Assessment of Multi-Slice Computed Tomography Angiography (MSCTA) Finding of Major Vascular Injuries in Blunt Abdominopelvic Trauma

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Abstract

Blunt abdominal trauma is a leading cause of morbidity and mortality among all age groups worldwide. The management of the blunt abdominal trauma patient is demanding and requires speed and efficiency. Diagnosing intra-abdominal injuries is often challenging because some of the injuries may not manifest during the initial assessment period. Those missed intra-abdominal injuries are frequent causes of morbidity and mortality, especially in patients who survive the initial phase of assessment. If the diagnosis of abdominal injury is not done properly, then a worse outcome is frequently associated. For example, if perforation of the gastrointestinal tract is involved, a delayed treatment can be associated with a high morbidity and mortality. However, even though most of abdominal trauma-related deaths are known to be preventable, studies have shown the abdominal trauma to be one of the most common causes of preventable deaths. Physical examination findings cannot be reliable in the case of blunt abdominal trauma. One reason is that mechanisms of injury can result in other associated injuries that may divert the physician's attention from potentially life-threatening intra-abdominal pathology. An altered mental state, drug use, and alcohol intoxication are other challenging reasons. The most common causes of blunt abdominal trauma are motor vehicle collisions (MCVs), assaults, recreational accidents, or falls; the most commonly injured organs are spleen, liver, retroperitoneum, small bowel, kidneys, bladder, colon, rectum, diaphragm, and pancreas; and men tend to be affected slightly more often than woman.

Introduction

Blunt abdominal trauma is a leading cause of morbidity and mortality among all age groups worldwide. The management of the blunt abdominal trauma patient is demanding and requires speed and efficiency.1&2

Diagnosing intra-abdominal injuries is often challenging because some of the injuries may not manifest during the initial assessment period. Those missed intra-abdominal injuries are frequent causes of morbidity and mortality, especially in patients who survive the initial phase of assessment. If the diagnosis of abdominal injury is not done properly, then a worse outcome is frequently associated. For example, if perforation of the gastrointestinal tract is involved, a delayed treatment can be associated with a high morbidity and mortality. 1&3

Physical examination findings cannot be reliable in the case of blunt abdominal trauma. One reason is that mechanisms of injury can result in other associated injuries that may divert the physician's attention from potentially life-threatening intra-abdominal pathology. An altered mental state, drug use, and alcohol intoxication are other challenging reasons.1,3&4

Several studies have shown the usefulness of the intravenous contrast CT in the diagnostic work-up of abdominal trauma, essentially for evaluating vascular injuries (5). Intravenous contrast material is crucial to diagnose active arterial extravasation, the use of CT with intravenous contrast in the examination of patients with blunt abdominal trauma, as well as, the trend toward non-operative management of many abdominal injuries, has decreased both the need for exploratory surgery and the frequency of non-therapeutic laparotomies.5

Multi-detector computed tomography (MDCT) Findings and procedure details for vascular anatomy:

MDCT is the imaging modality of choice for vascular anatomy characterization, specially using post-processing techniques such as MPR and 3D volume. Moreover, maximum intensity projection (MIP) techniques are highly recommended, as they greatly enhance the depiction of vascular structures at CT angiography. 6& 7

Celiac Trunk

The celiac trunk is the first anterior major branch of the abdominal aorta, originating near the level of the first lumbar vertebra. Normal anatomy of the celiac trunk includes three major branches: the common hepatic, left gastric and splenicarteries. 6

The normal CT anatomy of celiac trunk anatomy, accurately depicted on a single image in a 3D reconstruction (A) and partly depicted on the MIP reconstruction in the sagital plane (B), which is the preferred plane for the visualization of the abdominal aorta anterior branches.6& 8

The splenic artery and left gastric artery most commonly originate from the celiac trunk, up to 10% of cases have a different origin for the left gastric artery such as the abdominal aorta itself in rare cases. 6& 9

Superior mesenteric artery

The superior mesenteric artery is the second anterior branch of the abdominal aorta, originating 1 cm caudal to the celiac trunk, with a descending course lying to the left of the superior mesenteric vein. During its course, it gives origin to multiple branches to supply the majority of the small bowel (by means of the inferior pancreaticoduodenal, jejunal, and ileal arteries) and also the ascending and transverse colon (by means of the middle colic, right colic, and ileocolic arteries). 6&7

Lower abdominal vasculature

The inferior mesenteric artery is the third anterior branch of the abdominal aorta, originating from its distal portion at the level of the third lumbar vertebra. It can be found medial to the inferior mesenteric vein. It supplies the part of the colon which is not supplied by branches of the superior mesenteric artery (descending and sigmoid colon), as well as the superior rectum. Its four main branches are: the left colic artery, sigmoidal artery, rectosigmoid artery and the superior rectal artery. 6& 7

