Abdominal and Genitourinary Trauma

15

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Contents

15.1 Introduction

Who could have imagined the influence of James Simpson's publication in 1968 on the successful ***nonoperative*** treatment of select children presumed to have splenic injury. Nearly four decades later, the standard treatment of hemodynamically stable children with splenic injury is nonoperative and this concept has now been successfully applied to most blunt injuries of the liver, kidney, and pancreas as well. Surgical restraint has been the theme based on an increased awareness of the anatomic patterns and physiologic responses characteristic of injured children. Our colleagues in adult trauma care have slowly acknowledged this success and applied many of the principles learned in pediatric trauma to their patients.

Few surgeons have extensive experience with massive abdominal solid organ injury requiring immediate surgery. It is imperative that surgeons familiarize themselves with current treatment algorithms for life-threatening abdominal trauma. Important contributions have been made in the diagnosis and treatment of children with abdominal injury by radiologists and endoscopists. The resolution and speed of computed tomography (CT), screening capabilities of focused abdominal sonography for trauma (FAST), and the percutaneous, angiographic, and endoscopic interventions of non-surgeon members of the pediatric trauma team have all enhanced patient care and improved outcomes. Each section of this chapter will focus on the more common blunt injuries and unique aspects of care in children.

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15.2 Diagnostic Modalities

The initial evaluation of the acutely injured child is similar to that of the adult. Plain radiography of the C-spine, chest, and pelvis are obtained following the initial survey and evaluation of A (airway), B (breathing), and C (circulation). Other plain abdominal films offer little in the acute evaluation of the pediatric trauma patient. As imaging modalities have improved, treatment algorithms have changed significantly in children with suspected intra-abdominal injuries. Prompt identification of potentially life-threatening injuries is now possible in the vast majority of children.

15.2.1 Computerized Tomography

Computerized tomography has now become the imaging study of choice for the evaluation of injured children due to several advantages. It is readily accessible in most health care facilities, it is noninvasive, it is a very accurate method of identifying and qualifying the extent of abdominal injury, and it has reduced the incidence of nontherapeutic exploratory laparotomy.

Use of intravenous contrast is essential and utilization of "dynamic" methods of scanning have optimized vascular and parenchymal enhancement. A head CT, if indicated, should first be performed without contrast, to avoid contrast concealing a hemorrhagic brain injury. Enteral contrast for enhancement of the gastrointestinal tract is generally not required in the acute trauma setting and can lead to aspiration.

Not all children with potential abdominal injuries are candidates for CT evaluation. Obvious penetrating injury often necessitates immediate operative intervention. The hemodynamically unstable child should not be taken out of an appropriate resuscitation room for a CT. These children may benefit from an alternative diagnostic study, such as a diagnostic peritoneal lavage, FAST, or urgent operative intervention. The greatest limitation of abdominal CT scanning in trauma is the lack of ability to reliably identify intestinal rupture. Findings suggestive but not diagnostic of intestinal perforation are pneumoperitoneum, bowel wall thickening, free intraperitoneal fluid, bowel wall enhancement, and dilated bowel. A high index of suspicion should exist for the presence of a bowel injury in the child with intraperitoneal fluid and no identifiable solid organ injury on CT scanning. Diagnosis and treatment of bowel injury will be reviewed in detail below.

15.2.2 Focused Abdominal Sonography for Trauma

Clinician-performed sonography for the early evaluation of the injured child is currently being evaluated to determine its optimal use. Examination of Morrison's pouch, the pouch of Douglas, the left flank to include the peri-splenic anatomy, and a subxiphoid view to visualize the pericardium is the standard four-view FAST exam (Fig. 15.1). This bedside exam may be useful as a rapid screening study, particularly in patients who are too unstable to undergo an abdominal

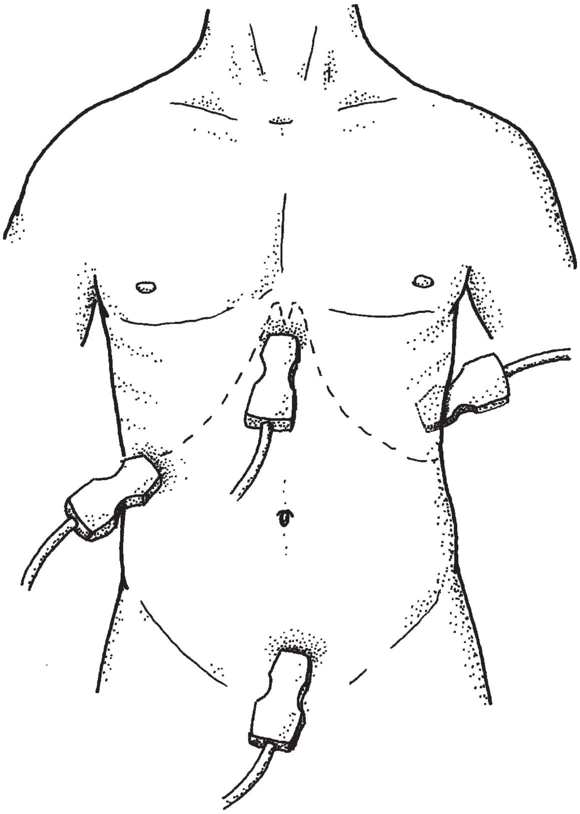


Fig. 15.1 Schematic of a FAST exam with emphasis on the subxiphoid, RUQ/Morrison's pouch, LUQ/left para-colic, and pelvic/Pouch of Douglas views
Source: Original illustration by Mark Mazziotti, MD

CT scan. Early reports have found FAST to be a useful screening tool in children, with a high specificity (95%), but a low sensitivity (33%) in identifying intestinal injury. A lack of identifiable free fluid does not exclude a significant injury. FAST may be very useful in decreasing the number of CT scans performed for "low-likelihood" injuries. The study may need to be repeated, dependent upon clinical correlation and the finding of free fluid in itself is not an indication for surgical intervention.

