THE ROLE OF IV CONTRAST MEDIUM IN DIAGNOSTIC BLUNT ABDOMINAL TRAUMA CT SCAN AT KENYATTA NATIONAL HOSPITAL

(KNH) – KENYA

A dissertation Submitted for the Award of Degree of Masters of Medicine (M.Med) in Diagnostic Imaging and Radiation Medicine, University of Nairobi (UON)

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DECLARATION

I, **Dr. Fidens Dusabeyezu** declare that the work contained herein is my original idea and has not been presented at any other university in Kenya to the best of my knowledge.

Signature……………………………………..Date…………………………………........

APPROVAL BY SUPERVISOR

This research proposal has been submitted with my approval as a university supervisor.

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To you all and to all those who helped me in one way or another, I humbly say THANK YOU AND MAY GOD BLESS YOU.

DEDICATION

To my dear and lovely wife, Diane Umutesi, for her support, patience and care.

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ABBREVIATIONS

AAST	American Association for the Surgery of Trauma
ALARA	As Low As Reasonably Achievable
cm	Centimetre
CT	Computed Tomography
DPL	Diagnostic Peritoneal Lavage
ERCP	Endoscopic Retrograde CholangioPancreatography
FAST	Focused Abdominal Sonography for Trauma
HU	Hounsfield Unit
HVI	Hollow Viscus Injury
IV	Intravenous
IVC	Inferior Vena Cava
kg	Kilogram
KNH	Kenyatta National Hospital
KVP	Peak Kilovoltage
mA	Milliampere
MBchB	Bachelor Of Medicine And Surgery
MDCT	Multidetector Computed Tomography
mg	Milligram
MI	Mesenteric Injury
ml	Millilitre
mm	Millimetre
MMed	Masters of Medicine
MPR	Multiplanar Reformatted
MVA	Motor Vehicle Accident
NOM	Nonoperative Management
sec	Second

ABSTRACT

Background: Previous studies have proven the intravenous contrast CT to be the cornerstone of the diagnostic work-up of abdominal trauma, essentially for evaluating solid parenchymal and vascular injuries. This study was aimed at determining the utility of IV contrast medium in diagnostic blunt abdominal trauma CT scan at Kenyatta National Hospital (KNH), since IV contrast medium was not routinely used in KNH for blunt abdominal trauma CT scan.

Methods: A standard questionnaire was used to record the socio-demographic characteristics of the study participants, the mode of trauma and CT scan findings. All patients sent for initial diagnostic abdominopelvic CT scan with recent history of blunt abdominal trauma, who could receive IV contrast medium and who consented participation over the study period made the study population. Each participant underwent at least two consecutive scans, one scan without IV contrast medium and another one with IV contrast medium for comparison of findings. For IV contrast scans a portal venous phase scan at 65 seconds and a delayed phase scan at 5 minutes after starting IV contrast injection were acquired to every patient in our study.

Results: Thirty nine patients were enrolled into the study. The male to female ratio was 3.8:1. Twenty one patients (53.9%) were in the age group of 21-40 years. Thirty patients (76.9%) sustained abdominal injuries following motor traffic accidents.
The spleen was the most commonly injured organ (41%), followed by the liver (38%) and the kidneys (15%). Hemoperitoneum was the most common CT finding (17 patients) and out of 115 injuries registered in our study, pre contrast scans could only detect 45 injuries which correspond to 39.1% (95 % CI 30.2 – 48.7). This means that 60.9% (95% CI 51.3 – 69.8) of injuries would have been missed without contrast injection.

Conclusion: The use of IV contrast medium assisted in the demonstration of 60.9 % (95% CI 51.3 – 69.8) of injuries that would have been missed without contrast injection. This confirms the usefulness of IV contrast injection in blunt abdominal CT scan.

Recommendations: In order to reach definite conclusions larger series are needed.
Diagnostic protocol for management of patients with blunt abdominal injuries should be made and be available for guiding radiologists and surgeons on management of patients with abdominal injuries.
A study to evaluate the accuracy of CT scan in the detection of blunt abdominal injuries by comparing CT findings and operative findings is needed.

CHAPTER I: INTRODUCTION AND LITERATURE REVIEW

I.1. INTRODUCTION

Despite advances in automobile safety and proliferation of injury prevention efforts, blunt trauma remains a substantial cause of morbidity and mortality among all age groups worldwide.

The care of the blunt abdominal trauma patient is demanding and requires speed and efficiency (1), (2).

Physical examination findings for these patients have been shown to be notoriously unreliable, and whilst sonography and conventional radiography remain well-established techniques, CT scanning of the abdomen and pelvis is the procedure of choice to evaluate the hemodynamically stable patient who has sustained blunt abdominal trauma (3). Studies have shown that with CT, up to 85% of solid organ injuries can be treated conservatively (4).

