PENETRATING ABDOMINAL INJURIES IN CHILDREN

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Abstract
Traumatic injuries are leading causes of morbidity and mortality in children. The ubiquity of various types of weaponry (which is culturally and geographically dependent) has created an epidemic of violence that is spreading into all walks of life, and affecting all ages. The abdomen is the third most commonly injured region in children; 20% of the abdominal injuries are of the penetrating variety, the small intestine being the most commonly injured organ. In this article two illustrative cases of penetrating abdominal injury (PAI), causes, mechanism and pathophysiology of PAI, resuscitation and evaluation are presented. Treatment options with particular reference to the four commonly injured viscera and experience are also discussed.

Introduction

Traumatic injuries are the leading causes of morbidity and mortality in children in the United States of America[1]. The incidence of abdominal injury in children is about 20% of all injuries [2]. The abdomen is the third most commonly injured region of the body and about 20% of these are penetrating injuries[3]. The incidence of trauma and penetrating abdominal injuries (PAI) in our environment is not known. Penetrating trauma commonly follows accidental injury, homicide, intentional or warfare injury. They are caused by a variety of missiles, instruments, implements and various objects like stick, wood peg, metal spikes, broken bottles, stab wounds, and gunshot wounds. In some agrarian environments, cow horn is a cause of PAI.

The most commonly injured organs associated with penetrating injuries are the small intestine (29%), liver (28%), and colon (23%)[4]. In a review of children who had laparotomy for abdominal injury in our Paedatric Surgery Division between January 1996 and August 2001, 8 (21%) of the 39 patients had penetrating abdominal injuries. In six of the patients (75%), the mechanism of injury was a fall, one had a gun shot wound (GSW) and another was assaulted. Five of the patients (62.5%) presented with omental and bowel evisceration, two with only omental evisceration and the one who had GSW had peritonitis. In this article we report two illustrative cases of PAI. The cause, mechanism, pathophysiology, resuscitation, and evaluation of PAI are discussed. The management of patients with PAI with particular reference to the four most commonly injured viscera is also discussed.

Case 1: Y.A. a 2-year old girl who presented with a two-day history of low velocity gunshot injury of the right buttock and back and one day history of progressively worsening abdominal pain. The injury was sustained accidentally during an armed robbery attack. There was associated abdominal distension, bilous vomiting and fever. Examination revealed a young girl who was pale

and dehydrated. There were pellet entry points at the right postero-inferior gluteal region, posterior upper third of the right thigh and the posterior chest wall, 2cm to the right of the 7th thoracic vertebra. She was in respiratory distress with a respiratory rate of 50cycles/minute and reduced breath sound over the right lower zone.

Thoracocentesis yielded 5mls of free flowing non-clotting blood. She also had abdominal Tenderness and guarding. A diagnosis of low velocity gun shot injury was made. There was penetrating chest injury with haemothorax as well as an abdominal injury with bowel involvement. The patient was resuscitated with intravenous normal saline, chest tube insertion, continuous nasogastric tube decompression, intravenous cefuroxime and metronidazole, and was given tetanus prophylaxis. The packed cell volume was 23%.

She had exploratory laparotomy, at which were found a single antimesenteric ileal perforation, right broad ligament and right ovarian laceration. The ileal perforation and ovarian leceration were repaired. She had 100mls blood transfused intra-operatively.
The post-operative recovery was uneventful and she was discharged home on the 8th day post-operatively.

Case 2:
M.Y. was a 9-year old boy who presented 3 hours after falling on an iron rod, which penetrated his abdomen while trying to cross a gutter. There was associated profuse bleeding and evisceration of intra-abdominal contents. Examination revealed a young boy who was pale and dehydrated. The respiratory rate was 30 cycles/min. and the pulse rate was 100/min. He had a right iliac fossa laceration with eviscerated omentum. The packed cell volume was 33%. He was resuscitated with intravenous normal saline, continuous nasogastric tube decompression, and intravenous cefuroxime and metronidazole. Tetanus prophylaxis was also given.

