CT OF BOWEL AND MESENTERIC INJURY

Stuart E. Mirvis, MD, FACR

Bowel and mesenteric injuries (BMI) are relatively uncommon being found in approximately 3 - 5% of patients undergoing laparotomy for blunt abdominal trauma. BMI is found in about 1% of all blunt abdominal trauma patients undergoing CT evaluation. Small bowel injuries typically occur in the proximal jejunum near the ligament of Treitz or at the distal ileum near the ileo-cecal junction where mobile and fixed segments are attached and prone to shear force injury. Bowel injuries are difficult to diagnose both clinically and by imaging studies. Clinical signs of bowel injury such as abdominal tenderness, rigidity, and diminished bowel sounds are present in < 50% of patients. Diagnostic peritoneal lavage (DPL) has been used traditionally to detect free hemorrhage or intestinal contents as evidence of potential bowel or mesenteric injury and is considered by some to be diagnostically superior to CT, In a study by Pikoulis et al DPL was positive for blood in 25 of 36 (69%) of patients with BMI. Well-known deficiencies of DPL include its high sensitivity to even minor self-limited injuries, its lack of sensitivity to retroperitoneal injuries that might involve the duodenum or parts of the colon, and non-specificity regarding both the site and extent of any intraperitoneal injury. Newer methods of cell count analysis using DPL, such as the "cell count ratio, the ratio between the white blood cell count and red blood cell count in lavage fluid divided by the same ratio in the peripheral blood, may improve the specificity of DPL for bowel injury. Abdominal sonography can be used to detect intraperitoneal free fluid and its accuracy to specifically detect BMI is unknown, but likely poor. In the study by Pikoulis et al abdominal sonography was positive for blood in only 13 of 25 (52%) of patients with BMI.

CT of bowel and mesenteric injury

In recent years CT has been found in both surgical and imaging studies to have reasonably high accuracy for the detection and characterization of BMI. In a survey conducted by the American Association for the Surgery of Trauma (AAST) 75% of respondents indicated that they use CT most or all of the time for patients with a possible diagnosis of small bowel injury, which was significantly higher ($p<0.05$) compared with other diagnostic modalities.

In the author's opinion it is generally helpful to administer oral contrast prior to CT of blunt trauma cases. Contrast may be given orally or per nasogastric tube as soon as the patients is scheduled for abdominal CT scan (450 ml). An additional oral contrast load can be given in the CT scanning room (450 ml). The oral contrast will usually fill the stomach and at least the proximal small bowel. Although there are rare reports of aspiration related to oral contrast administration, in general its administration appears safe and without complications. Opacification of the upper gastrointestinal tract can help assess for small bowel contusion, hematoma, and full-thickness tears. In addition, oral contrast helps delineate the pancreas and can be useful to diagnose pancreatic injury. Some authors have suggested that the use of oral contrast does not add anything to diagnostic accuracy of CT for BMI and delays performance of CT and that it delays the performance of CT. Stafford showed an average six-minute delay in starting CT for patients receiving oral contrast. CT should only be delayed to administer oral contrast, but not for migration of contrast to the distal small bowel.

The decision to perform abdominal-pelvic CT is made based on the patient overall hemodynamic status, clinical and laboratory findings, and proximity and availability of the CT scanner. In a hemodynamically unstable patient the abdomen is best assessed with rapid abdominal sonography as a prelude to surgery. In the hemodynamically stable patient the spectrum of patients that are appropriately studied by CT is broad and includes: 1) patients with an unreliable clinical assessment, 2) positive physical abdominal examination without overt peritoneal signs, 3) positive DPL or sonography, 4) suspicion of retroperitoneal injury based upon mechanism of injury, gross hematuria, or posterior lower rib fractures, flank, or back contusion, and 5) an undetermined source of blood loss.

