflow, distended ureters can be seen with POCUS. The cause of obstruction in trauma can be varied, such as hematoma and foreign body (**Figure 10**).

Figure 10.
Dilated proximal ureter with hydronephrosis [21].

4. Vascular injury

4.1 Abdominal aorta

Ideally, the abdominal aorta is to be scanned along its full length from the diaphragm to its bifurcation in both transverse and longitudinal planes with the patient in the supine position. Doppler imaging is not necessary unless to differentiate from other surrounding structures. Bowel gas and obesity may impede imaging, which can be reduced by applying firm pressure with the transducer probe.

Aorta is scanned starting at the epigastrium in the midline and proceeds caudally along its length. In the transverse plane, the aorta is identified lying anterior and to the left of the hyperechoic line of the spine as a pulsatile and round to oval structure. Tracing caudally, branches of the aorta, including superior mesenteric artery, renal artery, and then its bifurcation, can be identified. Similarly, a longitudinal view in the midline and coronal view from the right side along the anterior axillary line can be used to visualize the aorta from different angles.

Contained rupture of the aorta may be seen as a hypoechoic mixed density area surrounding the aorta. Traumatic aortic dissection can also occur, which can be seen as a dissection flap within the lumen of the aorta (**Figure 11**).

4.2 Inferior vena cava

Inferior vena cava (IVC) is identified by its termination into the right atrium of the heart by placing the curvilinear transducer in the longitudinal plane at the epigastrium with the pointer facing the head end of the patient. It is seen as a tubular structure with thin walls, varying size with respiration, and can be compressed with pressure from the transducer (**Figure 12**).

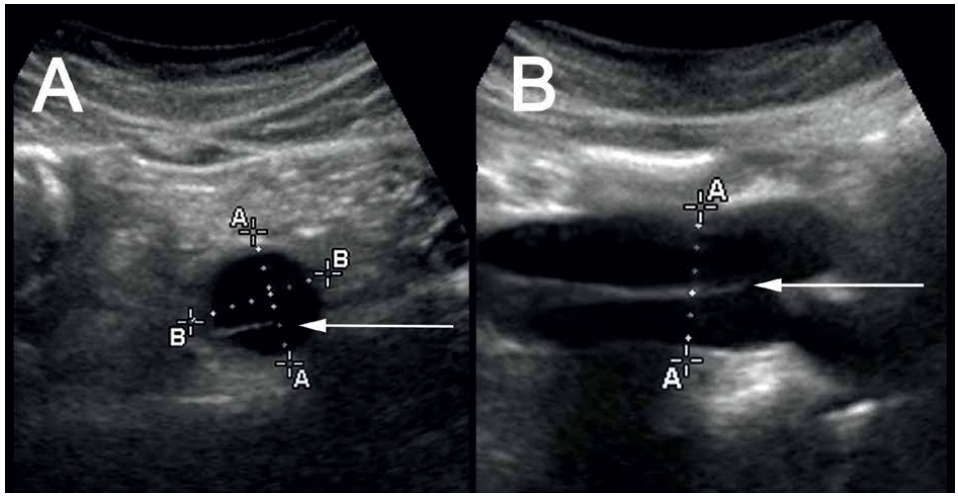

Figure 11.
Aortic dissection flap seen on USG in transverse view (A) and longitudinal view (B) [22].