Previous studies have highlighted the usefulness of the intravenous contrast CT in the diagnostic work-up of abdominal trauma, essentially for evaluating solid parenchymal and vascular injuries (5). Without intravenous contrast enhancement, injuries of those organs can often be imperceptible. In addition, active arterial extravasation is only detectable with intravenous contrast material. And the use of CT with intravenous contrast 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 (6) (7).

I.2. LITERATURE REVIEW

Blunt abdominal trauma is a leading cause of morbidity and mortality among all age groups. 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) (8).

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. (2), (9).

Physical examination findings can not 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 (1), (10).

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. CT has replaced Diagnostic Peritoneal Lavage (DPL) as the first method of choice in many trauma centres worldwide and its major advantage is that it is not only capable of revealing the presence of intra-abdominal or intra-thoracic haemorrhage but can also identify the organ involved (3).

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 (11).

However, FAST is still an important screening tool in blunt abdominal trauma, particularly looking for significant haemoperitoneum. If present in a patient who is haemodynamically unstable, emergency laparotomy would be warranted (12).

Plain abdominal radiography has no role in the assessment of blunt abdominal trauma, although some authorities continue to advocate its use (13). It does not visualize abdominal viscera or detect free fluid, so it cannot provide direct evidence of organ injury or indirect evidence of haemorrhage. Little evidence exists to support the use of plain abdominal radiograph in case of blunt abdominal injury, and it is difficult to justify conceptually.

However, abdominal radiography may provide indirect evidence of hollow viscus injury by showing air or gas in the peritoneum, but it lacks sensitivity and specificity. Chest and pelvic radiography continue to be important adjuncts to the primary survey. The results may suggest haemorrhage in adjacent cavities, but they cannot rule out intra-abdominal bleeding or visceral injury (14).

In view of all the above limitations, CT scan has gained much popularity among trauma surgeons in the evaluation of blunt abdominal trauma. It is non-invasive and allows immediate and specific information on the intra-abdominal, retroperitoneal and bony structures.

All these allow improved diagnostic accuracy in the presence and extent of injuries in patients with blunt abdominal trauma. But the main disadvantage of CT is the time required for the procedure to be performed, which may be critical in a trauma patient (15).

CT has been shown to be highly sensitive, specific, and accurate for use in detecting the presence or absence of injury and defining its extent. The diagnostic usefulness of CT made possible a nonoperative management of many posttraumatic injuries, particularly in the liver, spleen and kidney. (6) (7). CT can also detect most of posttraumatic injuries to the pancreas, bowel, and mesentery.

Even though the usefulness of CT in evaluating solid organ injuries is beyond doubt, no clear consensus exists in its usage in Hollow Viscous Injury/Mesenteric Injury (HVI/MI). In these areas, however, signs may be subtle, and a significant injury may be missed on an initial examination (16) (17). Several reports have quoted the effectiveness of CT in diagnosing HVI/MI to be from unreliable to very accurate (18) (19).

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. 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 (9) (10) (20).

Intravenous contrast is essential for evaluating solid parenchymal and vascular injuries as stated before. Enhancement of vascular structures and solid viscera is a key reason for the success of CT in Trauma. And again, intraparenchymal hematomas and lacerations alter the perfusion of contrast. They are generally significantly lower in attenuation than normally perfused parenchyma on contrast CT.

Primary vascular injuries such as aortic lacerations or areas of active arterial extravasation can only be confidently diagnosed with contrast administration. The current usage of helical and multidetector CT (MDCT) scanners has further increased the frequency with which active arterial extravasation can be seen.

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) that would be missed without contrast. The role of oral contrast in CT for blunt trauma is controversial. Various authors have evaluated the benefits (or disadvantages) of the addition of oral contrast agent for CT scanning. Older studies usually base their protocols on conventional single-detector row helical CT scan with use of oral and intravenous contrast. Although relatively rare and not always easy to detect, extravasation of oral contrast is highly specific for damage to the bowel and nearly always results in further surgical exploration. It is believed to be helpful in confirming or excluding bowel injury and to avoid confusing unopacified bowel with intraperitoneal blood. Those opposing the use of oral contrast argue the potential delay in patient care and the risk of aspiration, which although relatively uncommon, can end disastrous for the patient. Newer studies using (multidector) CT scanners in which oral contrast was omitted show comparable results, indicating that the administration of oral contrast can be avoided (16) (17).

I.2.1.TECHNIQUE OF CONTRAST ENHANCED CT SCAN

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

Multidetector CT offers significantly faster scanning times and improved image resolution due to thinner collimation and reduced partial volume and motion artefacts 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 (21) (22).

Depending on the available scanner, a typical protocol for multidetector CT of the abdomen and pelvis in the setting of trauma is as follows: 1-2.5 mm collimation; 1-1.75 pitch; and 100-150 ml (300-370 mg of iodine per millilitre) of contrast agent injected intravenously at 3-6ml/sec for an adult. IV contrast material can be given as an initial bolus of approximately 50 ml at a rate of 2-3 ml/sec, followed by a rapid infusion at 1 ml/sec.