Portal vein system

In standard portal vein anatomy, the splenic and superior mesenteric veins join to form the main portal vein, which typically divides into two main branches. Besides variations in the portal vein branches which should be carefully evaluated (including trifurcation of the main portal and the presence of separate branches for hepatic segments), other more dramatic changes can also be found, even incidentally on a CT examination performed for other reasons, including portal vein congenital absence, duplication, or rarely aneurysms. 7

Mechanism of Injury

Understanding the mechanism of injury is the key to correlates with the imaging findings, and allow deeper understanding of potential vascular injury patterns. Analysis of the injury mechanism gives the radiologist the ideas for constructing hypothetical models of force vectors to better understand the pathogenesis of potential vascular trauma and avoid missing injuries. Common blunt trauma mechanisms of injury include motor vehicle collisions, bicycle collisions, motorcycle collisions, falls, and assault.10&11

Major vascular and organ vascular injury in abdominopelvic trauma

Vascular Injuries in Trauma

The CT findings in vascular injury may be classified as direct or indirect. Direct signs, are more specific but less sensitive in detection of vascular trauma, and involve different abnormalities of the vessel wall such as laceration, intimal tear, dissection, pseudoaneurysm, intraluminal thrombosis, spasm, and arteriovenous fistulas 12. Indirect signs, are more sensitive but less specific, and include abnormalities of the perivascular tissues or end organs such as presence of a perivascular hematoma or fat stranding and end-organ hypoenhancement. 12

Active Contrast Material Extravasation

Active hemorrhage in traumatic vascular injury is typically seen as a defect in all three layers of the vessel wall (intima, media, and adventitia), which lead to extension of the contrast-enhanced blood beyond the vessel lumen. During CT imaging, an extravascular hyper-attenuating focus or “blush” is evident, and this focus continue to expands in subsequent more delayed phases of acquisition. Active extravasation can be seen in both the intra- and extraperitoneal spaces, adjacent to the injured vessel, or as intraparenchymal or intraluminal bleeding when a solid or hollow organ is injured. 13&14

Sites of Major Vascular Injury:

Aortic Injury

Aortic Injury is associated with high mortality rate, so it is imperative to immediately diagnose aortic injury. Multidetector CT is 98% sensitive in detecting aortic injury. Incomparison with the thoracic aorta, abdominal aortic injuries are rare. Ninety percent of aortic injuries occur at the aortic isthmus where the aorta is attached to the ligamentumarteriosum.15

Vascular Injury in the Pelvis

The pelvis is a bony ring composed of the sacrum along its posterior aspect and two lateral components (ilium, ischium, and pubis) that are fused along the anterior aspect at the pubic symphysis. The pelvic vessels include the common, internal, and external iliac arteries and their branches. Vascular injuries in pelvic trauma have a high morbidity and mortality. Up to 40% of blunt pelvic trauma is associated with significant pelvic bleeding.16

Visceral Organ Vascular Injury

Visceral organ vascular injuries during blunt abdominopelvic trauma can manifest as direct intraparenchymal vascular injury or indirectly as varying degrees of end-organ hypoenhancement on contrast-enhanced CT.17

Direct intraparenchymal vascular injury presentations include arteriovenous fistula, pseudoaneurysm, laceration, and hematoma.17

Liver:

The wide spectrum of visceral organ vascular injuries described earlier is commonly seen in liver injury; however, vascular injuries in the liver may be more complex due to its dual blood supply. In a portal venous injury, due to compensatory increased arterial inflow, the affected liver segment may appear relatively hyperattenuating in the arterial phase. Subsequently, the affected liver segment may appear relatively hypoattenuating in the portal venous phase with respect to the adjacent liver parenchyma due to the venous injury.18

Spleen:

Spleen is the most commonly affected organ during blunt abdominal trauma. The spleen is a highly vascular organ that is surrounded by a thin fibroelastic capsule. Its delicate capsule is advantageous in settings such as portal hypertension to accommodate expansion in elevated portal venous pressures. However, this sinusoidal organ is essentially a blood reservoir that lacks a thick fibrous capsule, reducing its ability to increase intraorgan pressures to tamponade parenchymal bleeding.19