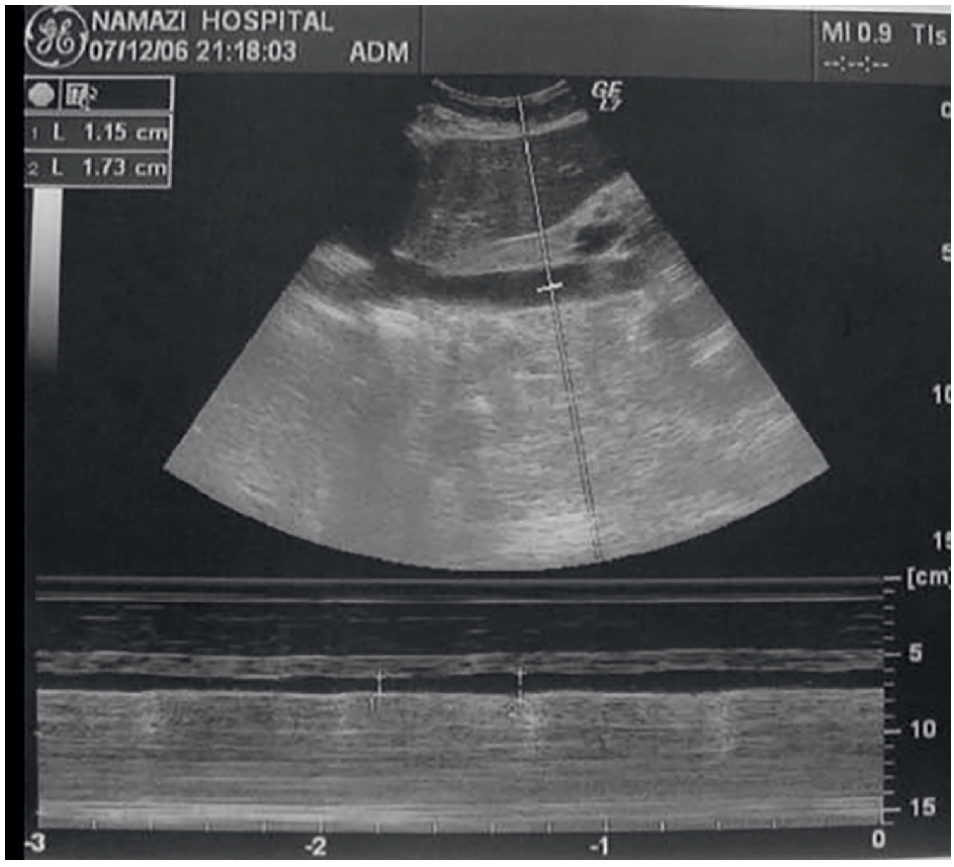

Figure 12.
Inferior vena cava on longitudinal view with M-mode applied for measurement of diameter and its variation with respiration [23].

Injuries to the IVC are uncommon. However, it has utility in trauma settings to assess the volume status of the patient. A cause of hypotension or any hemodynamic instability in a patient with trauma is due to blood loss unless proven otherwise. This is the reason ATLS guidelines stipulate every patient to receive one liter of pre-warmed lactated Ringer's solution and arrange blood products for transfusion.

IVC diameter and degree of collapse correlate with volume status in the setting of hemorrhagic shock. Diameter is less than 1 cm in hypovolemia and more than 50% collapsing. In patients with obstructive shock secondary to cardiac tamponade or tension pneumothorax, the IVC may be dilated more than 2 cm with less than 50% collapsing nature. Repeat measurements show the patient response to resuscitation.

In pediatric population, IVC/aorta ratio is used to allow assessment independent of patient size. IVC/aorta ratio less than or equal to 0.8 correlates well with hypovolemia.

4.3 Retroperitoneal hemorrhage

Retroperitoneal region is divided into three compartments – anterior, middle, and posterior. The anterior compartment houses the bowel, pancreas, and great vessels, middle is occupied by the kidneys, and posterior compartment contains muscles, such as psoas and quadratus lumborum. Bleeding into these compartments, due to trauma or vessel rupture, can sometimes be seen with POCUS.

5. Special populations

5.1 Pediatric

20–30% of pediatric trauma cases involve injury to the abdomen. CT is the most common modality of imaging utilized in pediatric trauma. Though sensitive to detecting injuries, children are more susceptible than adults to the adverse effects of exposure to ionizing radiation. Therefore, POCUS provides a safe, repeatable and quick alternative. In addition to screening for free fluid, POCUS can also detect injuries similar to those in adults. So far, observational studies have expounded on the utility of ultrasound imaging in pediatric trauma. Definitive trials are indicated to establish POCUS as the standard of care [24].

5.2 Pregnancy

Trauma in pregnancy endangers both mother and fetus, more often causing fetal than maternal mortality. However, the priority of care is given to the mother in order to ensure good outcomes for both. Ultrasonography is advantageous in pregnant trauma patients due to the lack of ionizing radiation and contrast exposure, which can be done at the bedside quickly. POCUS can detect free fluid in the abdomen, which can indicate either blood or amniotic fluid secondary to uterine rupture. Furthermore, fetal cardiac activity and gestational age can also be evaluated. POCUS can sometimes detect uterine rupture and placental abruption, but a negative scan cannot be used to rule out these diagnoses.

6. Discussion

The American College of Surgeons have detailed the use of ultrasonography for FAST and extended FAST (eFAST) examination as an adjunct to a primary survey of all trauma patients [5]. eFAST application was then well studied over the years. Netherton et al. conducted a systematic review and meta-analysis on the diagnostic accuracy of eFAST in trauma, which included seventy-five studies with a total of more than 24,000 patients [6]. Pooled specificity for detection of pneumothorax, pericardial effusion, and intra-abdominal free fluid were 99%, 94%, and 98%, respectively; whereas the sensitivity ranged between 69 and 91%. They concluded that eFAST was capable of ruling in the above diagnoses, but not adequate to rule out the same when negative. Their subgroup analysis showed that eFAST was more specific in detecting intra-abdominal fluid in normotensive than in hypotensive patients.

A similar meta-analysis on the application of FAST in the pediatric age group was conducted by Liang et al., including eight studies and an aggregate of more than 2000 patients [24]. FAST had a pooled specificity of 96%, but a poor sensitivity of 35%.

Practical implications of FAST in terms of predicting the need for laparotomy, cost-effectiveness, and reducing time to operative intervention have also been studied. A study by Lane BH showed that FAST examination is clearly cost-effective in unstable patients [12]. Moylan et al. noted that even in normotensive patients with blunt trauma, the positive FAST examination had a strong association with therapeutic laparotomy, or 116 [8]. In the pediatric population of unstable blunt abdominal trauma, Long et al. observed that positive FAST examination at 2 hours after ED arrival had 100% specificity and positive predictive value for early surgical intervention [11].