Alternatively, a single sustained bolus of contrast material at a rate of 1-3ml/sec may be administered, particularly if dynamic scanning capability is available. The dose is altered for children to 2-3 ml/kg bodyweight. A mechanical injector is useful for regulating the flow of contrast material, and dynamic scanning techniques are used to decrease examination time in this group of patients in whom expediency can be critical to successful treatment.

Scanning is performed beginning 60-70 seconds after the onset of contrast material injection in the portal venous phase from the dome of the diaphragm to the lesser trochanters. Scans are usually taken at 1 cm intervals from the dome of the diaphragm through the abdomen and at 1.5 to 2.0 cm intervals through the pelvis. Images are reconstructed with a 2.5-3 mm thickness at 2-3 mm intervals. Coronal and sagittal reformatted images may be obtained and sent for soft-copy interpretation along with the axial images. Alternatively, the thin-section axial data can be reformatted on the interpreting workstation as needed depending on the picture archiving and communication system (PACS) and workstation configuration in place (22).

The use of oral contrast material is optional. It has been shown to be safe in trauma patients, with a number of studies showing an extremely low risk of aspiration. Typical agents include 500-600ml of diluted (2-5%) water-soluble oral contrast material administered orally or through a nasogastric tube as the patient is being stabilized or transported to the CT suite. As stated before, recent literature suggests that the multidetector CT without oral contrast material may be adequate for the detection of bowel and mesenteric injuries and comparable to single detector row helical CT with oral contrast material (16) (22).

If there is suspicion injury to the thorax, thoracic CT with thin-collimation scanning can be performed initially during the vascular phase for MPR images of the aorta, followed immediately by scanning of the abdomen and pelvis during the parenchymal phase with use of the same intravenous contrast material bolus.

Delayed scanning (5-8minute delay) may be helpful in cases of suspected intra-abdominal bleeding or in the evaluation of urinary tract injuries when renal or severe pelvic injuries are identified.

Imaging artefacts can be avoided by placing the patient’s arms above the abdomen if possible, and positioning monitoring devices, tubes, and wires out of the scan plane. It is advisable to partially withdraw a nasogastric tube so that the tip is positioned within the distal oesophagus and repositioned after the examination is completed. A large field of view decreases artefacts from structures that cannot be removed from the scan field.

Restraints or sedation may be necessary to avoid motion artefacts in patients unable to maintain the proper position and fast scans (<2sec) may be performed with many scanners to minimize motion artefacts (20) (21).

Depending on the scanning mode and patient’s size, 100-300 mA and 140 KVp are typicaly used. If there is suspicion of bladder injury, for example in case of gross hematuria or pelvic ring fracture, cystography or CT cystography should be performed. It has been shown that standard CT with intravenous contrast enhancement has a lower sensitivity for these injuries. CT cystography can offer a few advantages over conventional cystography. First, the patient can be evaluated by CT cystography after the initial scan without the need to move to another location and CT cystography can also distinguish intraperitoneal, extraperitoneal, or combined bladder rupture. For CT cystogram, a delay of 180 seconds prior to pelvic scanning permits the bladder to opacify (16).

When CT cystography is performed, the urinary bladder is first drained by Foley catheter following the abdominal CT scan. The CT cystogram is done with either standard scans or scout imaging. The cystogram should be performed before intravenous injection of contrast media. In the adult, a minimum of 300 ml of dilute contrast media is used. If this is normal, drainage and wash out (bladder flushed with sterile fluid) may be performed but is not routinely needed (21).

Usage of various CT windows is crucial. In addition to soft-tissue window settings, lung window settings are obtained for evaluation of the lower chest for significant injuries such as pneumothorax, lung parenchymal injuries, or free peritoneal air indicating hollow viscus injury, and bone window settings are used for bony fractures. It is also useful to view images directly on the console video monitor, so that window and level settings can be manipulated to appreciate subtle but potentially significant findings.

Patients are monitored throughout the examination, and emergent resuscitation equipment should be readily available (20).

I.2.2. 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 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.

The entire system review has been called the “every-organ-on-every-slice” approach. It is believed that, with the modern Picture Archiving and Communication System (PACs) workstation, image review is best accomplished by rapidly paging through the images multiple times, with special attention to one organ at a time; hence, “every slice of every organ.” With this method, subtle injuries can be readily identified (23).

I.2.3. 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. Hemoperitoneum is differentiated from other fluid because of increased attenuation, averaging 45 Hounsfield Units (HU) and always greater than 30 HU if less than 48 hours old. Hemoperitoneum 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 is seen in the abdominal recesses (24) (25).

There has been controversy concerning the amount of intraabdominal haemorrhage and severity of organic injury. Federle and Jeffrey (24) used CT to quantify hemoperitoneum into small, moderate, and large collections. They attempted to correlate estimates of the amount of haemorrhage with severity of visceral organ injury and outcome from either operative or nonoperative treatment. Kearney et al. (26), however, using Federle and Jeffrey’s classification, did not find quantification of hemoperitoneum useful in predicting the need for surgery. CT is useful, however, for detecting the resolution of hemoperitoneum.