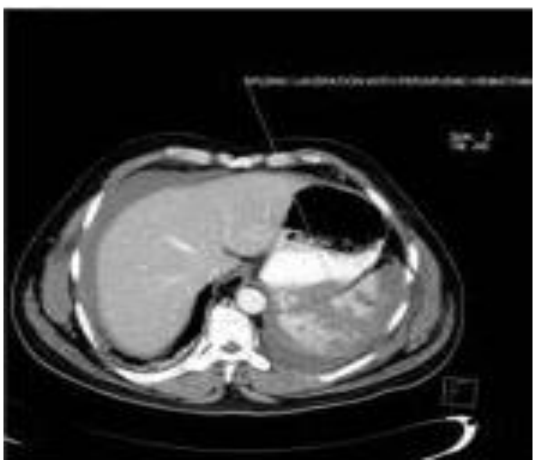
Splenic vascular injuries have a wide range of presentations, including splenic artery or vein laceration, intraparenchymal hematoma, subcapsular hematoma, pseudoaneurysms and arteriovenous fistulas. The sinusoidal architecture of the splenic parenchyma causes it to have heterogeneous enhancement in the arterial phase, limiting the ability to detect parenchymal defects. As discussed earlier, lacerations of the solid organs, commonly the spleen, can lead to linear or irregular parenchymal hypoenhancement with associated active contrast material extravasation (Fig.1,2,3).

Fig. (1): CT scan of liver injury in a 48-year-old man with MVA. CT demonstrates a subcapsular haematoma that appears as a hypodense collection, compressing on the underlying liver parenchyma (arrows).

Fig. (2): Renal artery injury with no renal enhancement.

Fig. (3): a- Splenic contusion, b- Splenic laceration with perisplenic hematoma.

a



b

Kidneys:

In the kidneys, major vascular injury may also have various presentations. When the kidney is lacerated into multiple portions, it is considered "shattered." A shattered kidney will be presented on radiological images as active hemorrhage that usually needs urgent surgery or endovascular repair.20 Renal vein injury can have obvious imaging findings such as transection or thrombosis. Secondary findings include changes related to acute venous hypertension of the affected kidney, including nephromegaly, delayed nephrogram, and decreased excretion of contrast material at delayed phase imaging.19

Dissection or intimal injury to renal artery caused by rapid deceleration and stretching of the renal artery across a vertebral body or transverse process lead to renal artery occlusion.19&20

At CT, renal artery occlusion results in distal nonenhancement and ischemia of the affected segment of the kidney. Occasionally, renal artery occlusion can cause reflux of contrast material into the renal vein from the inferior vena cava, owing to lack of forward flow of blood in the affected renal vein.19

Bowel and Mesentery:

Variable imaging manifestations as active extravasation, mesenteric vessel vasoconstriction, mesenteric vessel beading, and abrupt termination of the mesenteric vasculature at sites of injury, all are wide range of CT presentations during blunt trauma of the mesentery and bowel.21

Brofman et al 22 retrospectively reviewed CT studies of patients with surgically proven bowel injury, mesenteric injury, or both. Their study demonstrated that active mesenteric extravasation (17%), mesenteric vascular beading (35%), and abrupt termination of the mesenteric vessels (39%) are vascular injury imaging findings highly suggestive direct signs of potential mesenteric and/or bowel injury.22

Organ Injury Grading Systems

Understanding the vascular injury in the visceral organs need analysis both the history and current trends in organ injury grading scales. In 1987, the Organ Injury Scaling (OIS) Committee of the American Association for the Surgery of Trauma (AAST) devised injury severity grades for individual organs for the purposes of having a common nomenclature in trauma as well as for future clinical research. AAST organ injury grading scales are based on the gross anatomic appearance of injured organs seen during surgery, with increasing severity from grade 1 to grade 6.23

The different AAST organ injury grading scales share certain features of traumatic injury such as size of lacerations, major vessel injury, segmental or complete infarction, and organ shattering. Each AAST OIS grade is assigned as an abbreviated injury severity score (AIS), which is used to calculate the injury severity score (ISS), and used as a predictor of patient survival.23&24

Radiological evaluation of Patients with blunt abdominal trauma

Diagnosing intra-abdominal injuries is often challenging because some of the injuries may not manifest during the initial assessment period. Those missed intra-abdominal injuries are frequent causes of morbidity and mortality, especially in patients who survive the initial phase of assessment.25

Physical examination findings cannot be reliable in the case of blunt abdominal trauma. One reason is that mechanisms of injury can result in other associated injuries that may divert the physician's attention from potentially life-threatening intra-abdominal pathology. An altered mental state, drug use, and alcohol intoxication are other challenging reasons.26