Applications of ultrasonography beyond eFAST then began to be explored. Solid organ injury is easily identified by POCUS. Richards et al. studied over 2000 patients with blunt abdominal trauma who underwent POCUS for identifying the splenic injury [13]. They found that ultrasonography had an overall sensitivity of 69% for splenic injury, and this increased to 89% for grade 3 or higher injuries. Similarly, McGahan et al. noted that acute renal trauma can be detected by ultrasonography, especially with higher-grade injuries [14].

A newer technique was introduced that allowed better delineation of solid organ injury - contrast-enhanced ultrasonography (CEUS). Valentino et al. studied 133 patients with blunt abdominal trauma by performing standard ultrasonography and CEUS [16]. These were compared with injuries detected on CT scans. CEUS had a sensitivity and specificity of 96.4% and 98%, respectively, and was thus nearly as accurate as CT scans.

Other than solid organ trauma, hollow viscus and vascular structures can also be scanned with POCUS. Moriwaki et al. performed ultrasonography on 484 patients with severe abdominal pain with or without blunt trauma for detecting intra-peritoneal free air. It had a sensitivity of 85.7% and a specificity of 99.6% [25]. Ultrasound-guided suprapubic catheter placement into the urinary bladder has been studied to be safe as per Muhammad AS et al. even in resource-poor settings without incidence of any major complication [26]. Scanning of large blood vessels of the abdomen, such as aorta and inferior vena cava, is challenging due to the overlying bowel with gas content. Sefidbakht S et al. measured the diameter of inferior vena cava (IVC) and its variation with respiration in 88 patients of trauma, with or without hemodynamic instability. The average diameter of the vessel was smaller in those with shock ($p < 0.0001$) and the collapsibility index of IVC was significantly higher in the

unstable trauma patients ($p < 0.001$). Thus, IVC diameter can be a reliable indicator of shock [23].

This chapter has described the possible applications of POCUS in abdominal trauma, but it is not an exhaustive list. Research and development in this field are ever-growing and further utility of ultrasonography remains to be seen.

7. Conclusion

POCUS is a great tool in the armamentarium of a physician in the evaluation and monitoring of a patient with abdominal trauma. Trained non-radiologists can perform POCUS reliably and identify injuries at the bedside.

Diagnostic utility of POCUS at the bedside has been well studied. It is a noninvasive, easily repeatable, and cost-effective modality. It is crucial to the time when POCUS is performed so as to prevent any delay in treatment of patients with abdominal trauma. This can be achieved by using the time of resuscitation in the emergency department. A focused approach based on the type and location of injury can be used to closely scan the likely affected organs. Trauma to solid organs, that is, liver, spleen, and kidney are best picked up on ultrasound.

Newer techniques, such as Doppler mode and contrasted-enhanced ultrasonography, allow better visualization and/or identification of injuries without any increase in risk to the patient. Thus, POCUS is a growing field and its applications are vast, beyond the standard eFAST.

Conflict of interest

The authors declare no conflict of interest.

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Chapter 5

Pediatric Abdominal Trauma

Zehra Serpil Ustalar Ozgen and Dilek Altun

Abstract

Pediatric patients are more prone to trauma than adults. Trauma is one of the most common causes of death in children. Their small and fragile bodies, big organs relative to their bodies, are the major causes of injury in children. Their body surface area is relatively larger than adults, which makes them vulnerable to trauma. A higher percentage of the children admitted to emergency departments need the help of anesthesiologists in the management of airway, resuscitation, mechanical ventilation, maintenance of hemodynamic stability, transfusion, management of coagulopathy, hypothermia, pain, and monitorization. Serious abdominal trauma is seen in 5–10% of multiple traumas and 25% of blunt abdominal trauma in children. Despite improvements in emergency diagnostics and evaluation, controversy still exists regarding the optimal assessment and management of pediatric trauma patients with abdominal trauma. It can be difficult to accurately describe the major abdominal traumas and symptoms that occur in children. The most important factor in accurately detecting injuries that may occur due to abdominal trauma in this age group is high suspicion. Creating a targeted treatment strategy by understanding the mechanism of injury with a detailed and careful history and physical examination may be the basic step in saving life in these patients. This chapter is aimed to discuss the management of abdominal trauma in pediatric patients.

Keywords: trauma, abdominal, anesthesia, pediatric, pediatric abdominal trauma

1. Introduction

Abdominal trauma (AT) accounts for the majority of abdominal injuries in the pediatric population. AT can be either blunt or penetrating. Blunt abdominal trauma involves compression, crushing, or deceleration forces being exerted on the abdominal cavity. In children, the spleen and liver are most commonly injured followed by the kidneys [1]. Motor vehicle-related injuries, seat belts, bicycle handlebars, or an elbow, foot, or knee during sports, child abuse are the most common causes of blunt force to the fragile abdomen of a child. Blunt abdominal trauma is the second leading cause of abusive trauma mortality [2–4]. Two-thirds of victims are male [2, 5]. Unintentional injury is the leading cause of death in children ages 1–19 years. Traumatic abdominal injuries are more common than traumatic thoracic injuries but are less associated with death. The abdomen is the most common site of unrecognized fatal injury in pediatric patients [2, 5–7].