The accuracy of CT for BMI has improved steadily in the last decade as faster CT scanners with diminished artifacts entered clinical use. Specifically, the introduction of helical and multi-slice helical CT has proved a major leap forward in this area. Early studies were compromised by both technical limitations (motion, volume averaging, and slice thickness) and lack of familiarity by interpreting physicians of both diagnostic and suspicious CT findings reported a prospective 64% sensitivity, 97% specificity and 82% accuracy of CT for BMI. Sherk et al reported a sensitivity of 92%, specificity of 94%, accuracy of 94%, negative predictive value of 100%, and positive predictive value of 30% among in a group of 26 patients with small bowel injury. Killeen et al studied CT scans of 150 blunt abdominal trauma patients with a prospective CT or operative diagnosis of BMI. Scans were graded as positive or negative for BMI and surgical or non-surgical injury. CT scans were 94% sensitive in detecting bowel injury and 96% accurate at identifying those cases requiring surgery. CT was 86% sensitive in identifying mesenteric injuries and 75% accurate in determining those that required surgical intervention. In part this lower accuracy for surgical intervention in mesenteric injury was related to non-standardized treatment approaches to some mesenteric injuries found at surgery. Another study by Dowe et al showed CT was 89% accurate to detect mesenteric injury.

CT signs of bowel injury - Pneumoperitoneum

CT signs of bowel injury can be defined as diagnostic or suspicious. Pneumoperitoneum, without a known source indicates a full-thickness bowel injury until proven otherwise. Other sources of pneumoperitoneum include, most commonly, dissection from the thorax, diagnostic lavage, and combined penetrating and blunt abdominal injury. The majority of patients with full-thickness bowl injury will not demonstrate pneumoperitoneum on their admission CT. Pneumoperitoneum usually accumulates beneath the anterior abdominal wall and is easiest to detect adjacent to the soft tissue mass of the liver. Bowel gas associated with rupture may also collect in the porta hepatis, mesentery, bowel wall, and rarely the portal vein. It is important to review abdominal images in windows for lung or preferably bone as small amounts of extraluminal air may be difficult to see in normal soft tissue window/level settings and otherwise difficult to distinguish from adjacent intraluminal gas. Whenever air is detected in the peritoneal cavity, bowel wall, mesentery, or portal veins and no other extraabdominal source is apparent, the diagnosis of full-thickness hollow viscous tear should be considered highly probable.

Direct tear in the bowel wall

The diagnosis of bowel injury can be made if interruption of the bowel lumen is directly visualized. Although this is a relatively rare observation, the use of thin section, multi-slice spiral CT should increase its recognition by decreasing motion and volume averaging. Direct spillage or oral contrast material into the peritoneal cavity is similarly diagnostic of full-thickness bowel injury. Again, this is a relatively uncommon finding of full-thickness bowel injury, but very obvious when it occurs. Extravasated contrast spills into the low resistance intraperitoneal space. Alternatively, active arterial bleeding usually dissects into the mesentery under pressure and is surrounded by a non-enhanced hematoma. Extravasated urine from intraperitoneal bladder rupture could be confused with an oral contrast leak.

Intraperitoneal free fluid

Intraperitoneal free fluid is another important finding that may be an indirect sign of BMI. Small amounts of free fluid are not uncommonly seen in the cul-de-sac of women of child- bearing age. If only a small amount of fluid is seen in this setting, clinical observation is typically sufficient for management. CT detection of free abdominal fluid should otherwise suggest other non-physiologic sources including the bowel, mesentery, and occult solid visceral injury. Measurement of CT density should be routinely performed to help differentiate serous fluid from blood. Several studies have been performed to clarify the significance of isolated free fluid on CT of the blunt posttrauma abdomen. Breen et al found isolated free fluid with no apparent source in 11 (58%) of 19 patients with proven BMI. Brasel et al found isolated free fluid in 3% (34 of 1141 blunt trauma CT cases). Among these 34 patients there were 10 described as having only trace fluid and none of these had a missed injury. Levine et al analyzed 60 patients with abdominal CT for blunt trauma with free intraperitoneal fluid noting location and volume based on the sum of individual locations. They observed that patients with larger amounts of fluid were more likely to require surgery and to have bowel or mesenteric injuries than those with small quantities. They suggested use of DPL in patients with small amounts of fluid. Hulka et al found 24 (9%) of 259 abdominal CT studies for trauma had free intraperitoneal fluid as the only finding. Two of 16 patients with a small amount of fluid required laparotomy and four of eight with moderate amounts did as well. When fluid was observed in more than one anatomic location

50% of patients had bowel injury. In a study by Nolan et al five of seven falsely negative CT studies occurred among patients with operatively confirmed bowel or mesenteric injury had free fluid that was not prospectively appreciated. Cunningham et al found 18 patients with bowel injury and eight with mesenteric injury among 31 patients in whom abdominal CT showed only free fluid. They recommended mandatory laparotomy given this CT finding, but this appears to be a minority opinion.