15.2.2.1 Laparoscopy

Large prospective trials in adults utilizing laparoscopy have demonstrated an increased diagnostic accuracy, decreased nontherapeutic laparotomy rates, and significant decrease in length of stay with attendant reduction in costs. Multiple studies have shown (principally in adults) the utility of laparoscopy in not only trauma evaluation but in definitive management of related injuries. Repairs of intestinal perforations, bladder ruptures, liver lacerations, diaphragmatic injuries, gastrostomy repair, splenic injuries, etc. have all been reported. The extent of operations feasible is directly related to the skill of the surgeon at advanced laparoscopic techniques and the overall stability of the patient. As with elective abdominal surgery, the role of laparoscopy in trauma will increase substantially as training programs and trauma centers redirect their training of residents to this modality and as more pediatric centers report outcome studies for laparoscopic trauma management in children.

15.3 Solid Organ Injury

15.3.1 Spleen and Liver

The spleen and liver are the organs most commonly injured in blunt abdominal trauma with each accounting for one third of the injuries. Nonoperative treatment of isolated splenic and hepatic injuries in stable children is now standard practice. Although nonoperative treatment of children with isolated, blunt spleen or liver injury has been universally successful, there has been great variation in the management algorithms used by individual pediatric surgeons. Controversy also exists regarding the utility of CT grading and the finding of contrast "blush" as predictors of outcome in liver and spleen injury. Several recent studies have reported rates of contrast "blush" on CT between 7% and 12% in 365 children with blunt spleen injury. The rate of operation in the "blush" group approached or exceeded 20%. The authors emphasized that CT "blush" was worrisome but that most patients could still be managed successfully without operation. The role of angiographic embolization in pediatric spleen injury has yet to be determined.

Recently, the American Pediatric Surgical Association (APSA) Trauma Committee has defined consensus guidelines for resource utilization in hemodynamically stable children with isolated liver or spleen injury based on CT grading by analyzing a contemporary, multi-institution database of 832 children treated nonoperatively at 32 centers in North America from 1995 to 1997. Consensus guidelines on ICU stay, length of hospital stay, use of follow-up imaging, and physical activity restriction for clinically stable children with isolated spleen or liver injuries (Grades I–IV) were defined by analysis of this database (Table 15.1).

The guidelines were then applied prospectively in 312 children with liver or spleen injuries treated nonoperatively at 16 centers from 1998 to 2000. Patients with other minor injuries such as non-displaced, non-comminuted fractures or soft tissue injuries were included as long as the associated injuries did not influence the variables in this study. The patients were grouped by severity of injury defined by CT grade. Compliance with the proposed guidelines was analyzed for age, organ injured, and injury grade. The recovery of all patients was monitored for 4 months

Table 15.1 Proposed guidelines for resource utilization in children with isolated spleen or liver injury

CT Grade	I	II	III	IV
ICU days	None	None	None	1 day
Hospital stay	2 days	3 days	4 days	5 days
Pre-discharge imaging	None	None	None	None
Post-discharge imaging	None	None	None	None
Activity restriction[a]	3 weeks	4 weeks	5 weeks	6 weeks

[a] Return to **full contact, competitive sports** (i.e., football, wrestling, hockey, lacrosse, mountain climbing, etc.) should be at the discretion of the individual pediatric trauma surgeon. The proposed guidelines for return to unrestricted activity include **"normal" age-appropriate activities**.

Table 15.2 Effect of hospital-type and professional training on the probability of splenic operation

Database	Comparison	Number of Patients	Patient Distrib.	Adjusted Odds Ratio (95% CI)	*P* Value
Kid 2000—AHRQ	General hospital vs. children's hospital	2191	85:15	**2.85** (1.43, 5.69)	<0.003
New England Pediatric Trauma Database—UHDDS	General surgeon vs. pediatric surgeon	2631	68:32	**3.1** (2.3, 4.4)	<0.0001
Pennsylvania UHDDS	Adult or non-TC vs. pediatric TC	3145	85:15	**6.19** (4.43, 8.66)	<0.0001
CA, FL, NJ, NY UHDDS	Non-TC vs. TC	3232	34:66	**2.12** (1.45, 3.09)	<0.0001

Kid 2000—AHRQ: Agency for Healthcare Research and Quality's Hospital Cost Utilization Project State Inpatient Database for the Year 2000.

UHDDS: uniform hospital discharge data sets; TC: trauma center; CI: confidence intervals.

after injury. It is imperative to emphasize that these proposed guidelines assume hemodynamic stability. The extremely low rates of transfusion and operation document the stability of the study patients.

Not surprisingly, adult trauma services have reported excellent survival rates for pediatric trauma patients; however, analysis of treatment for spleen and liver injuries reveals alarmingly high rates of operative treatment (Table 15.2). This discrepancy in operative rates emphasizes the importance of disseminating effective guidelines as the majority of seriously injured children are treated outside of dedicated pediatric trauma centers.

15.3.2 Complications of Nonoperative Treatment

Nonoperative treatment protocols have been the standard for most children with blunt liver and spleen injury during the past two decades. The cumulative experience gained allows us to evaluate both the benefits and risks of the nonoperative approach. Fundamental to the success of the nonoperative strategy is the early, spontaneous cessation of hemorrhage. Transfusion rates for children with isolated spleen or liver injury have fallen below 10% confirming the lack of continued blood loss in the majority of patients. Despite many favorable observations, isolated reports of significant delayed hemorrhage with adverse outcome continue to appear. Shilyansky et al. reported two children with delayed hemorrhage 10 days after blunt liver injury. Both children had persistent right upper quadrant (RUQ) and right shoulder pain despite normal vital signs and stable hematocrits. The authors recommended continued in-house observation until symptoms resolve. Recent reports described patients with significant bleeding 38 days after Grade II spleen injury and 24 days after Grade IV liver injury. These rare occurrences create anxiety in identifying the minimum safe interval prior to resuming unrestricted activities.

15.3.3 Sequelae of Damage Control Strategies

Even the most severe solid organ injuries can be treated without surgery if there is prompt response to resuscitation. In contrast, emergency laparotomy and/or embolization are indicated in patients who are hemodynamically unstable despite fluid and red blood cell transfusion. Most spleen and liver injuries requiring operation are amenable to simple methods of hemostasis using a combination of manual compression, direct suture, topical hemostatic agents, and mesh wrapping. In young children with significant hepatic injury, the sternum can be divided rapidly to expose the supra-hepatic or intra-pericardial inferior vena cava (IVC) allowing for total hepatic vascular isolation (Fig. 15.2). Children will tolerate periods of vascular isolation as long as their blood volume is replenished. With this exposure the liver and major peri-hepatic veins can be isolated and the bleeding controlled to permit direct suture repair or ligation of the offending vessel. While the cumbersome and dangerous technique of atrio-caval shunting has been largely abandoned, newer endovascular balloon catheters can be useful for temporary vascular occlusion to allow access to the juxtahepatic vena cava.