He had exploratory laparotomy, at which a 2cm by 2cm right iliac fossa abdominal wall laceration, eviscerated omentum and contused ileum were noted. The eviscerated omentum was resected and peritoneal lavage performed. The post-operative recovery was uneventful and he was discharge home on the 7th post-operative day.

Discussion
Mechanism of injury: Penetrating abdominal injuries are caused by a direct or indirect effect of the offending instrument. The instruments include knives, bottles, high- and low- velocity projectiles. The commonest type of weapon is dependent on culture and geography. The gun has replaced the knife as the most common cause in the western world [4]. The injury severity is dependent on the instrument (type, size, shape, mass, range, velocity, wound angle and composition), number of wounds and target organ density or elasticity.

Stab wounds and impalements cause injury in the direct path of the offending implement. Gunshot wounds on the other hand have a much broader injury pattern due to several mechanisms. First, any structure directly in the path of the missile suffers a loss of integrity. The

Transfer of kinetic energy from the missile to surrounding tissue as it traverses its path creates injury in several unique fashions. Kinetic energy is directly proportional to the mass and the square of the missile impact velocity ($1/2mv^2$)[5]. The impact speed is affected by several factors,

including target distance, missile velocity, missile mass shape, and drag.

Wound size increases sharply at close range due to greater energy impacted and the aerodynamically unstable nature of bullets in the first 100metre of flight[6]. A missile creates longitudinal and horizontal shock and shear waves as it traverses different media. It can cause damage at a considerable distance from the wound. The temporary cavity formed depends on the density and elasticity and the wound. It results in suctioning of debris via the entrance and exit wounds. It collapses in a pulsatile fashion leaving a macerated tract. Some bullets disintegrate in the body causing damage.

Pathology: Tissue is lacerated, crushed and or avulsed by the passage of the wounding implement. Laceration of hollow or solid organs results in hemorrhage and or leakage of contained fluid (e.g., succus entericus, bile) into the peritoneal and / or retroperitoneal space. Impaling objects may tamponade an otherwise uncontrolled hemorrhage if the object resides within or crosses a major vessel or solid organ such as the portal vein or liver. Therefore, penetrative objects should not be removed except within an operating room. If the structure is a vein, surrounding tissue may tamponade bleeding. Partially transected arterial walls will continue to bleed as the elastic tissue of the media contracts and further widens the wound. Completely divided arteries on the other hand may contract enough to arrest hemorrhage.

Intraperitoneal blood can induce severe local irritation and pain, which usually is accompanied by a sympathetic discharge resulting in tachycardia. Intraperitoneal blood also can induce a seemingly paradoxic vagal response and an associated bradycardia by unclear mechanisms when the blood loss is small [4] A large-volume hemorrhage may present with bradycardia as a preterminal event, signifying a severe reduction in coronary perfusion pressure with sinoatrial and atrioventricular node ischemia.

The peritoneal or retroperitoneal blood and/or organ contents inflame deeper nerve endings (visceral afferent pain fibers) and result in poorly defined and localised somatic pain. The back or shoulder distribution of pain may provide an excellent clue to the damaged organ (e.g., shoulder pain from a damaged spleen with subphrenic blood). Irritated nerve endings at the skin and fascial levels result in local wound pain. Peritoneal signs develop when the peritoneal envelop and the posterior aspect of the anterior abdominal wall are both inflamed. Evisceration of abdominal organs can also occur.

Resuscitation

Prehospital Care: Rapid transport of the patient to the closest appropriate facility is done following expeditious evaluation of airway patency, protection of the cervical spine, and

Maintenance of breathing and circulation (ABCs). This concept is known as "scoop and run". This is in contrast to patients with primarily cardiac illness who obtain benefit from a more detailed prehospital care regimen, known as "stay and play"[4] Maintenance of circulation using a large bore cannula with 20ml/kg of Normal Saline, and control of external hemorrhage are essential parts of prehospital treatment. Direct pressure must be applied to obvious bleeding points to prevent further blood loss. The patient is commenced on high-flow oxygen by facemask concurrently with

the assessment of airway, breathing, and circulation.