Clotted blood has a higher attenuation (> 60 HU) than does free blood. A localized collection of clotted blood, the “sentinel clot,” is an accurate sign of injury to an adjacent organ. This sign may help in detecting subtle bowel, mesenteric, or solid organ lesions. The presence of hemoperitoneum on a single CT study does not indicate that active bleeding is present. Some authors, using dynamic scanning techniques, described CT signs of active intra-abdominal arterial bleeding. Most frequently seen is a focal high-density area of 80-130 HU (higher attenuation than free or clotted blood) that is isodense with adjacent major arteries. Seen less frequently, a diffuse high density area may simulate extravasation of oral contrast material from perforated bowel, although other signs of bowel perforation are not present. In most patients with active intra-abdominal bleeding, CT is rarely performed because of hemodynamic instability. Occasionally, however, a patient with active abdominal haemorrhage may become hemodynamically stable and then undergo CT. Detection of haemorrhage is then of vital importance, so that proper, potentially life-saving treatment can be instituted quickly (24) (27).

Signs of hypovolemic shock on CT include a small aorta, a collapsed inferior vena cava, marked enhancement of the kidneys, and initially diminished density of spleen compared with liver after contrast enhancement (28). Some authors described a hypoperfusion complex in children that consists of marked, diffuse dilatation of the intestine by fluid; abnormally intense contrast enhancement of the bowel wall, mesentery, kidneys, and/or pancreas; decreased calibre of the aorta and inferior vena cava; and significant abdominal fluid (29).

I.2.3.1. INJURY TO THE LIVER

The liver is the second most commonly involved solid organ in blunt abdominal trauma after the spleen. However liver injury is the most common cause of death. In children, the liver is the most commonly injured abdominal organ.

The liver is the most vulnerable abdominal organ to blunt injury because of its size and location (in the upper right quadrant of the abdomen), and is injured in about 5% of all people admitted to a hospital for trauma. Liver tissue is delicate and has a large blood supply and capacity like IVC, hepatic veins, hepatic artery and portal vein, which explains why liver injuries present a serious risk for shock (20) (30) (31).

The liver may be lacerated or contused, and a hematoma may develop. It may leak bile, usually without serious consequences. If severely injured, the liver may cause exsanguination (bleeding to death), requiring emergency surgery to stop bleeding (2) (8).

In majority of patients with hepatic injuries, significant damage is obvious, and because of shock or peritonitis such patients have immediate surgery without preliminary imaging studies. CT has proved to be highly sensitive, specific and accurate in defining and characterizing hepatic injury and associated hemoperitoneum in hemodynamically stable patients. The right hepatic lobe has been shown to be injured more frequently, probably because of its large size and proximity to the lower ribs. It is important to remember, especially if you are doing ultrasound, that the posterior segment of the right lobe of the liver is the most frequently injured part, and that this part involves the bare area which can lead to retroperitoneal bleeding rather than bleeding into the peritoneal cavity (20) (32).

The CT findings in hepatic injury include contusions (the mildest injury), subcapsular hematomas, intraparenchymal hematomas, and single or multiple lacerations and fractures through the hepatic parenchyma. Lack of enhancement of fractures indicates loss of vascular supply with the potential for hepatic necrosis. Periportal tracking (areas of perivascular low-attenuation surrounding peripheral subsegmental portal venous branches) also has been described as a sign of hepatic injury on CT and may be the only finding. Although some authors presume that such tracking is a sign of blood loss, others ascribe the finding to distension of periportal lymphatics because of associated hypotension and subsequent large fluid volume replacement in traumatized patients with no other evidence of abdominal trauma. Hepatic subcapsular and parenchymal gas seen on CT 2 to 3 days after hepatic trauma may be due to hepatic necrosis and may not be related to infection (32) (33).

Liver injury has been being managed surgically, but more recent studies discovered that 70% of bleedings can be found already stopped by the time surgery. Importantly, it was stated that there are more transfusions and complications with surgery than with nonoperative management. That is because the liver has a remarkable ability to heal even after severe injury. Therefore, nonoperative management of such injuries in hemodynamically stable patients is now accepted. Today approximately 80% of liver injury is managed nonoperatively (20).

Unlike the spleen, the liver does not exhibit delayed rupture. Attempting to define the role of CT in management decisions, Moon and Federle (34) and Meyer et al. (35) reported that limited hepatic injury without evidence of active bleeding and with little or no hemoperitoneum could be managed successfully without surgery. And it has also been shown that stable patients with severe hepatic injuries and significant hemoperitoneum may be treated nonoperatively without significant sequelae.