In summary, the presence of free fluid without an obvious solid visceral source should be regarded with suspicion particularly if more than a trace amount. The next diagnostic decision depends in part on the reliability of the physical examination. Early DPL may indicate elevated white cell count or intestinal chyme and lead to surgery. Careful follow-up abdominal examination and blood studies to detect early peritoneal inflammation may also be utilized. Alternatively, a repeat CT within about 6 hours can also be used to monitor any progression or early resolution of initial CT findings; information that will influence the decision for exploration of the abdomen.

Bowel wall thickening

The detection of bowel wall thickening is in part a subjective determination. The normal small bowel wall is typically 1-2 mm in thickness by CT when partially distended and 3-4 mm thick when collapsed. When there is contrast or fluid clearly visible within the bowel lumen the author considers 5-6 mm as mild thickening, 7-8 mm as moderate thickening, and > 8 mm as marked thickening. In the author’s experience bowel wall thickening is most commonly evident in the proximal jejunum just distal to the ligament of Treitz and involves several adjacent bowel loops. The finding of localized, but unequivocal bowel wall thickening is considered to represent bowel wall contusion as an isolated finding. Diffuse small bowel wall thickening is atypical for contusion and may be a manifestation of either systemic volume overload (bowel edema) or “shock-bowel” (reperfusion “third spacing”) (see below). Dowe et al have observed that bowel wall thickening associated with infiltration of the adjacent mesentery or mesenteric hematoma is more likely to represent a bowel or mesenteric injury that requires surgical repair. When the admission CT study demonstrates focal bowel wall thickening without other signs of BMI without another indication for celiotomy a repeat CT is performed after 6 hours along with serial physical examination and appropriate laboratory studies. If these studies indicate both clinical and imaging stability, expectant management is adopted.

Bowel wall enhancement

In additional to increased thickness of the bowel wall related to edema or perhaps some intramural hemorrhage, the bowel may, when injured, exhibit a patchy type of increased wall enhancement after intravenous contrast. The mechanism of this pattern is uncertain, but may relate to slowed perfusion of contrast material through injured areas of the bowel wall or leakage of contrast into areas of capillary damage either from prior ischemia or mechanical disruption. This finding, like bowel wall thickening, is suggestive, but non-diagnostic of full thickness injury and mandates careful follow-up if seen as an isolated finding. In the author's experience this CT finding is usually accompanied by several other suggestive or diagnostic CT findings of full thickness bowel injury or clinical findings mandating exploration.

The bowel may manifest other signs of injury in the setting of blunt trauma. Duncan et al reported intussusception causing post-laparotomy obstruction in six blunt abdominal trauma patients without bowel injury at surgery. The intussusception was usually jejuno-jenunal with three patients presenting in the first eight post-operative days. No clear etiology was established for this entity. The bowel can also obstruct from incarceration within mesenteric tears, or traumatic hernias. Killeen et al described 15 patients with traumatic incarceration of the bowel among patients who sustain acute lumbar hernias in blunt trauma Eldridge et al reported a patient with small bowel incarceration within a lumbar spine distraction injury and Stubbart et al a traumatic bowel entrapment in a pelvic fracture. It should be remembered that bowel injuries should be excluded in any patient sustaining a Chance-type flexion-distraction fracture of the lumbar spine. The bowel can also sustain indirect injury through interruption of its blood supply by injury to the mesentery or avulsion of its major arterial supply although major vascular injuries are far more commonly related to penetrating trauma.