Emergency Department Care: The initial evaluation and resuscitation of trauma patients with penetrating abdominal injury is based on advanced trauma life support (ATLS) standards. The rapid assessment is as follows:

A Airway with cervical spine (C-spine) control as needed
B Breathing
C Circulation with hemorrhage control
D Disability (pupils and AVPU alert, voice responsive, pain responsive, unresponsive)
E Exposure/environment control Exposure of the trauma patient is critical to avoid missing relatively hidden injuries. Eviscerated organs are covered with a saline-moistened gauze and another sterile dressing, which is secured with tape to prevent further evisceration en route to the operating room. During the initial assessment, the patient is connected to a cardiac monitor, pulse oximeter, and 100% nonrebreathing oxygen mask. In pediatric patients (<6 years), an intraosseous line may be the easiest and fastest way to obtain vascular access. Place a Foley catheter to monitor urine output and to check for hematuria, along with a nasogastric tube to evaluate for intragastric blood and to decompress the stomach to reduce the risk of aspiration and diaphragmatic splinting.

If the patient remains hypotensive after the initial 20mls/kg of crystalloid, blood component therapy, packed red blood cells (PRBC) may be started. Type-specific packed cells are preferred, but, if unavailable, universal donor O-negative blood is used. Immediate initiation of the PRBC infusion is prudent for patients with obvious blood loss. Other causes of hypotension should be sought when blood loss is not commensurate to the hypotension. Medications aimed at pain control, airway control, sedation, tetanus prophylaxis, and antimicrobial coverage are also given.

It is helpful to assess the patient's condition by the injury severity score, the abbreviated injury scale, or the paediatric trauma score, all of which appear to give reliable data in children. They correlate with survival outcome in children and have medicolegal implications. Paediatric trauma score PTS (table 1) assesses 6 parameters, the sum of which varies from +12 to 6. PTS

System gives good correlation with the ISS system and a reliable prediction of injury severity. The lower the score the higher the probability of mortality in the trauma patient.

Table I. Paediatric trauma score (Tapes et al 1987)

Component	Category		
	+2	*+1*	*-1*
Size	*>20kg*	*10 20kg*	*<10kg*
Airway	*Normal*	*Maintainable*	*Unmaintainable*
Systolic BP	*>90mmHg*	*90-50mmHg*	*<50mmHg*
CNS	*Awake*	*Obtunded / LOC**	*Coma / Decerebrate*
Open wound	*None*	*Minor*	*Major / penetrating*
Skeletal	*No fracture*	*Closed fracture*	*Open / multiple fractures*

**LOC: Loss of consciousness*

MANAGEMENT

History

History is taken after primary patient survey and resuscitation [5]. History is usually that of a child who fell on a sharp object or received GSW or stab wound (SW) to the abdomen. History gives clues to likely injury complex and potential therapeutic priorities. Important information is obtained by taking the A.M.P.L.E history thus:

A Allergies
M Medications
P Prior illness and operations
L Last meal
E Events and environment surrounding the injury

Clues to the injury complex are determined from the history of injury location, associated weapon (knife, gun) or the other injury causing object, number of gunshots heard, number of times stabbed, position of the patient at time of injury which describes trajectory and path of injuring object. In GSW the range of gunshot is important. The quantity and character of blood loss at the site of injury should be determined as this may inform transfusion need and give away a major vascular injury. [4]

Physical Examination

Initial examination is rapidly conducted to determine perfusion status, presence of external haemorrhage and the level of consciousness. The primary survey and resuscitation should be done using the B.T.L.S system [5]. A head to toe physical examination including digital rectal examination (D.R.E) and vaginal examination (V.E) is done after consent from the parents. If there is life threatening injury detailed examination may be delayed until after an urgent operative therapy is carried out. Vital signs including hourly urine output are taken and recorded. Table II shows normal vital signs by age group of patients.

Hypotension, narrow pulse pressure, tachycardia and tachypnea in PAI provide evidence of significant intraabdominal injury and warrant exploration in the Operating Room (O.R).