The early morbidity and mortality of severe hepatic injuries are related to the effects of massive blood loss

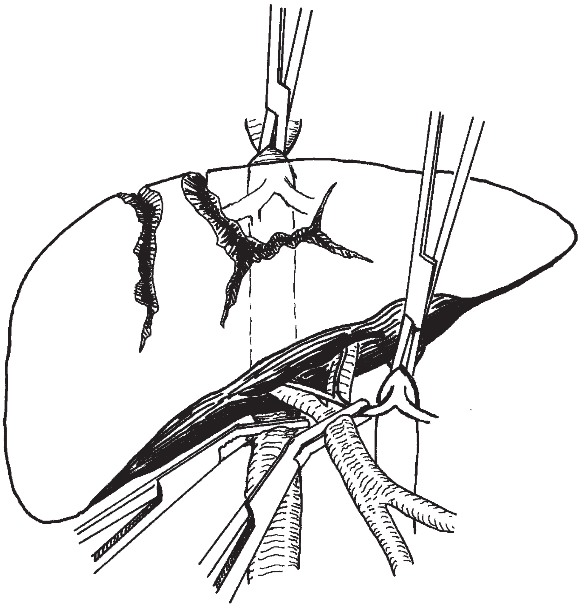


Fig. 15.2 Total hepatic vascular isolation with occlusion of the porta, supra-, and infra-hepatic inferior vena cava, and supraceliac aorta (optional)
Source: Original illustration by Mark Mazziotti, MD

and replacement with large volumes of cold blood products. The consequences of prolonged operations with massive blood product replacement include hypothermia, coagulopathy, and acidosis. Maintenance of physiologic stability during the struggle for surgical control of severe bleeding is a formidable challenge even for the most experienced operative team, particularly when hypothermia, coagulopathy, and acidosis occur. This triad creates a vicious cycle in which each derangement exacerbates the others and the physiologic and metabolic consequences of the triad often preclude completion of the procedure. Lethal coagulopathy from dilution, hypothermia, and acidosis can occur rapidly. The infusion of activated recombinant Factor VII in patients with massive hemorrhage has been promising in several case reports.

Increased emphasis on physiologic and metabolic stability in emergency abdominal operations has led to the development of staged, multidisciplinary treatment plans including abbreviated laparotomy, peri-hepatic packing, temporary abdominal closure, angiographic embolization, and endoscopic biliary stenting. Trauma surgeons treating critically injured children must familiarize themselves with this life-saving technique. Abbreviated laparotomy with packing for hemostasis allowing resuscitation prior to planned reoperation is an alternative in unstable patients where further blood loss would be untenable. This "damage control" philosophy is a systematic, phased approach to the management of the exsanguinating trauma patient. The three phases of damage control are detailed in Table 15.3. Once patients are rewarmed, coagulation factors replaced, and oxygen delivery optimized the patient can be returned to the operating room for pack removal and definitive repair of injuries.

Table 15.3 "Damage control" strategy in the exsanguinating trauma patient

Phase 1	Abbreviated laparotomy for exploration Control of hemorrhage and contamination Packing and temporary abdominal wall closure
Phase 2	Aggressive ICU resuscitation Core rewarming Optimize volume and oxygen delivery Correction of coagulopathy
Phase 3	Planned reoperation(s) for packing change Definitive repair of injuries Abdominal wall closure

It is essential to emphasize that the success of the abbreviated laparotomy and planned reoperation depends on an early decision to employ this strategy prior to irreversible shock. Abdominal packing, when employed as a desperate, last-ditch resort after prolonged attempts at hemostasis have failed has been uniformly unsuccessful. Physiologic and anatomic criteria have been identified as indications for abdominal packing. Most of these have focused on intra-operative parameters including pH (~7.2), core temperature (<35°C), and coagulation values (prothrombin time > 16 s) in the patient with profuse hemorrhage requiring large volumes of blood product transfusion.

The optimal time for reexploration is controversial because neither the physiologic endpoints of resuscitation nor the increased risk of infection with prolonged packing are well defined. The obvious benefits of hemostasis provided by packing are also balanced against the potential deleterious effects of increased intra-abdominal pressure on ventilation, cardiac output, renal function, mesenteric circulation, and intracranial pressure. Timely alleviation of the secondary "abdominal compartment syndrome" may be a critical salvage maneuver for patients. Temporary abdominal wall closure at the time of packing can prevent the abdominal compartment syndrome. We recommend temporary abdominal wall expansion in all patients requiring packing until the hemostasis is obtained and visceral edema subsides.

A staged operative strategy for unstable trauma patients represents **advanced** surgical care and requires sound judgment and technical expertise. Intra-abdominal packing for control of exsanguinating hemorrhage is a life-saving maneuver in highly selected patients in whom coagulopathy, hypothermia and acidosis render further surgical procedures unduly hazardous. Early identification of patients likely to benefit from abbreviated laparotomy techniques is crucial for success.

15.3.4 Abdominal Compartment Syndrome

The abdominal compartment syndrome is a term used to describe the deleterious effects of increased intra-abdominal pressure. The "syndrome" includes respiratory insufficiency from worsening ventilation/perfusion mismatch, hemodynamic compromise from pre-load reduction due to IVC compression, impaired renal function from renal vein compression as well as decreased cardiac output, intracranial hypertension from increased ventilator pressures, splanchnic hypoperfusion, and abdominal wall overdistention. The causes of intra-abdominal hypertension in trauma patients include hemoperitoneum, retroperitoneal, and/or bowel edema and use of abdominal/pelvic packing. The combination of tissue injury and hemodynamic shock creates a cascade of events including capillary leak, ischemia-reperfusion, and release of vasoactive mediators and free radicals, which combine to increase extracellular volume and tissue edema. Experimental evidence indicates significant alterations in cytokine levels in the presence of sustained intra-abdominal pressure elevation. Once the combined effects of tissue edema and intra-abdominal fluid exceed a certain level, abdominal decompression must be considered.