Mortality in pediatric trauma has trimodal distribution, 50% of the victims die at the scene either from TBI or hemorrhage, 30% die within the first few hours ("golden

hour"), the rest of the patients die due to inadequate resuscitation, management, sepsis, and multiorgan failure in days to weeks after initial injury, which is preventable by rapid identification and early aggressive treatment of the cause [8].

2. Discussion

There are major anatomical and physical differences that cause pediatric patients to be at greater risk for intra-abdominal injuries than adults. Children have thin, compliant, and flexible abdomen walls and this structure does not effectively protect the corresponding viscera [9]. Relatively larger body surface area increases the risk of hypothermia and insensible losses and hides shock well. They have a smaller circulating blood volume, and even if they lose more than 25% of their blood volume, there may be no change in their blood pressure [7–12]. Their relatively compact torso and smaller anteroposterior diameter make the distribution of the traumatic forces possible over a smaller body mass.

The ribs are more pliable, and this causes severe intrathoracic pathology to occur without visible injury or rib fractures. Larger abdominal organs in children result in an increased risk of direct injury. Insulation and protection are less due to less abdominal fat and musculature. The liver and spleen are less protected by the rib cage in infants and toddlers, so, they are more prone to direct injury. The liver has less fibrous stroma than adults, which makes it more susceptible to lacerations and bleeding. Spleen has a thicker capsule which allows it to contain bleeding better than adults and may contribute to better success with nonoperative management. The bladder is an abdominal rather than a pelvic organ in young children. Renal injury is more likely in children because kidneys are proportionally larger, with less perinephric fat for protection [9, 13].

Physical examination should be done meticulously, as well as with a detailed history of trauma if possible. If physical examination reveals the presence of shoulder or lap belt marks on the abdomen, this should alert the physician of trauma to the internal organs. The pliant lower ribs can transmit the force of trauma to the underlying liver, spleen, and kidneys. The most common injuries are to renal, hepatic, bowel, and splenic structures. The massive blood loss may remain concealed or tamponaded in abdominal injuries until the clot is removed [14–21].

The physical examination should be carried out in the presence of the parents or caregivers, a familiar face with the child, since he may be frightened and the examination of the abdomen may be too difficult. Crying causes air swallowing, subsequently distension, and tenderness of the abdomen, which may complicate the clinical examination. Distension of the urinary bladder carries the same difficulty. If there is no facial trauma, decompression of the stomach with a nasogastric tube, if there is facial trauma, with an orogastric tube may be helpful. If there is no suspected urethral injury, decompression of the urinary bladder would help. It should be kept in mind that hard manipulation and extreme movements, and positioning of the victim may cause further trauma or decompensation **Figure 1** [22].

Blunt abdominal trauma (BAT) accounts for most trauma in children. Focused abdominal sonography for trauma (FAST) has recently become a useful and practical part of the initial trauma evaluation. It can be performed in a short time, noninvasive, portable, and can also be performed during resuscitation. Free fluid in Morrison's pouch, the pelvis, the peri-splenic region, and the pericardium should be sought during FAST examination. FAST is extremely sensitive to peritoneal fluid

and hemoperitoneum, whereas ultrasonography may miss specific visceral injury (liver, spleen, and bowel injury). Although the focused assessment with sonography in trauma (FAST) is considered standard of care in the evaluation of adults with traumatic injuries, there is limited evidence to support its use as an isolated evaluation tool for intra-abdominal injury related to BAT in children. Although a positive FAST examination could obviate the need for a computed tomography scan before

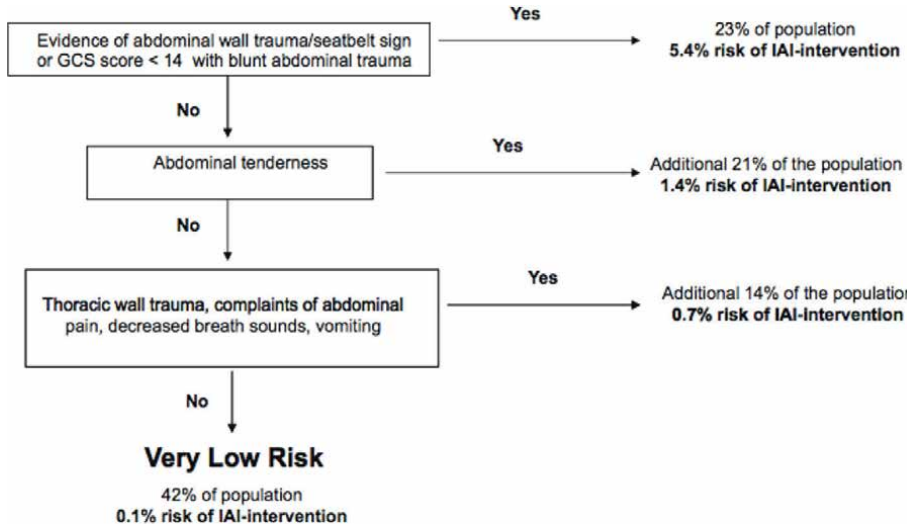

Figure 1.
Risk of IAA-intervention following pediatric abdominal blunt trauma. *IAI-intervention: traumatic laparotomy, angiographic embolization, blood transfusion for abdominal hemorrhage, or intravenous fluids >2 nights for pancreatic/gastrointestinal injury. IAI, intra-abdominal injury; BAT, blunt abdominal trauma.*