Table II. Normal Vital Signs by Age Group* (Rowe M.I et al 1995)

Age (years)	Heart rate (beats/min)	Blood Pressure (mmHg)	Respiration (cycles/min)
0 - 1	*120*	*80/40*	*40*
1 - 5	*100*	*100/60*	*30*
5 - 10	*80*	*120/80*	*20*

**Urinary output should average 1ml/kg in all age groups*

Abdomen

Inspection of the abdomen for injury site(s), laceration or avulsion of abdominal wall is done. Eviscerated viscera is covered with wet saline gauze and secured with tape. Abdominal distension in spite of hypotension and resuscitation is an indication of major intra abdominal catastrophe. External genitalia, perineum and the back should be inspected otherwise some injuries may be

missed. Localized or generalized tenderness, involuntary guarding and rebound tenderness are important signs in patients who are alert and well resuscitated. Tympany following PAI suggests hollow viscus injury: a strong indication for exploration. Dullness to percussion indicates presence of intraabdominal fluid or blood. Bleeding from the rectum suggests a rectal injury. Abdominal paracentesis in the 4 quadrants is a crude tool in the determination of the presence of haemoperitoneum. Repeated abdominal examination including serial abdominal girth measurement is necessary as delayed injury may become apparent especially in patients who are thought not to have full thickness injury of the abdomen[4].

Laboratory Studies

All patients with PAI who require surgery and blood component therapy and have evidence of hypoperfusion on admission should have complete laboratory profiles[4]. See Table III.

Table III. Laboratory Investigations in PAI

Blood group and cross match	*Complete blood count*
Serial PCV assessment	*Urinalysis*
Serum electrolyte and urea	*Glucose*
Clotting Profile	*Arterial lactate*
Arterial lactate	*Arterial blood gases*
Ca^{+2}, Mg^{+2} and $PO4^{-2}$	*Serum amylase.*

Decision to operate should be based on clinical findings rather than laboratory findings.

Imaging Studies (See Table IV)

Imaging needs of patients differ. The aim of imaging study is to confirm or rule out abdominal visceral injuries. Patients who have hypotension and or peritonitis should have exploration without delay.

Table IV: Relevant Imaging Studies

Study	*Possible findings*
Plain chest Xray	*Presence of thoracic injury*
Plain abdominal Xray	*Presence of foreign body or missiles*
	Fractures of ribs or vertebrae,
	Deviation of colonic or gastric shadow
Abdominal Ultrasound	*Free peritoneal fluid; breech in integrity of solid Organ like Liver, Spleen, Kidneys and pancreas.*
Abdominal C.T scan with contrast	*Further information on organ blood flow, Presence of devascularised segment and contrast extravasation.*

Diagnostic Peritoneal Lavage (DPL)

DPL was introduced before the modern CT scanner. DPL in children is quite reliable to exclude presence of haemoperitoneum, pancreatic fracture and intestinal perforation. This is important in children who are to undergo extra abdominal procedure e.g neurosurgical procedure yet intra abdominal injury has to be ruled out. It is a useful tool in the absence of USS or CT. An open method of DPL using 20ml of Normal Saline per kg body weight is recommended. Presence of bile, bacteria, intestinal content, frank blood, high amylase level, 10,000 rbc or 500 wbc per cubic mm in the effluent indicates the need for exploration. DPL in children cannot be done under local anaesthesia.

Preparation for Surgery

All patients with PAI should be prepared for OR. The patient's circulatory status is maximised by placement of large bore I.V cannula, infusion of appropriate I.V fluid and blood component

Therapy. Evidence of sustainable circulatory status is obtained from hourly urine output of 1-2.5ml/kg/hour and improving vital signs. Prophylactic antibiotic with metronidazole and a cephalosporin against enteric organisms is useful in the presence of extensive soft tissue injury, severe I.S.S score and prolonged shock. Avoid hypothermia by turning off the air conditioner, warming up the I.V fluid and blood, covering patient up with thick blanket or aluminum foil and warming up the cot with hot water bottle. Antitetanus immunisation is indicated.