Colonic and rectal injury in blunt trauma

Nolan et al that colonic injury occurs one-fifth as commonly as small bowel injury from blunt trauma and was found in 286 (0.5%) of 54,361 major blunt trauma patients reported by Ross et al in a multi-center study. The spectrum of potential injuries is similar to that seen in small bowel injury, but these injuries may remain clinically silent for longer periods when they involve the retroperitoneal regions. The majority of injuries described are serosal tears and contusion. Intramural hematomas, full-thickness tears, and devascularized segments also occur. Bugis et al report that the left colon is more frequently injured than the right in blunt force injury, whereas the right and transverse were more are involved from penetrating injury. In the author’s experience rectal injuries are most commonly the result of penetrating trauma and are extremely rare with blunt injury unless related to direct peroneal impact. Colon and rectal injuries represent 5% of all intraabdominal injuries. In another study of 109 patients with colon and rectal injury from blunt trauma the transverse colon injuries were most commonly involved. Most transverse colonic injuries were contusions or seromuscular, non-full thickness, lacerations. In general, mesenteric avulsion, ischemia, and full-thickness colon tears were uncommon but accounted for most morbidity and mortality. Overall, mortality was related to concurrent major injuries that were present in 85% of the patients.

Mesenteric Injury

Relatively few imaging studies have been performed specifically addressing the CT diagnosis of mesenteric injury. Jansen et al. described 13 patients with mesenteric injury diagnosed by CT and reported an overall accuracy of 77%, specificity of 93%, and negative predictive value of 93%. These authors were only able to distinguish major (surgical) injury form minor (non-surgical injury) in 54% of their patients. Dowe et al evaluated 27 patients with a CT or surgical diagnosis of mesenteric injury in whom 24 (89%) had laparotomy. In two cases CT was falsely negative. CT findings indicating a high likelihood of finding a surgical lesion with active mesenteric contrast extravasation, bowel wall thickening associated with adjacent mesenteric infiltration or hematoma, and mesenteric hematoma enveloping or surrounding the adjacent bowel. The finding of mesenteric infiltration of focal hematoma without adjacent bowel wall thickening was less specific as an indicator of a surgical mesenteric lesion. Killeen et al studied 150 patients with CT or operative diagnosis of BMI. In this series CT was 96% sensitive in detecting mesenteric injury based on initial interpretation, and was able to differentiate surgical from non-surgical findings in 75% of cases.

Mesenteric injuries can appear as streaky infiltration hematomas, or active bleeding within the mesentery. As noted above the presence of active bleeding and a hematoma enveloping the adjacent bowel constitute definitive indications for surgery. Active bleeding appears as high density contrast material (within 10 HU of an adjacent contrast-enhanced artery) surrounded by lower attenuation hematoma. In most cases in the author's experience the hematoma dissects and is confined within the leaves of the mesentery. Contrast extravasation into the bowel lumen may also occur.

Mimics and Masks of Bowel and Mesenteric Injury

There are two relatively common pathologic processes that occur in the blunt trauma setting that can obscure or mimic BMI. Increased central venous pressure (CVP) may result from over-hydration, cardiac tamponade, tension pneumothorax, or obstruction of the IVC by adjacent hematoma. It causes distension of the inferior vena cava (IVC) and renal veins, periportal lymphedema, subserosal pericholecystic fluid accumulation, bowel wall, mesenteric, and retroperitoneal edema. Distention of the high capacitance IVC and renal veins occurs initially, followed by periportal lymphatic distention, and last by bowel wall, mesenteric, and retroperitoneal edema. The small bowel wall is typically diffusely involved with edema, as may be the mesentery. The colon is usually spared. In this setting, other CT findings of BMI may be masked by bowel and mesenteric edema and the diagnosis requires detection of pneumoperitoneum, oral contrast leak, or other diagnostic CT finding. Given these findings it is prudent to comment that bowel wall and mesenteric injury cannot be reliably excluded.

“Shock-bowel” occurs after prolonged hypotension or cardiac arrest “in-the-field”. The bowel appears thickened, dilated, fluid-filled, and the wall enhances in a patchy but diffuse pattern. Again, the small bowel is most commonly involved, but the colon occasionally is a well. The IVC is collapsed (although it may not be if there is massive volume resuscitation preceeding the CT) and there is no evidence of periportal lymphedema. The mesentery often appears edematous as well. Again, in this physiologic setting some of the CT signs of BMI are mimicked or could be hidden and the diagnosis is made more difficult again requiring the presence of diagnostic findings. Both elevated IVP and shock bowel patterns revert to a normal pattern when the hypoperfusion and elevated CVP are corrected.