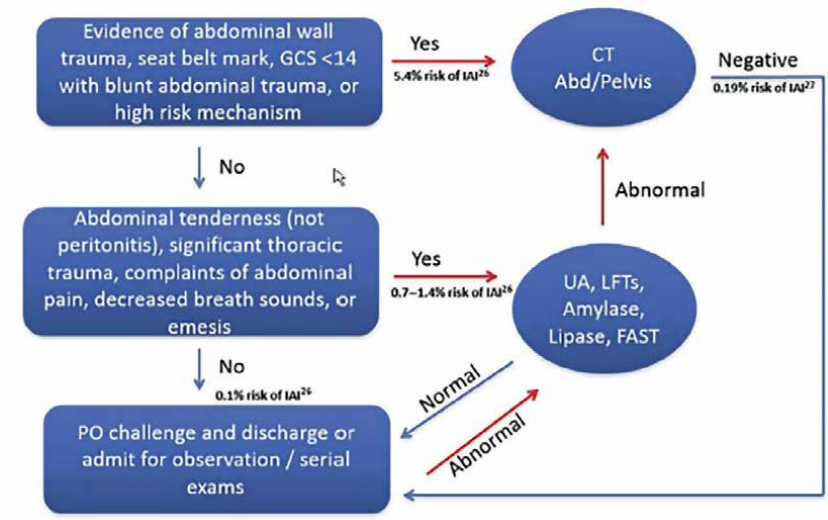

Figure 2.
Pediatric abdominal trauma evaluation. Abd, abdomen; CT, computed tomography; FAST, Focal Assessment with Sonography in Trauma; GCS, Glasgow Coma Scale; IAI, intraabdominal injury requiring intervention; PO, oral; UA, urinalysis. Data from [23, 24].

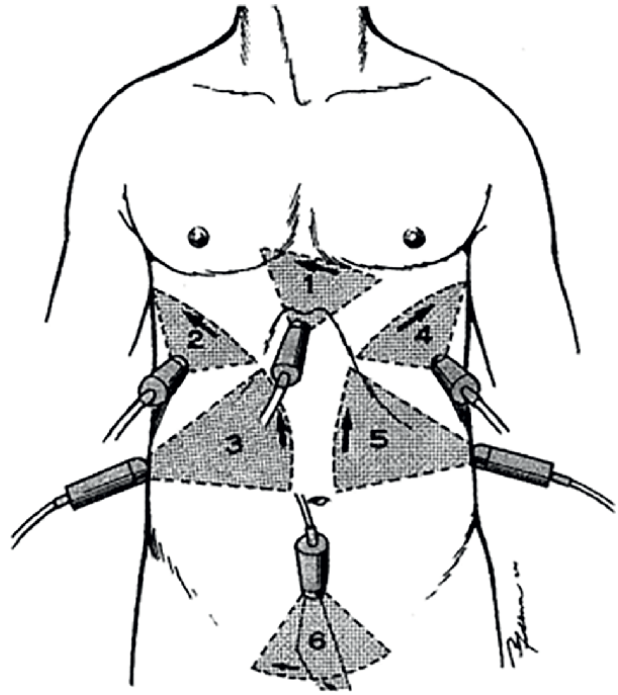

Figure 3.
Components of the FAST examination. Evaluation of hemoperitoneum using a single versus multiple view ultrasonographic examination [18].

operating room evaluation in a hemodynamically unstable patient, a negative FAST examination cannot exclude intra-abdominal injury related to BAT in isolation **Figure 2** [25]. Brenkert et al. review the evaluation of BAT in children, describe the evaluation for free intraperitoneal fluid and pericardial fluid using the FAST examination, and discuss the limitations of the FAST examination in pediatric patients **Figure 3** [18, 24]. Since FAST has modest sensitivity for hemoperitoneum and intraabdominal injury (IAI) in the pediatric trauma patient, patients with concern for undiagnosed IAI, including bowel injury, may be considered for hospital admission and serial abdominal exams without an increased risk of complications, if an exploratory laparotomy is not performed emergently [26–30]. In another study by Quan et al., it was concluded that caution is needed in applying a single initial FAST to patients with minor abdominal trauma or with suspected injuries to organs other than the spleen or bladder [27].

Abdomino-pelvic CT scanning for blunt abdominal trauma has a sensitivity of 96%, a specificity of 98%, and an accuracy of 97%. CT is organ-specific, allowing the identification and grading of injured organs and the quantification of intraperitoneal fluid or blood. This allows for the non-operative management of stable patients, thereby reducing the rate of non-therapeutic laparotomy. If available, CT is the preferred diagnostic test [31–33].