However, management decisions in the setting of hepatic injury should be based on clinical factors, and CT should be used to depict the injury and detect healing and resorption of hemoperitoneum. Peritoneal blood is normally resorbed and therefore significantly reduced or absent within one week on follow-up CT scans. Otherwise, continued haemorrhage should be suspected. Subcapsular hematoma usually resolves within 6-8 weeks. Intraparenchymal hematomas heal much more slowly and may persist for several years, as bile in the hematoma delays clot resorption and adversely affects parenchymal healing. Persistent intraparenchymal hematoma appears as a collection with a high attenuation (30-50 HU). A water-density posttraumatic cyst or biloma may result. Lacerations, conversely, appear to heal more rapidly, and significant healing is seen on serial CT examinations over a 3-week period. Clearly, any patient selected for conservative therapy requires continued hemodynamic monitoring and laboratory assessment; transfusion as needed; and the availability of nursing, surgical, and imaging facilities if hemodynamic instability develops (36).

Some centres have developed a CT grading system for liver injury. The following is the CT grading system from the American Association for the Surgery of Trauma (AAST).

Table 1: The American association for the surgery of trauma (AAST) hepatic injury severity scale

Hepatic CT Injury Grading Scale	
Grade I	**Laceration(s) < 1 cm deep**
	Subcapsular hematoma<1 cm diameter
Grade II	**Laceration(s) 1-3 cm deep**
	Subcapsular or central hematoma 1-3cm diameter
Grade III	**Laceration(s) 3-10 cm deep**
	Subcapsular or central hematoma 3-10 cm diameter
Grade IV	**Laceration(s) > 10 cm deep**
	Subcapsular or central hematoma > 10 cm diameter
	Lobar maceration or devascularization
Grade V	**Bilobar tissue maceration or devascularization**

However, there is some important information like active bleeding demonstrated by contrast blush that is not part of this grading system, and that makes it of limited help in the management of the patient despite the fact that different series showed a positive correlation between grade of injury and increased likelihood of failed nonoperative management (20).

I.2.3.2. INJURY TO THE SPLEEN

The spleen is the most common damaged organ in blunt abdominal trauma. It is the second most commonly injured intra-abdominal organ in children. A laceration of the spleen may be associated with hematoma and because of the spleen's ability to bleed profusely, a ruptured spleen can be life-threatening, resulting in shock. Studies have found that fractures of the left lower ribs are associated with spleen lacerations in 20 percent of cases (2) (8) (9) (20).

CT is extremely sensitive and specific in determining the presence and extent of splenic injury in the traumatized patient, and the CT features of splenic trauma have been well described. Subcapsular hematomas appear as crescentic fluid collections that flatten or indent the splenic margin. Initially, hematomas may be isodense with splenic parenchyma on contrast-enhanced scans, particularly if adequate volumes of contrast material are not given. Intrasplenic hematomas are seen on CT as rounded low-density areas.

Lacerations appear as linear low-density areas within the spleen. Multiple lacerations may have the appearance of a fragmented or shattered spleen. Unenhancing portions of the spleen should suggest injury or thrombosis of the artery to the affected segment. Disruption of the splenic capsule can result in visible hemoperitoneum in up to 98% of patients with splenic injury (37).

Perisplenic clot also is associated with splenic injury. Both hemoperitoneum and splenic clot may be present in cases of splenic injury without evidence of a splenic laceration on CT. Therefore, presence of either should prompt a search for splenic injury. Occasionally, splenic injury may manifest as heterogenous parenchyma with mottled irregular enhancement. This finding is almost always associated with peritoneal blood and perisplenic clot and by itself is merely suggestive of splenic injury. It is important to remember that the spleen may also transiently appear inhomogeneous during the early capillary phase of a contrast-enhanced dynamic CT study. Certain finding on CT may result in a false-positive diagnosis of splenic injury. Splenic lobulations and congenital clefts, and a prominent left hepatic lobe extending across the midline to lie immediately adjacent to the spleen, may simulate a splenic laceration. Streak and motion artefacts can also result in incorrect diagnoses. The spleen may seem to enlarge on serial CT scans after blunt abdominal trauma. This is a result of initial splenic contraction from adrenergic stimulation at the time of acute injury, which resolves with time and volume replacement (37) (38).

Although rare, delayed splenic rupture has been reported in patients in whom an initial CT scan after injury showed no evidence of splenic abnormality. Suboptimal contrast enhancement techniques may be partially responsible for this missed diagnosis. Subtle inhomogeneities of the splenic parenchyma and minimal thickening of the lateroconal fascia and the left anterior renal fascia may be the only signs initially seen in some cases of delayed splenic rupture (29) (39).

Some studies reported the increased risk of late sepsis after splenectomy in both children and adults. This observation has encouraged nonoperative management and splenic salvage procedures in appropriate patients. The role of CT in selecting between conservative and operative treatment of splenic injuries remains unclear (40). As for the liver, the standard CT grade of splenic injury of the American Association for the Surgery of Trauma (AAST) is of limited value since it does not predict the success rate of a nonoperative management.