Whilst sonography and conventional radiography remain well-established techniques, CT scanning of the abdomen and pelvis has been shown to be the procedure of choice in evaluating the hemodyanamically stable patient who has sustained blunt abdominal trauma.26

Though Focused Abdominal Sonography for Trauma (FAST) is highly sensitive and specific for intra-abdominal fluid, it is unable to yield any information on the types and details of the injuries sustained, and it is also known to be user-dependent. 27

Plain abdominal radiography has no role in the assessment of blunt abdominal trauma, as it does not visualize abdominal viscera or detect free fluid, and could not provide direct evidence of organ injury or indirect evidence of haemorrhage.28

However, abdominal radiography may provide indirect evidence of hollow viscous injury by showing air or gas in the peritoneum, but it lacks sensitivity and specificity. Chest and pelvic radiography is important during the primary survey.29

The use of CT in the examination of patients with blunt abdominal trauma, along with a trend toward nonoperative management of many abdominal injuries, has decreased the need for exploratory surgery and reduced the frequency of non-therapeutic laparotomies.26

Nowadays there is a trend towards nonoperative management of blunt abdominal trauma. With CT, it has been shown that up to 85% of abdominal solid organ injuries can be treated conservatively, and that more than 50% of splenic injury, 80% of liver injury and virtually all renal injuries can be managed nonoperatively, because patients proved to have better outcomes on the long term related to visceral salvage.26

Both IV and oral contrast may be given in trauma cases. Of these, IV contrast is more important as it allows detection of injuries to solid organs (liver, spleen, pancreas, and kidneys) as well as vascular structures that would be missed without contrast.30&31

1- Technique of contrast enhanced CT scan:

Proper technique is critical for accurate abdominal CT examination of patients with blunt abdominal trauma. 32

Multidetector CT offers significantly faster scanning times and improved image resolution due to thinner collimation and reduced partial volume and motion artifacts compared with single-section helical CT. The improved coverage speed and Z-axis resolution have made angiographic, multiplanar reformatted (MPR), maximum-intensity-projection (MIP), and volume-rendered images available for clinical applications.32&33

2- CT Interpretation:

CT scans for blunt abdominal trauma must be meticulously reviewed for proper interpretation. On the evaluation, urgent life-threatening injuries, such as a large hemoperitoneum, a large or tension pneumothorax, pneumoperitoneum, signs of hypovolemic shock, or active arterial extravasation, should be sought out first. Then, a thorough interrogation for injury of the abdomen and pelvis is performed as follows: liver and right paracolic gutter, spleen and left paracolic gutter; upper abdominal organs, including the stomach, duodenum, pancreas, gallbladder and biliary tree; retroperitoneum, including the adrenals, kidneys, inferior vena cava, and aorta; small bowel, colon, and mesentery; pelvis, including the urinary bladder; muscles, including the abdominal wall, psoas, iliacus, and gluteals; bones, including the spine and pelvis; and thighs.32

3. Expected CT scan findings and management decisions in blunt abdominal trauma:

Many trauma patients have multiorgan injuries. Therefore, a thorough evaluation of all abdominal components is warranted as already mentioned. Hemoperitoneum is easily seen on CT and may be the only or most obvious sign of abdominal injury. Its presence should prompt a thorough search for injury to visceral organs.34&35

Hemoperitoneum is differentiated from other fluid by its increased attenuation, averaging 45 Hounsfield Units (HU) and always greater than 30 HU if less than 48 hours old, it tends to be identified near the source of bleeding, spreading throughout the abdominal cavity and into the pelvis along pathways common to all abdominal fluid collections. Free collections of intraperitoneal blood are most often seen in the Morrison's pouch, the most dependent peritoneal recess in the upper abdomen, and are frequently seen in the perihepatic space and the right paracolic gutter. The pelvis is the most dependent portion of the peritoneal cavity, and large collections of blood may be present in the pelvis even when little blood collection is seen in the abdominal recesses. 34&35

4- Injury to the major blood vessels:

The incidence of abdominal vessel injury in patients with blunt trauma is estimated at approximately 5-10%. In blunt trauma, rapid deceleration during a motor vehicle accident.36

Motor vehicle accident (MVA) results in an avulsion of the small branches of major vessels (e.g. mesenteric tear).36

Another mechanism of injury is related to a direct crush or blow to the major vessels, resulting in an intimal tear with thrombosis or vessel rupture and haemorrhage.36

Hemodynamically stable patients with blunt trauma and suspected abdominal vascular injuries may benefit from abdominal computed tomography (CT) scanning, which helps to localize a haematoma and evaluate solid organ injuries. Angiography with or without embolization may be considered in stable patients, particularly in patients with blunt trauma.36

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