Prompt laparotomy is indicated if the child is unstable and the diagnostic test shows free blood in the abdomen, or there is a rupture of a hollow viscous. Injury to the liver, spleen, and kidneys can be managed conservatively; however, close supervision is necessary [7–11].

An often missed entity is abdominal compartment syndrome (ACS). This is a condition in which increased pressure in the anatomic space results in organ dysfunction. Undetected increases in intra-abdominal pressure (IAP) can be life-threatening. ACS is defined by IAP > 20 mmHg (with or without an abdominal perfusion pressure < 60 mmHg) with a minimum of three standardized measurements taken 4–6 hours apart plus at least one new end-organ failure. Injury to the pelvis is associated with pelvic fractures and concealed hemorrhage. Blood at the urethral meatus is strongly suggestive of urethral injury.

3. Specific injuries

3.1 Liver

It is usually associated with other abdominal or extra-abdominal injuries and is most commonly associated with spleen injuries. Since the posterior right lobe is fixed by the coronary ligaments, most injuries occur in this part.

Although liver injuries require aggressive resuscitation and close observation, they often require surgical intervention, which is done based on adult protocols. The greatest challenge in the management of liver injuries is their timely identification and the correct timing of aggressive resuscitation and laparotomy. Surgery should be considered in unstable patients, and it should be performed in experienced centers since liver injuries in the pediatric age group can be difficult to manage and have high morbidity and mortality.

Complications consisting of hemobilia, intrahepatic duct rupture and accompanying biliary fistula, bilemia, intrahepatic hematoma, vascular outflow obstruction, and gallstones can be seen in the early or late period. The prognosis is generally good if treated early.

The grading of liver injury performed by the American Association for the Surgery of Trauma (AAST) is given in **Table 1** [20].

Even if stability is ensured, the patient should be followed closely for late complications, especially bleeding that may occur in the late period, and CT imaging should be performed. Especially in patients with ongoing abdominal pain, care should be taken in terms of bleeding and long bed rest should be provided if necessary [8–11].

3.2 Spleen

Another organ frequently injured in blunt trauma is the spleen which is also seen quite frequently with other organ injuries. Because it is smaller than other organs, it may show varying degrees of fragmentation and may be associated with intraparenchymal or subcapsular hematoma. However, unlike hepatic injury, intraperitoneal bleeding may not always be seen. If there is no rupture in the splenic cilium, a retroperitoneal hematoma extending into the anterior pararenal space may be seen. Bed rest should be given to patients with splenic injury until the pain subsides. In clinically stable patients, it may not be necessary to repeat the ultrasound [9–11].

Bleeding seen in spleen injuries can often stop spontaneously without the need for surgery. Splapsule, the hemoperitoneum may not be seen. If there is an injury extending to the henic clefts can be confused with splenic tears and may be misdiagnosed after splenic injuries.

Grade 1	Subcapsular hematoma less than 1 cm in maximal thickness, capsular avulsion, superficial parenchymal laceration less than 1 cm deep, and isolated periportal blood tracking
Grade 2	Parenchymal laceration 1–3 cm deep and parenchymal/subcapsular hematomas 1–3 cm thick
Grade 3	Parenchymal laceration more than 3 cm deep and parenchymal or subcapsular hematoma more than 3 cm in diameter
Grade 4	Parenchymal/subcapsular hematoma more than 10 cm in diameter, lobar destruction, or devascularization
Grade 5	Global destruction or devascularization of the liver
Grade 6	Hepatic avulsion (CT scan grade not AAST grade)

Table 1.
Criteria for staging liver trauma based on the American Association for the Surgery of Trauma (AAST) liver injury scale.

Grade 1	Subcapsular hematoma of less than 10% of surface area or capsular tear of less than 1 cm in depth
Grade 2	Subcapsular hematoma of 10–50% of surface area, intraparenchymal hematoma of less than 5 cm in diameter, or laceration of 1–3 cm in depth and not involving trabecular vessels pediatric blunt abdominal trauma
Grade 3	Subcapsular hematoma of more than 50% of surface area or expanding and ruptured subcapsular or parenchymal hematoma, intraparenchymal hematoma of more than 5 cm or expanding, or laceration of more than 3 cm in depth or involving trabecular vessels
Grade 4	Laceration involving segmental or hilar vessels with devascularization of more than 25% of the spleen
Grade 5	Shattered spleen or hilar vascular injury

Table 2.
Criteria for staging splenic trauma based on the AAST splenic injury scale.

However, splenic clefts can be easily distinguished from tears by their smooth contours and the absence of hematoma or fluid around them [24].

The grading of spleen injury performed by the American Association for the Surgery of Trauma (AAST) is given in **Table 2** [20].

3.3 Kidney

Kidney injury, which is the third most common organ injury after blunt trauma in children, may be complicated by subcapsular or perinephric hematoma that can be distinguished by CT [32].