Table 2: The American association for the surgery of trauma (AAST) splenic injury severity scale

Splenic CT Injury Grading Scale	
Grade I	**Laceration(s) < 1 cm deep**
	Subcapsular hematoma <1 cm diameter
Grade II	**Laceration(s) 1-3 cm deep**
	Subcapsular or central hematoma 1-3 cm diameter
Grade III	**Laceration(s) 3-10 cm deep**
	Subcapsular or central hematoma 3-10 cm diameter
Grade IV	**Laceration(s) > 10 cm deep**
	Subcapsular or central heamatoma > 10 cm diameter
Grade V	**Splenic tissue maceration or devascularization**

The shortcomings of this grading scale are the possibility of underestimation of injury extent, significant interobserver variability, lack of information about active bleeding, contusion and post-traumatic infarcts, and most importantly, no predictive value for nonoperative management (NOM).

The finding of contrast extravasation on the other hand, which is not part of this grading system, has great impact on the patient's management because, when there is active bleeding, there may be a failure of nonoperative management in up to 80% of the cases. In these patients the need for intervention is almost ten times as high compared to patients without extravasation (33). Some studies found that these systems were not completely reliable. In particular, delayed splenic rupture remains a distinct problem in a small percentage of patients in whom the spleen is normal or shows only a limited injury on the initial CT scan (41). On the other hand, Brick et al (32) have shown that the moderate or severe splenic injury in children or injury associated with a moderate or large amount of hemoperitoneum may be treated successfully without surgery. At this time, although CT is extremely useful in characterizing initial injury and following the evolution of splenic trauma, the final decision on whether to operate or not should be made by the trauma surgeon on the basis of clinical presentation.

I.2.3.3. INJURY TO THE KIDNEYS

The kidneys may also be injured; they are somewhat but not completely protected by the ribs. Studies showed that in 90% of cases renal injury is due to blunt trauma. The kidney is the third most common involved organ in adults. Kidney lacerations and contusions may also occur. In children with blunt abdominal trauma, kidney injury is a common finding and may be associated with bloody urine. Kidney lacerations may be associated with urinoma (leakage of urine into the abdomen). A shattered kidney is one with multiple lacerations and an associated fragmentation of the kidney tissue (8) (20) (42) (43).

Renal injuries after blunt abdominal trauma can be categorized as minor, intermediate, and severe. Most renal injuries (75-85%) are minor and include contusions, intrarenal hematomas, small subcapsular hematomas, small lacerations that do not communicate with the colleting system, and small segmental infarcts. Patients are usually hemodynamically stable, have microscopic hematuria, and are treated conservatively. Intermediate injuries, which account for approximately 10% of renal trauma, include deep lacerations that communicate with the collecting system and result in urine extravasation. Treatment of such injuries is somewhat controversial; some advocate conservative management unless severe bleeding or clinical deterioration ensues; others stress early surgery to avoid complications. The remaining 5% of renal injuries are severe, including shattered kidneys, renal pedicle injuries, and avulsion and laceration of the renal pelvis. These catastrophic injuries require immediate surgery (44).

Of all imaging techniques, CT most accurately depicts the character and extent of renal injury, best displays perirenal hematomas and extravasation of urine, best distinguishes between the categories of renal trauma, and, therefore, is most useful in case management. CT also detects associated injuries within the peritoneal cavity and retroperitoneum that may influence the management. In a stable patient with a suspected isolated renal injury, excretory urography will usually suffice as an initial examination. Normal findings on excretory urography exclude significant renal injury. However, evidence of significant renal trauma on excretory urography often requires further evaluation with CT. The appearance of renal injuries on enhanced CT has been well documented. Contusion, the mildest renal injury, results in oedema and extravasation of small amounts of blood and urine into the interstitial space. Contusion may be subtle and missed on contrast-enhanced CT. When present, it appears as poorly defined areas of decreased enhancement (44) (45).

Lang et al (45) described the appearance of a small collection of contrast medium in the renal interstitium on delayed scans as a sign of contusion. Contusions usually resolve within one week. Intrarenal hematomas appear as areas of decreased enhancement that may be poorly defined or well marginated.

Subcapsular hematomas are confined by the renal capsule, are often lenticular, and may flatten the renal border. An apparent low-attenuation region around the surface of the kidney may be caused by respiratory motion during the scan and result in a false diagnosis of subcapsular hematoma. In such cases, a similar appearance is noted anterior to the abdominal wall.

Lacerations appear as focal parenchymal injuries with decreased enhancement. If they involve the collecting system, contrast-laden urine extravasates and is easily seen on CT. A significant perirenal hematoma is usually present with severe lacerations.