The adverse effects of abdominal compartment syndrome have been acknowledged for decades; however, abdominal compartment syndrome has only recently been recognized as a life-threatening yet potentially treatable entity. The measurement of intra-abdominal pressure can be useful in determining the contribution of abdominal compartment syndrome to altered physiologic and metabolic parameters. Intra-abdominal pressure can be determined by measuring bladder pressure. This involves instilling 1 ml/kg of saline into the Foley catheter and connecting it to a pressure transducer or manometer via a three-way stopcock. The symphysis pubis is used as the zero reference point and the pressure measured in cm H_2O or mm Hg. Intra-abdominal pressures in the range of 20–35 cm H_2O or 15–25 mm Hg have been identified as an indication to decompress the abdomen. Many prefer to intervene according to alterations in other physiologic and metabolic parameters rather than a specific pressure measurement. Anecdotally, decompressive laparotomy has been used successfully to reduce refractory intracranial hypertension in patients with isolated brain injury without overt signs of abdominal compartment syndrome.

Many materials have been suggested for use in temporary patch abdominoplasty including silastic sheeting, Goretex® sheeting, intravenous bags, cystoscopy bags, ostomy appliances, and various mesh materials (Fig. 15.3). The vacuum pack technique, used successfully in adults, seems promising.

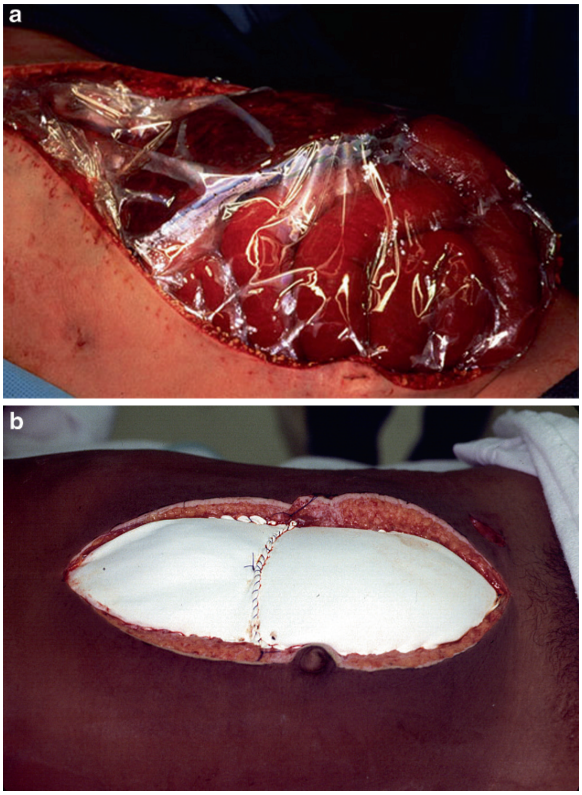


Fig. 15.3 **a**. Abdominal wall expansion with silastic sheeting. **b**. Abdominal wall expansion with goretex patch

15.3.5 Bile Duct Injury

Nonoperative management of pediatric blunt liver injury is highly successful but is complicated by a 4% risk of persistent bile leakage. Radionucleide scanning is recommended when biliary tree injury is suspected. Delayed views may show a bile leak even if early views are normal. Several reports have highlighted the benefits of endoscopic retrograde cholangio-pancreatography (ERCP) with placement of transampullary biliary stents for biliary duct injury following blunt hepatic trauma acknowledging that while ERCP is invasive and requires conscious sedation, it can pinpoint the site of injury and allow treatment of the injured ducts without open surgery. Endoscopic transampullary biliary decompression is a recent addition to treatment for patients with persistent bile leakage. The addition of sphincterotomy during ERCP for persistent bile leakage following blunt liver injury has been advocated to decrease intrabiliary pressure and encouraged internal decompression. It is important to note that endoscopic biliary stents may migrate or clog and require specific treatment.

15.4 Injuries to the Duodenum and Pancreas

In contrast to the liver and spleen, injuries to the duodenum and pancreas are much less frequent, reported as less than 10% of intra-abdominal injuries in children sustaining blunt trauma. Isolated duodenal and pancreatic injuries occur in approximately two third of cases with combined injury to both organs in the remainder of cases. The severity of the injury and other associated injuries determines the necessity for operative versus nonoperative management. The “protected” retroperitoneum both limits the chance of injury but increases the difficulty in early diagnosis. Added to this diagnostic dilemma is the frequency of associated intra-abdominal and/or multisystem injuries, which can mask subtle physical and radiographic diagnostic signs found in injury to the duodenum and pancreas.

15.4.1 Duodenum

A single-center experience in 27 children sustaining blunt duodenal injury (mean age of 7 years) revealed that 13 children had duodenal perforations (mean age = 9) and 14 sustained duodenal hematomas (mean age = 5). Associated injuries were seen in 19 (10 pancreas, 5 spleen, 4 hepatic, 2 long bone fracture, 1 CNS,1 renal contusion, 1 jejunal perforation, and 1 gastric rupture). The median interval from injury to surgery was 6 h in those sustaining perforation. The clinical presentation, laboratory evaluation, and radiographic findings of those with duodenal hematoma versus perforation are summarized in Table 15.4. Most patients had abdominal CT scans performed with oral and IV contrast. A comparison of CT findings in these patient groups is

Table 15.4 Comparison of the presenting symptoms and signs in children with duodenal hematoma and duodenal perforation

Patient Characteristics	Duodenal Hematoma	Duodenal Perforation
N	14	13
Age (yr)	5	9*
ISS score	10	25*
Seat belt worn: *n* (%)	6 (100)	5 (71)
Presentation		
Pain or tenderness: *n* (%)	10 (71)	12 (92)
Bruising: *n* (%)	6 (43)	11(85)
Glasgow coma scale	15	15
Associated injuries		
Pancreatic injury: *n* (%)	7 (50)	3 (23)
Lumbar spine injury: *n* (%)	1 (7)	4 (31)
Total: *n* (%)	11 (79)	8 (62)
Laboratory evaluation		
Hgb: (mg%)/Hct	12.3/0.36	12.1/0.37
Amylase: U (%)	678 (64)	332 (46)

*Statistically significant difference.