General Indications for Laparatomy in PAI

All gunshot injuries (G.S.W)
Hypotension
Unexplained blood loss
Evisceration
Peritonitis and
Positive signs of free peritoneal fluid e.g. blood, intestinal content etc on DPL or CT.
Non operative conservation is pursued in patients with single penetrating wound without clinical or radiological evidence of intraabdominal injury.

Management of PAI of specific organs

Small intestinal injuries resulting from PAI are all treated by operation and direct repairs. Multiple perforations in a short segment of bowel loop can be resected and anastomosis performed. Duodenal injuries require more than primary repairs. This may include Roux-en-Y anastomosis, distal gastrectomy, gastrojejunostomy and duodenal closure. Diverticularisation procedure is reserved for patients with major injuries of the duodenum and head of pancreas. The procedure includes distal gastrectomy, gastrojejunostomy, closure of duodenum at pylorus level, repair of duodenal injury and catheter drainage of the duodenal remnant. In addition cholecystostomy is performed for controlled biliary drainage. A wide drainage of the duodenum is also instituted[3].

Penetrating gastric injuries are rare in childhood[3]. Patient presents with peritonitis. There is massive free air under the diaphragm on chest radiograph. The edges of the wound are debrided and two layer closure performed. Feeding is reinstituted after several days of drainage of the stomach via a nasogastric or gastrostomy tube.

Primary closure of small colonic perforations not associated with significant peritoneal contamination is usually safe and successful. Such patients need to get to operating room within 1 hour of sustaining injury. Extensive colonic injuries such as is seen in GSW or those associated with extensive contamination are best treated by closure and protective colostomy.

Rectal injuries from impalement may result from child abuse or accidental fall on a sharp object. The treatment of choice is drainage of perirectal space and temporary proximal colostomy.

PAI may result in disruption of mesenteric vessels. Early recognition is important. Devascularisation

may lead to delayed necrosis of a segment of the intestine. In case of major visceral vascular disruption, direct repair is the best course to follow.

The liver in young children is relatively large and occupies much of the abdomen, hence it is vulnerable to direct trauma. Mortality following liver injury is high because of frequent involvement of the great vessels like inferior vena cava and hepatic veins. Diagnosis is made by the presence of entry missile site(s) in the right upper quadrant of the abdomen. The patient has hypotension and marked abdominal distension. If the patient responds to fluid resuscitation and blood replacement, abdominal CT scan with IV contrast or abdominal ultrasound should be done, the liver injury graded and laparotomy performed.

Simple fractures of the liver not involving deep structures such as bile ducts are treated by simple suturing of liver parenchyma with or without application of haemostatic topical agents. Large fractures must be explored in depth to permit direct sutures of bleeding vessels and leaking bile ducts and placement of appropriate haemostatic mattress sutures. The Pringle maneuver of occluding the hepatic artery and portal vein at the hepatoduodenal ligament serves the useful purpose of controlling extensive bleeding.

In major central hepatic rupture with laceration of the major hepatic veins, total vascular isolation of the liver by placement of proximal and distal vascular clamps or placement of a shunt catheter through the right atrium into the IVC permits control of bleeding and repair.

Intraoperative complications are exsanguinating haemorrhage, consumption coagulopathy and extreme hypothermia[3].

PAI of spleen requires laparotomy to rule out associated injuries particularly that of the colon. At laparotomy if there was no concomitant bowel injury and the patient does not have massive heamorrhage, which makes lengthy surgery precarious, splenorraphy by simple closure of laceration, resection of devascularised segment with closure by the use of pledgets of Teflon felt or a pedicle of omentum may be performed. In the presence of irreparable damage to the organ

Or a major vascular injury, splenectomy is done. Patients who had splenectomy require constant follow up and prophylactic penicillin administration. They should also receive active and passive immunization against encapsulated organisms[3].

In conclusion, the outcome of management of children who sustained PAI depends on a quick and adequate evaluation, resuscitation and appropriate operative surgical intervention. This management approach prevents avoidable complications that usually worsens prognosis.

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