Renal parenchymal damage can be seen, as well as vascular and collecting system damage. The injured kidney appears larger than the other kidney on CT due to edema. Early diagnosis can be made easily by imaging with ultrasound, but patients may require contrast-enhanced CT. If there is ongoing bleeding despite resuscitation treatments, laparotomy may be required, which may result in nephrectomy [30–32].

Ongoing hematuria may be seen due to AV fistula. Patients with serious injuries should be followed up with repeat ultrasound and dimercaptosuccinic acid (DMSA) scanning [7–11].

3.4 Pancreas

While pancreatic injury alone is rare in children, it can usually be seen together with other organ injuries. If the pancreas is small and has little surrounding fat, it can mask signs of injury. Unexplained peripancreatic fluid seen on CT is the best indicator of pancreatic damage. Fluid collected in the anterior pararenal space may cause dissection between the pancreas and the splenic vein. At the same time, trauma can cause pancreatitis in children [20–25, 34].

It may cause peripancreatic fluid collection that transforms into a pancreatic pseudocyst or resolves spontaneously after pancreatic injury.

Initial serum amylase level does not correlate with the severity of the pancreatic injury.

There is no indication of emergency laparotomy in pancreatic injuries. Pain, nausea, and vomiting should be treated with a conservative approach, oral intake should be stopped until symptoms improve, and a CT scan should be performed in severe traumas [20–22].

3.5 Intestine

Intestinal injury, which is rare in children, is usually associated with mesenteric injury. It is mostly seen in cases where seat belts are not worn after traffic accidents [7–11].

Diagnosis is often difficult and delayed due to the late onset or absence of symptoms, and often a CT scan may be required. Free air on CT supports the diagnosis. If there is no significant free air in the radiographs, it may not be possible to diagnose perforation in blunt abdominal traumas. Initially, localized tenderness may worsen within 6–10 hours, and peritonitis or obstruction may develop during this time. In contrast to CT, it may be possible to diagnose enteric deterioration earlier with repeated physical examinations and serial examinations. If perforation is detected, laparotomy should be performed in the early period [20–22].

Chemical peritonitis due to perforations of the proximal gastrointestinal tract is painful and can be diagnosed early. However, since perforations occurring in the distal part of the intestine have a neutral pH and a lower bacterial load, they may be asymptomatic initially, while the onset of symptoms may be delayed, and the diagnosis due to abdominal peritonitis or sepsis may be delayed up to 24 hours, which causes a serious increase in mortality and morbidity [18–21].

Diagnosis of duodenum perforations is difficult as in other intestinal parts. The presence of extraluminal air and fluid and extravasation of oral contrast should lead to suspicion of perforation [19–22].

Intramural hematoma due to partial tear, most commonly seen in the duodenum; or rupture, most commonly located in the jejunum. Unexplained peritoneal fluid on CT is the most common finding after bowel rupture and may be the only finding [18–20].

In addition, thickening of the intestinal wall, mesentery damage, and chemical irritation may also occur. If there is intraperitoneal gas, an emergency laparotomy should be performed [20].

3.6 Bowel

Another organ that can be damaged in abdominal trauma is the intestines. In a possible trauma, all intestines should be evaluated from the esophagus to the rectum. Serious infections may occur due to contamination of the abdominal cavity in intestinal traumas. This is because large bowel traumas are detected later than small bowel injuries due to their retroperitoneal location. However, in pediatric patients, complete recovery can often be achieved with primary treatment without fecal contamination [26–30].

Perforations occurring in the rectosigmoid region may cause contamination of the abdominal cavity. Because of its retroperitoneal nature, colonic injuries often cannot be diagnosed early, resulting in fecal contamination. However, colonic injuries in pediatric patients can often be repaired with the primary repair without significant fecal contamination, except for diversions [28–30].

3.7 Bladder

Bladder injury, which is rare in children, can be intraperitoneal or extraperitoneal. It is accompanied by bruising in the suprapubic region. After a traffic accident, intraperitoneal injury is observed due to the compression of the seat belt on the full bladder, while extraperitoneal injury is observed due to pelvic fractures. Ultrasound can be helpful in diagnosis [18–20].

Although bladder rupture is very rare in the pediatric age group, it should be suspected in a patient with no urine output after blunt trauma, abdominal bloating, abdominal tenderness, and pain. As with other organ ruptures, a delayed diagnosis will increase morbidity and mortality. Extravasation of urine and blood into the peritoneal cavity due to bladder rupture may cause electrolyte imbalance, and uremia due to urine absorption [18–20].

Bladder injury can be diagnosed by demonstrating extravasation of IV contrast media on CT. At the same time, the location of the iv contrast agent on CT enables differentiation of intraperitoneal and extraperitoneal bladder rupture. Recognition of this is important in guiding treatment. Extraperitoneal injuries can be treated conservatively, whereas intraperitoneal injuries require immediate surgical repair [20–22, 25].

A suprapubic catheter may be required for bladder neck injuries [20].