Table 15.5 Comparison of CT findings of children with duodenal hematoma and duodenal perforation

CT Findings	Duodenal Hematoma, *N* = 10 *N* (%)	Duodenal Perforation, *N* = 9 *B* (%)
Free air	1 (10)[a]	2 (22)
Free fluid	8 (80)	9 (100)
Retroperitoneal fluid	9 (90)	9 (100)
Bowel wall and peritoneal enhancement	2 (20)	4 (44)
Duodenal caliber change	4 (40)	3 (33)
Thickened duodenum	10 (100)	8 (89)
Mural hematoma	10 (100)	0
Retroperitoneal air	0	8 (89)
Retroperitoneal contrast[b]	0	4 (57)
Retroperitoneal air or contrast	0	9 (100)

[a] The child had an associated jejunal perforation.

[b] Enteral contrast was not administered in two children.

depicted in Table 15.5. These data demonstrate that the clinical presentation is strikingly similar in both groups with only age and ISS achieving significance statistically (but of little clinical relevance in individual patients). However, in comparing CT findings, extravasation of air or enteral contrast into the retroperitoneal, peri-duodenal, or pre-renal space was noted in every child with a duodenal perforation (9 of 9) and in none of 10 who had duodenal hematoma. The authors note that few previous reports in the literature describe these specific CT findings with duodenal injuries in general and no previous series of pediatric patients in particular with this data had previously been reported. The management of duodenal hematoma is expectant in most cases. The CT scans (or upper GI contrast studies in equivocal cases) showing duodenal narrowing, corkscrewing, or obstruction without extravasation was diagnostic in all. The experiences from Salt Lake City and Pittsburgh emphasize an alarming finding that a common cause of duodenal trauma was child abuse, especially in younger patients. Therefore, isolated duodenal injures should raise suspicion if the history and/or mechanism of injury described is inconsistent.

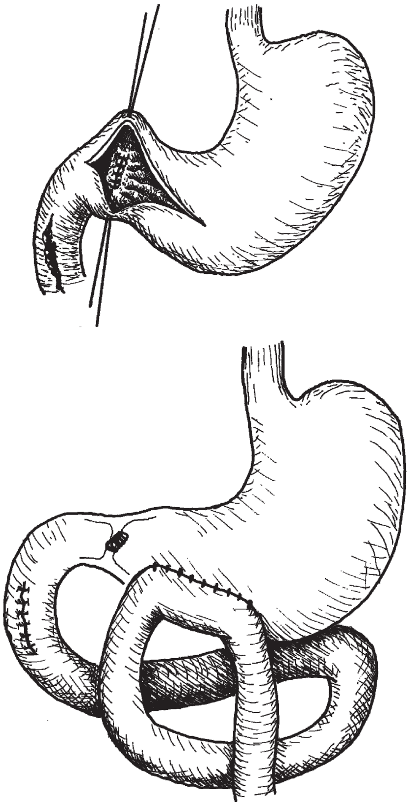


Fig. 15.4 Lateral duodenal injury treated by primary duodenal repair and "pyloric exclusion" consisting of closing the pylorus with an absorbable suture and gastrojejunostomy. Closed suction drainage of the repair is not depicted in this drawing
Source: Original illustration by Mark Mazziotti, MD

In all of these series, patients sustaining duodenal perforation were treated operatively in a variety of ways depending on the severity of the injury and surgeon's preference. We recommend primary closure of the duodenal perforation (whenever possible). Primary closure can be combined with duodenal drainage and either pyloric exclusion with gastro-jejunostomy (Fig. 15.4) or gastric drainage with feeding jejunostomy. These surgical options decrease the incidence of duodenal fistula, reduce the time to GI tract alimentation, and shorten hospital stay. An effective combination, when faced with complicated duodenal trauma, is the "three tube technique": duodenal closure (primary repair, serosal patch, or anastomosis) with duodenal drainage tube for decompression (tube 1), pyloric exclusion with an absorbable suture via gastrotomy and gastric tube placement (tube 2), and feeding jejunostomy (tube 3). Several closed suction drains are placed adjacent to the repair. When the duodenum is excluded (via an absorbable suture for temporary closure of the pylorus), complete healing of the injury routinely occurs prior to the spontaneous reopening of the pyloric channel (Fig. 15.5). However, no matter what repair the surgeon selects, a summary of the literature demonstrates that protecting the duodenal closure (drain and exclusion) and a route for enteral feeds (gastrojejunostomy or feeding jejunostomy) reduces morbidity and shortens hospital stay. A summary of the surgical options are listed in Table 15.6 and illustrated in Figs. 15.4 and 15.5. Of note, a pancreaticoduodenectomy (Whipple Procedure) should rarely be required. Although occasionally reported in the literature, pancreaticoduodenectomy should be reserved for the most severe injuries to the duodenum and pancreas when the common blood supply is destroyed and any possibility of reconstruction is impossible.

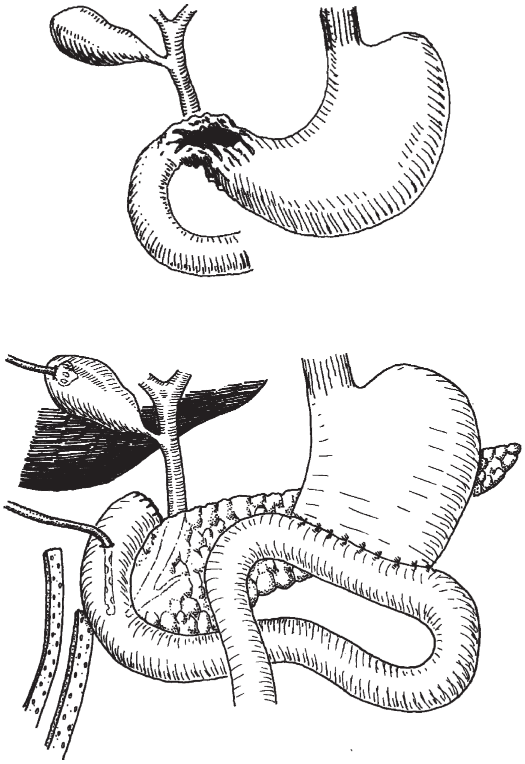


Fig. 15.5 Duodenal diverticularization for combined proximal duodenal and pancreatic injury. Resection and closure of the duodenal stump, tube duodenostomy, tube cholecystectomy, gastrojejunostomy, and multiple closed suction drains are depicted.A feeding jejunostomy should be strongly considered (not depicted) *Source*: Original illustration by Mark Mazziotti, MD