Penetrating trauma involving bowel and mesentery

In hemodynamically stable patients with penetrating trauma to the flank and back CT can be used to assess presence and extent of retro and intraperitoneal injury. The procedure requires administration of oral, intravenous, and rectal contrast. The colonic contrast opacification is crucial to detect perforations in the posterior, retroperitoneal portions of the bowel. Any evidence of bowel perforation or intraperitoneal intrusion by the penetrating object requires surgical exploration. Recently, at the author's institution the use of CT scanning with triple-contrast has been extended to include non-ballistic tangential and right upper quadrant wounding of the abdomen, as well as in cases where shallow penetration is suspected by wound inspection. Preliminary data indicates that single and multi-slice spiral CT applied to these types of penetrating trauma can reliably demonstrate or exclude injuries requiring exploration. Indications of intraperitoneal penetration such as pneumoperitoneum or hemoperitoneum are usually adequate for exploration. In many cases direct evidence of bowel involvement is apparent by CT findings including bowel wall edema, oral or colonic contrast extravasation, or intramural or intramesenteric air. Similarly mesenteric hematoma or infiltration in the setting of penetrating trauma is sufficient for abdominal cavity exploration. CT evidence of penetrating injury confined to the right upper quadrant (liver) without active bleeding or other evidence of intraperitoneal organ involvement is increasingly being managed by observation and follow-up imaging

Selected References:

1. Pikoulis E, Delis S, Psalidas N, et al. Presentation of blunt small intestinal and mesenteric injuries. Ann R Coll Surg Engl. 2000 Mar;82(2):103-6.
2. Killeen KL, Shanmuganathan K, Poletti PA, Cooper C, Mirvis SE. Helical computed tomography of bowel and mesenteric injuries. J Trauma. 2001 Jul;51(1):26-36.
3. Breen DJ, Janzen DL, Zwirewich CV, Nagy AG. Blunt bowel and mesenteric injury: diagnostic performance of CT signs. J Comput Assist Tomogr. 1997 Sep-Oct;21(5):706-12.
4. Brasel KJ, Olson CJ, Stafford RE, Johnson TJ. Incidence and significance of free fluid on abdominal computed tomographic scan in blunt trauma. J Trauma. 1998 May;44(5):889-92.
5. Hulka F, Mullins RJ, Leonardo V, Harrison MW, Silberberg P. Significance of peritoneal fluid as an isolated finding on abdominal computed tomographic scans in pediatric trauma patients. J Trauma. 1998 Jun;44(6):1069-72.
6. Nolan BW, Gabram SG, Schwartz RJ, Jacobs LM. Mesenteric injury from blunt abdominal trauma. Am Surg. 1995 Jun;61(6):501-6.
7. Cunningham MA, Tyroch AH, Kaups KL, Davis JW. Does free fluid on abdominal computed tomographic scan after blunt trauma require laparotomy? J Trauma. 1998 Apr;44(4):599-602; discussion 603.
8. Dowe MF, Shanmuganathan K, Mirvis SE, Steiner RC, Cooper C. CT findings of mesenteric injury after blunt trauma: implications for surgical intervention. AJR Am J Roentgenol. 1997 Feb;168(2):425-8.
9. Ross SE, Cobean RA, Hoyt DB, et al. Blunt colonic injury--a multicenter review. J Trauma. 1992 Sep;33(3):379-84.
10. Tarrant AM, Ryan MF, Hamilton PA, Benjaminov O. A pictorial review of hypovolaemic shock in adults. Br J Radiol. 2008 Mar;81(963):252-7.
11. Stuhlfaut JW, Anderson SW, Soto JA. Blunt abdominal trauma: current imaging techniques and CT findings in patients with solid organ, bowel, and mesenteric injury. Semin Ultrasound CT MR. 2007 Apr;28(2):115-29. Review.
12. Peters E, LoSasso B, Foley J, Rodarte A, Duthie S, Senac MO Jr. Blunt bowel and mesenteric injuries in children: Do nonspecific computed tomography findings reliably identify these injuries? Pediatr Crit Care Med. 2006 Nov;7(6):551-6.
13. Brofman N, Atri M, Hanson JM, Grinblat L, Chughtai T, Brenneman F. Evaluation of bowel and mesenteric blunt trauma with multidetector CT. Radiographics. 2006 Jul-Aug;26(4):1119-31. Review.