4. Trauma anesthesia in a pediatric patient

Anesthetic management of a pediatric trauma patient has multiple issues to consider; management of the airway (may be traumatized or difficult), especially in the presence of a cervical spine injury, the possibility of full stomach (the stomach may be full of blood or secretions at least), the need for rapid sequence intubation, unstable or immediately decompensated hemodynamic status, particularly in the presence of traumatic brain injury (TBI), the possibility of significant hemorrhage and transfusion. Intraabdominal trauma occurs frequently (10%) and is the leading cause of initially unrecognized fatal injury and hemorrhage; the most injured organs, with the descending order, are the spleen, liver, renal, intestine then pancreas.

The mortality decreases with good prehospital care, appropriate triage, and effective resuscitation. Basic Advanced Trauma Life Support principles apply; initial stages of resuscitation, stabilization, and definitive management. Anesthetists should know

the management of the trauma patient in the prehospital care and emergency department, to provide better intraoperative anesthetic management. A thorough yet quick history must be taken, regarding TBI, breathing, airway, intubation, manual in-line stabilization, and assessment of neurological and hemodynamic status. If the patient is not stabilized after two 20 ml/kg boluses of crystalloid, a transfusion of 10–20 ml/kg of packed red blood cells (PRBCs) should be prepared [8, 33]. After that, a secondary survey with diagnostic testing is completed. After all injuries are identified, definitive care and if necessary, surgical care should be decided.

The management of anesthetic induction should be performed regarding the child's injury, presence, or absence of TBI, hemodynamic stability, and the anesthetists' experience. Besides ASA standard monitorization, a functional intravenous line is essential. If not intubated before coming to the operating room, caution must be applied regarding difficult mask, airway, and full stomach (blood, mucus in the mouth, or previously aspirated or swallowed blood). If intubated, the location of the endotracheal tube should be verified.

If there is hemorrhage, damage control resuscitation will be planned and guided by both laboratory and clinical criteria, restrictive blood transfusion thresholds should be considered guiding allogenic blood transfusion. Damage control resuscitation is the strategy of treating massive hemorrhage with the transfusion of blood and blood components [35]. Crystalloid predominant resuscitation in the bleeding pediatric patient has negative influence on mortality and discouraged.

There is no consensus or universal protocols or definition of massive transfusion in pediatric patient. The dynamic definition of massive transfusion in children and neonates is suggested by Diab et al. [36] "transfusion of >50% of total body volume (TBV) in 3 hours, transfusion >100% TBV in 24 hours, or transfusion support to replace ongoing blood loss of >10% TBV per min". Other definitions, transfusion requirements of 40 ml/kg in 12 hours or 80 ml/kg within 24 hours [37].

Protocols involving early and liberal use of a fixed ratio of red blood cells:fresh frozen plasma (FFP):platelets have been used, with most suggesting 1:1:1, while occasionally 2:1:1 has also been described [35, 38]. Consideration must be given to the patient's volume, hemodynamic status, tissue oxygenation, hemorrhage control, coagulation abnormalities, large volume blood, and blood products administration problems like potassium, ionized calcium, acid–base balance changes, and hypothermia. Acidosis, hypothermia, and coagulopathy constitute the "deadly" triad.

Trauma-induced coagulopathy (TIC) can be managed by early identification, massive transfusion protocols (MTP), tranexamic acid, and recombinant factor VIIa usage, desmopressin, and prothrombin complex concentrate. If available, coagulation tests, including thromboelastogram (TEG), rotational thromboelastometry (RoTEM), and impedance aggregometry can be used to guide, evaluate, and inform TIC in children older than 1 year.

Pain management needs careful titration and judicious use of multimodal techniques to benefit from regional as well as pharmacological and non-pharmacological interventions.

5. Conclusion

Pediatric patients present a unique set of challenges for the emergency physician, pediatrician, surgeon, or pediatric anesthesiologist after abdominal trauma. One of

the most common problems encountered in pediatric patients after abdominal trauma is that it is detected late and leads to poor outcomes due to improper management.

Since abdominal trauma is still the most important cause of mortality in pediatrics, the primary rule to reduce mortality in these patients is to diagnose and start treatment in the first hours immediately. Observation and re-evaluation should be our main goals in the management of abdominal trauma cases.

Initial FAST and then CT is important in the evaluation of these patients. However, in the detection of asymptomatic cases, CT together with FAST may give more accurate and reliable results in selected cases with a high index of suspicion.

Laparoscopy is a safe method in both the evaluation and treatment of selective blunt and penetrating abdominal injuries in hemodynamically stable patients. However, it may not be beneficial in patients with delayed findings.

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Edited by Dmitry Victorovich Garbuzenko

Closed injuries and abdominal wounds have always been a difficult surgical problem. The presence of many vital organs in the abdominal cavity, the specifics of their anatomical structure, vascular architectonics, and innervation, the immediate proximity of intestinal contents rich in pathogenic flora, and the presence of organs producing extremely active enzymes lead to massive internal bleeding, rapid development of peritonitis, and irreversible changes in organs and tissues. The problem of modern diagnostic and therapeutic approaches to abdominal trauma is very relevant and requires detailed coverage. This book provides a comprehensive overview of the different types of abdominal trauma and their treatment.

Published in London, UK

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ISBN 978-1-80355-812-7