Table 15.6 Surgical options in duodenal trauma

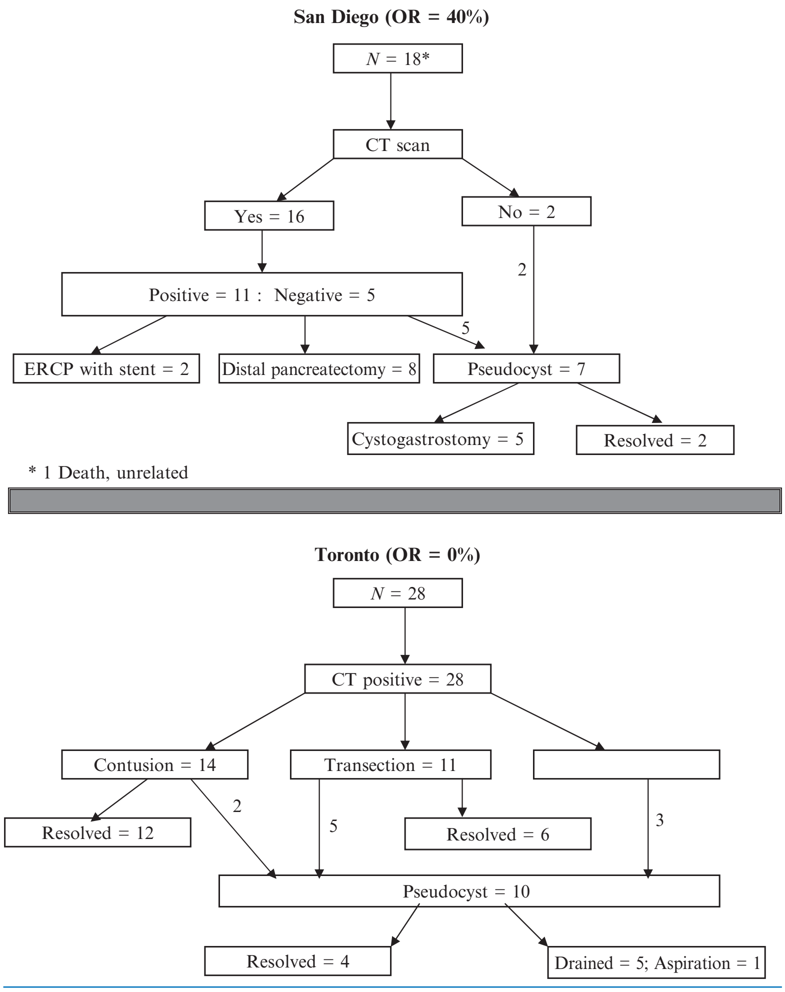
Repair of the duodenum
Diversion of the GI tract (pyloric exclusion or a duodenal diverticulization)
Gastric decompression (gastric tube insertion or gastrojejunostomy)
GI tract access for feeding (jejunostomy tube or gastrojejunal anastomosis)
Decompression of the duodenum (duodenostomy tube)
Biliary tube drainage
Wide drainage of the repaired area (lateral duodenal drains)

15.4.2 Pancreas

Injuries to the pancreas are slightly more frequent than duodenal injuries with estimated ranges from 3% to 12% in children sustaining blunt abdominal trauma. Recently, two centers (Toronto and San Diego) reported their experience with divergent methods of managing blunt traumatic pancreatic injuries in a series of reports. A summary comparing the San Diego and Toronto protocols is depicted in Table 15.7. The striking differences in these series are: the 100% diagnostic sensitivity of CT scanning in Toronto versus 69% in San Diego and the 44% operative rate in San Diego versus 0% in Toronto. The authors of the Toronto protocol conclude that following nonoperative management of pancreatic blunt trauma, atrophy (distal) or recanalization occurs in all cases with no long-term morbidity. Important concepts include the efficacy of magnetic resonance cholangio-pancreatography (MRCP) as a diagnostic tool, early ERCP intervention for diagnosis and treatment with ductal stenting, and the use of somatostatin to decrease pancreatic secretions and promote healing.

These reports from major pediatric trauma centers are clearly in conflict. Some favor and document the efficacy and safety of observational care for virtually all pancreatic traumas to include duct disruption while others advocate aggressive surgical management with debridement and/or resections. Since proponents of each supply compelling data for these treatments algorithms individual hospital/surgeon preference will probably determine which treatment plan is selected. However, it is clear that with simple transection of the pancreas at or to the left of the spine, spleen-sparing distal pancreatectomy

Table 15.7 A comparison of protocols in the management of blunt pancreas injury in children



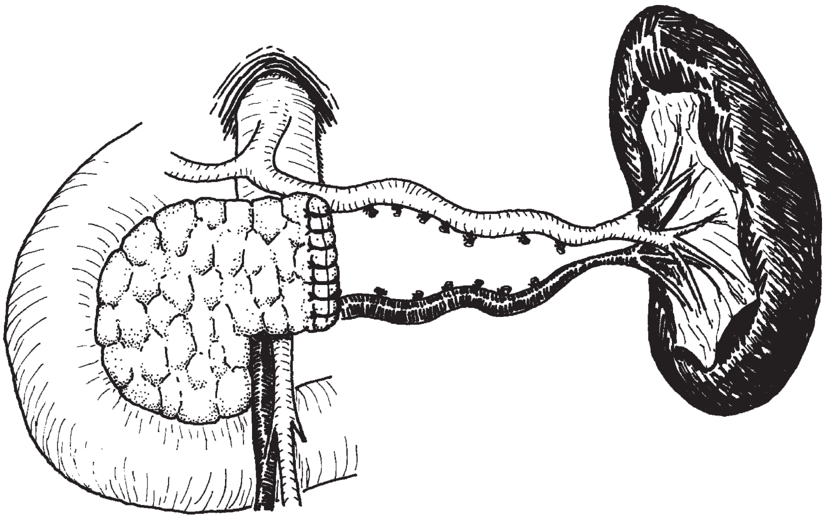


Fig. 15.6 Spleen-sparing distal pancreatectomy *Source*: Original illustration by Mark Mazziotti, MD

can accomplish definitive care for this isolated injury with short hospitalization and acceptable morbidity (Fig. 15.6).