Because of fascial fusions in the retroperitoneum, hematoma due to or associated with renal trauma tend not to cross the midline; the presence of such a hematoma should prompt a search for injury to the aorta, its branches, or other midline structures. Lacerations that completely transect the kidney into two separate poles are often called fractures. Lacerations usually occur parallel to the main vascular structures, preserving them, and parenchymal enhancement is observed. The margins of lacerated fragments may have an inhomogeneous, mottled appearance, possibly the result of vasospasm. The shattered kidney contains multiple lacerations, some of which may shear across vascular planes and produce devascularized fragments with nonenhancing parenchyma. A section through the hilar lip of the kidney may appear as fracture, but its characteristic posterolateral location should prevent confusion. A segmental renal infarct may result from injury to an intrarenal or polar arterial branch and appears as a wedge-shaped or hemispheric area of non perfusion with the apex pointing toward the renal hilum. A thin enhancing rim may be seen. Eventually a deep scar forms in the area of infarction. Laceration of the renal pelvis or avulsion of the ureteropelvic junction causes extravasation of contrast-laden urine. Extravasation without evident renal injury should raise suspicion of such injuries of the renal pelvis (44) (45).

In many cases an injury of the renal pedicle resulting in arterial or venous occlusion can be clearly documented on CT because the kidney does not enhance. A cortical rim of enhancement may be present as a result of collateral blood flow from the capsular arteries. An abrupt cutoff of the contrast-enhanced renal artery is seen occasionally.

The reliability of CT in detecting injuries of the renal pedicle has been in dispute. Sclafani et al consider CT the method of choice and confirmatory angiography unnecessary. Lupetin et al on the other hand, found CT less reliable in the detection of trauma to the renal artery, as the diagnosis was missed on CT in five of seven patients in their series. Injury to the renal vein after blunt trauma is missed more often than injury to the artery; in addition to lack of enhancement, the kidney may appear enlarged, the rim enhancement may be thicker, and thrombus in the vein may be seen (43) (44) (45).

As for spleen and liver injury the American Association of Surgery and Trauma (AAST) has developed a renal injury scale in order to improve management of renal injuries.

Table 3: The American association for the surgery of trauma (AAST) renal injury severity scale

Renal Injury Scale	
Grade I	Contusion/ Subcapsular hematoma
	No parenchymal laceration
Grade II	Laceration < 1 cm depth of renal cortex
	No urinary extravasation
Grade III	Laceration >1 cm depth of renal cortex
	No urinary extravasation
Grade IV	Laceration extending through renal cortex, medulla and into collecting system
	Minor renal artery or vein injury with contained hematoma
Grade V	Shattered kidney.
	Devascularized kidney, hilar avulsion

This grading system has proven to be of value in the management of the patient. However, like all other grading systems seen before, this system also has its limitations (20).

The treatment of most grade I, II, or III renal injuries is usually conservative, except when a vigorous active haemorrhage is present. In such cases, the active haemorrhage may be treated successfully with selective catheter embolization in an otherwise stable patient.

Occasionally, continued bleeding or extravasation can lead to complications and higher morbidity if not identified and managed appropriately. Follow-up CT is useful for restaging the renal trauma and helps in identifying the patients with progressive worsening on conservative management. Appropriate intervention in these patients can help prevent complications (4) (46).

I.2.3.4. INJURY TO THE PANCREAS

The pancreas may be injured in abdominal trauma, for example by laceration or contusion. Pancreatic injuries, most commonly caused by bicycle accidents (especially by impact with the handlebars) in children and vehicular accidents in adults, usually occur in isolation in children and accompanied by other injuries in adults (package injury). Indications that the pancreas is injured include enlargement and the presence of fluid around the pancreas. Pancreatic injuries, including pancreatic duct disruption, fractures, contusions, and traumatic pancreatitis, represents 3-12% of all abdominal injuries from blunt trauma. They are clinically important, however, because death occurs in 16-20% of cases of pancreatic trauma, and major posttraumatic complications (pseudocyst, abscess, haemorrhage, acute recurring pancreatitis, and fistulae) occur in one of three survivors. Delay in diagnosis leads to an increase in the mortality and morbidity rate. The typical clinical findings of upper abdominal pain, leukocytosis, and increased serum amylase may not be apparent for one or more days after acute pancreatic trauma. In addition, an increase in the serum amylase level after trauma may be present without pancreatic injury (20) (43) (47).

Pancreatic injury may be difficult to diagnose on CT since little evidence of pancreatic injury may appear on CT examinations performed soon after the traumatic event. Pancreatic duct disruption is the most significant pancreatic injury. Although this abnormality cannot be seen directly on CT, associated injury to the pancreas may be detected. Fracture of the pancreas, depicted as clear separation or low-density line through the long axis, occurs most commonly in the neck of the pancreas as a result of compression of the organ against the spine. Thickening of the left anterior renal fascia, although not specific for pancreatic injury, is frequently present and should raise the possibility of pancreatic injury. Other signs include focal or diffuse enlargement of the organ, areas of decreased attenuation, and peripancreatic oedema and fluid collections. If the possibility of pancreatic trauma persists despite initially normal CT findings, a second CT examination in 12-24 hours may be warranted, because signs of injury can be delayed.