15.5 The "Seat Belt Sign"

Frequent physical exams and vigilance is required for the subset of injuries caused in children with lap belt restraints while passengers in high speed automobile crashes. These children present with visible "seat belt signs" on physical exam of the abdomen (Fig. 15.7). Multiple studies have documented increased abdominal injuries to both solid and hollow organs with this finding. An interesting triad of injuries have been noted with abdominal wall contusions/herniation, chance fractures of the lumbar spine, and isolated jejunal/ileal perforations. One report reviewed 95 patients all wearing seat belts admitted with abdominal trauma. In 60 of 95, there was an occurrence of "seat belt sign." The proportion of patients with intestinal injuries with and without the seat belt sign were 9/60 and 0/35, respectively. The more common injuries described above can distract both the patient and the trauma team causing delay in the diagnosis of serious vascular injuries involving the aorta and iliac vessels.

One in every nine children with an abdominal seat belt sign has a significant intra-abdominal injury. Therefore, although the seat belt sign is rare, CT scanning, admission, and serial examination is mandated when it is present. After adjusting for age and seating position, optimally restrained children were more than three times less likely as suboptimally restrained children to suffer an abdominal injury.

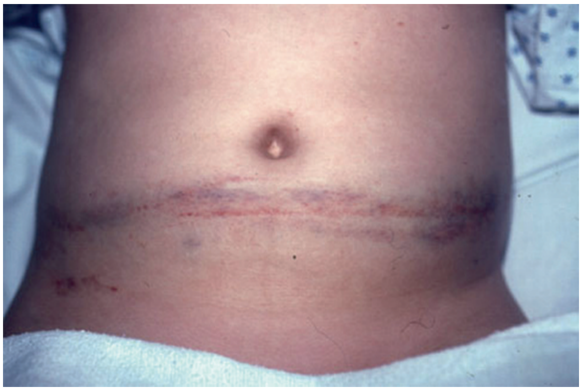


Fig. 15.7 Seat belt sign across lower abdomen

15.5.1 *Imaging for Gastrointestinal Injury*

Imaging of the GI tract has evolved over the past decade, with spiral CT and/or a FAST exam done by surgeons in the ER directly impacting our diagnostic accuracy and decision making. Some of the strengths and weaknesses of CT diagnosis have been discussed. However, our ability to diagnose and treat blunt abdominal trauma in children has been clearly enhanced by this modality. The significance of isolated free intraperitoneal fluid in the absence of solid organ injury has frequently been heralded as a sign of intestinal trauma. FAST was found to be useful as a screening tool with high specificity (95%), but unfortunately low sensitivity (33%) in evaluating intestinal injury. Clearly, as a screening tool, FAST can perhaps decrease the number of CT scans performed, but it will not allow for the diagnosis of specific abdominal organs injured. Finally, to come full circle, in a large study from Pittsburgh, 350 children with abdominal trauma were reviewed, with 30 requiring laparotomy (8.5%). There were 5 false negative CT scans (26%) in 19 patients who underwent delayed laparotomy (3.5 h or more post-injury). They concluded that serial physical examination and not CT scanning was the "gold standard" for diagnosing GI tract perforations in children. We concur!

15.6 Renal Trauma

The kidney is the most commonly injured organ in the urogenital system and children appear to be more susceptible to major renal trauma than adults. Several unique anatomic aspects contribute to this observation including: less cushioning from perirenal fat, weaker abdominal musculature, and a less well ossified thoracic cage. The child's kidney also occupies a proportionally larger space in the retroperitoneum than does an adult's kidney. In addition, the pediatric kidney may retain fetal lobulations, permitting easier parenchymal disruption.

Preexisting or congenital renal abnormalities, such as hydronephrosis, tumors, or abnormal position, may predispose the kidney to trauma despite relatively mild traumatic forces. Historically, congenital abnormalities in injured kidneys have been reported to vary from 1% to 21%. More accurate recent reviews have shown that incidence rates are 1–5%. Renal abnormalities, particularly hydronephrotic kidneys, may be first diagnosed after minor blunt abdominal trauma. Most often, these patients present with hematuria following blunt trauma. Others may present with an acute abdomen secondary to intraperitoneal rupture of the hydronephrotic kidney.

Major deceleration and flexion injuries can lead to renal artery or vein injuries due to stretching forces on a normally fixed vascular pedicle. This type of injury may be more common in children because of their increased flexibility and renal mobility. Posttraumatic thrombosis of the renal artery occurs secondary to an intimal tear. The intimal layer tears from the wall of the vessel because the media and adventitia of the renal artery are more elastic than the intima. The intimal tear produces turbulence, thrombosis, and eventual occlusion that then results in renal ischemia. A high index of suspicion must be maintained in order to identify these injuries.

15.6.1 Diagnosis of Renal Injury

Once the patient has been resuscitated and life-threatening injuries have been addressed, evaluation of the genitourinary system can be undertaken. Following any blunt injury, the presence of hematuria (microscopic or gross), a palpable flank mass, or flank hematomas are indications for urologic evaluations. Most major blunt renal injuries occur in association with other major injuries of the head, chest, and abdomen. Urologic investigations should be undertaken when trauma to the lower chest is associated with rib, thoracic, or lumbar spine fractures. It should also be undertaken in all crush injuries to the abdomen or pelvis when the patient has sustained a severe deceleration injury. Since a renal pedicle injury or ureteropelvic junction (UPJ) disruption may not be associated with one of the classic signs of renal injury, such as hematuria, radiologic evaluation of the urinary tract should always be considered in patients with a mechanism of injury that could potentially injure the upper urinary tract.

Gross hematuria is the most reliable indicator for serious urological injury. The need for imaging in the patient with blunt trauma and microscopic hematuria is not as clear cut. The degree of hematuria does not always correlate with the degree of injury. Renal vascular pedicle avulsion or acute thrombosis of segmental arteries can occur in the absence of hematuria while mild renal contusions can present with gross hematuria. Guidelines for evaluating the pediatric population are not as clearly defined. All children with any degree of microscopic hematuria after blunt trauma have traditionally undergone renal imaging. The presence of multisystem trauma significantly increases the risk for significant renal damage. It is reasonable to consider observation with no renal imaging in children with microscopic hematuria of <50 RBC/HPF that are stable and without a mechanism of injury that is suspect for renal injury.

CT scans are now used almost exclusively as the imaging study of choice for suspected renal trauma in hemodynamically stable adults and children. CT is both sensitive and specific for demonstrating parenchymal laceration, urinary extravasation, delineating segmental parenchymal infarcts, determining the size and location of the surrounding retroperitoneal hematoma, and/or associated intra-abdominal injury. CT also allows for accurate staging of the renal injury.

It is imperative to acknowledge that major renal injuries such as UPJ disruption or segmental arterial thrombosis may occur without the presence of hematuria or hypotension. Therefore, a high index of suspicion is necessary to diagnose these injuries. Nonvisualization of the injured kidney on intra-venous pyelogram (IVP), or failure to uptake contrast with a large associated perirenal hematoma on CT are hallmark findings for renal artery thrombosis. UPJ disruption is classically seen as perihilar extravasation of contrast with nonvisualization of the distal ureter.

15.6.2 Treatment of Renal Injury

In most patients, attempts should be made to manage all renal injuries conservatively. Minor renal injuries constitute the majority of blunt renal injuries and usually resolve without incident. The management of major renal parenchymal lacerations, although accounting for only 10–15% of all renal trauma patients, is currently controversial. Surgery is not always mandatory and many major renal injuries due to blunt trauma may be managed conservatively. When necessary, the goals of surgical renal exploration are to either definitively treat major renal injuries with preservation of renal parenchyma when possible, or to thoroughly evaluate a suspected renal injury. The need for surgical exploration is much higher in patients with penetrating trauma as opposed to blunt trauma.

The indications for renal exploration vary greatly between individual trauma centers. Most centers manage Grade I–III injuries with bed rest and observation, as expected. Controversies arise in the management of Grade IV–V injuries. The majority of blunt renal injuries sustained are contusions and lacerations that are minor in nature. Even in the presence of gross hematuria, most blunt renal injuries will not require exploration and will have excellent long-term outcomes. **Absolute indications** for renal exploration include persistent life-threatening bleeding, an expanding, pulsatile, or uncontained retroperitoneal hematoma, or suspected renal pedicle avulsion. Relative indications for exploration include substantial devitalized renal parenchyma or urinary extravasation. Urinary extravasation in itself does not demand surgical exploration. Matthews reported that in patients with major renal injury and urinary extravasation that are managed conservatively, urinary extravasation resolved spontaneously in 87%. Extravasation persisted in 13% and was successfully managed endoscopically. Incomplete staging of the renal injury demands either further imaging or renal exploration and reconstruction. Most commonly, these patients undergo renal exploration because they have persistent bleeding, or because they have an associated injury that requires laparotomy.

When conservative management is chosen, supportive care with bed rest, hydration, antibiotics, and serial hemoglobin and blood pressure monitoring is required for uneventful healing. After the gross hematuria resolves, limited activity is allowed for 2–4 weeks until microscopic hematuria ceases. Early complications can occur with observation within the first 4 weeks of injury and include delayed bleeding, abscess, sepsis, urinary fistula, urinary extravasation and urinoma, and hypertension. The greatest risk is delayed hemorrhage occurring within the first 2 weeks of injury and this may be life threatening. Immediate surgical exploration or angiographic embolization is indicated. Angiographic embolization is an alternative to surgery in a hemodynamically stable patient in whom persistent gross hematuria signifies persistent low grade hemorrhage from the injured kidney. Persistent urinary extravasation has successfully been managed by percutaneous drainage. Hypertension in the early post-trauma period is uncommon. Hypertension may develop in the ensuing months and in most instances is treated with medical management.

15.6.3 Renal Exploration and Reconstruction

If operation is required, early control of the vessels increases the rate of renal salvage. When proximal vascular control is initially achieved before any renal exploration, nephrectomy is required in less than 12% of cases. When primary vascular control is not achieved and massive bleeding is encountered, in the rush to control bleeding, a kidney that could have been salvaged may be sacrificed unnecessarily. The surgeon must carefully identify the kidney's relationships with the posterior abdomen and the posterior parietal peritoneum. The colon is lifted from the abdomen and placed on the anterior chest in order to allow mobilization of the small bowel. The inferior mesenteric vein and the aorta are identified at this point, and the posterior peritoneum is incised medial to the inferior epigastric vein. The aorta is dissected above the level of the ligament of Treitz, where the left renal vein is found crossing anterior to the aorta. Retraction of the left renal vein exposes both renal arteries beneath, which may now be isolated and controlled with vessel loops. Once vessel isolation is complete, an incision is made in the peritoneum just lateral to the colon. The colon is reflected medially to expose the retroperitoneal hematoma in its entirety and the kidney may be exposed. If significant bleeding is encountered, the ipsilateral renal vessels may be occluded. Warm ischemia time should not surpass 30 min.

Renal vascular injuries must be addressed promptly. Major lacerations to the renal vein are repaired directly by venorrhaphy. Repair of renal arterial injuries may require a variety of techniques, including resection and end-to-end anastomosis, bypass graft with autogenous vein or a synthetic graft, and arteriorrhaphy. Traumatic renal artery occlusion requires many of the same techniques for repair. However this must be performed in the first 12 h from the time of injury, otherwise, the kidney is usually nonviable following this length of ischemia.

Summary

Recent advances in the delivery of trauma and critical care in children have resulted in improved outcome following major injuries. It is imperative that pediatric surgeons familiarize themselves with current treatment algorithms for life-threatening abdominal trauma such as "damage control" and the consequences of the abdominal compartment syndrome. Important contributions have been made in the diagnosis and treatment of children with abdominal injury by radiologists and endoscopists. Clinical experience and published reports addressing specific concerns about the nonoperative treatment of children with solid organ injuries and recent radiologic and endoscopic contributions have made pediatric trauma care increasingly nonoperative. Although the trend is in this direction, the pediatric surgeon should remain the physician-of-record in the multidisciplinary care of critically injured children. *The decision not to operate is always a surgical decision!*

Further Reading

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