Endoscopic retrograde cholangiopancreatography (ERCP), which directly visualizes the pancreatic duct, may also be necessary for further evaluation when CT findings are equivocal or CT is technically inadequate. Immediate surgery is the recommended treatment for pancreatic fracture (43) (47).

I.2.3.5. INJURY TO THE BOWEL AND MESENTERY

Bowel and mesenteric injuries after blunt trauma are infrequent but serious injuries. These injuries are difficult to diagnose clinically, as the physical and laboratory findings may be subtle and are often overshadowed by other injuries in patients with multisystem trauma. Consequently, the clinical suspicion of bowel or mesenteric rupture is often delayed, adversely affecting patient morbidity and mortality. Unrecognized bowel injuries may result in peritonitis from perforation or significant intra-abdominal haemorrhage. Mesenteric injuries may likewise produce significant blood loss or may result in bowel ischemia and necrosis with delayed rupture. Segmental bowel ischemia following mesenteric vascular injury may also result in delayed ischemic strictures of the small bowel or colon (48) (49).

Bowel and mesentery injuries are reported to occur in less than 5% of blunt trauma cases. As these injuries are most commonly seen in restrained motor vehicle accident victims, the incidence may rise as seat belt usage increases. Although HVI and MI account for less than 5% of all injuries after blunt abdominal trauma, the consequences of missed or delayed diagnosis are significant. Higher morbidity and mortality ensued should surgical intervention be delayed. These complications include systemic sepsis, intra-abdominal collections or abscess, peritonitis, bowel strictures or bowel obstructions, wound dehiscence and formation of fistula (18) (43) (50).

Early diagnosis is important and for nonoperative management of solid organ injuries to be consistently safe, HVI and MI must be reliably excluded by non-invasive means. In patients with duodenal perforation, surgery performed within 24 hours of injury has a 5% mortality rate, whereas delayed diagnosis and treatment leads to a mortality rate of more than 30% (10) (49) (51).

Gas within the abdominal cavity seen on CT is understood to be a diagnostic sign of bowel perforation; however intra-abdominal air can also be caused by pneumothorax or pneumomediastinum. The injury may not be detected on CT although bowel perforation requires surgery.

If there is clinical deterioration, it is advisable to observe and recheck patients with suspicion of hollow viscous injuries who have initial negative CT scan, since subtle injuries can be missed (43) (52).

The usefulness of CT in evaluating solid organ injuries is beyond doubt, but no clear consensus exists in its usage in HVI/MI. Several reports have quoted the effectiveness of CT in diagnosing HVI/MI to be from unreliable to very accurate (16) (17) (18) (19) (53).

With an increasing proportion of patients with solid organ injuries being managed conservatively the importance of CT scans in excluding HVI/MI is of paramount importance. As stated before, missed diagnosis of HVI/MI would delay the appropriate management and often result in significant morbidity and mortality (50) (54).

CT signs of bowel and mesenteric injury include extraluminal air, extravasation of oral contrast material, peritoneal or retroperitoneal fluid in the absence of solid organ injury, thickened bowel wall, high-density clot (sentinel clot) adjacent to the involved bowel, mesenteric haemorrhage/haematoma, mesenteric fat stranding and focal mesenteric infiltration (10) (55). It is very uncommon to identify findings that are specific for bowel injury like extravasation of oral contrast or bowel content. Most commonly you will find a combination of intraperitoneal fluid and mesenteric stranding, focal bowel thickening or interloop fluid, which is very suggestive for bowel injury (20).

Some of the CT scan findings that mandate exploratory laparotomy include extra-luminal gas, extravasation of oral contrast, disruption of bowel wall and active intravenous contrast extravasation. Free air in either the peritoneal cavity or the retroperitoneum from injury to the retroperitoneal duodenum, small bowel, or colon is a relatively specific sign of bowel perforation but is seen in only half of cases. The volume of air may be quite small and subtle. Wide window or lung settings will aid in detection. The most common location in which to detect free intraperitoneal air is the subdiaphragmatic area, anterior to the liver. Extraluminal air also may be present within the leaves of the mesentery or in the retroperitoneum, particularly in the anterior pararenal space. Occasionally, pneumoperitoneum results from pneumomediastinum, pneumothorax, bladder rupture, or previous peritoneal lavage and is not related to bowel trauma. Extravasation of oral contrast material from the bowel lumen is a specific sign of bowel perforation. Unfortunately, its presence is shown on CT in only a minority of cases. Intra-abdominal fluid, although seen in nearly all cases of bowel or mesenteric injury, is not a specific indicator.

Moderate or large amounts of fluid are associated with significant bowel or mesenteric trauma. If no associated solid visceral injury is noted, bowel or mesenteric injury should be suspected. To diagnose unexplained free fluid, patients must not have any diagnostic peritoneal lavage, underlying disease that could result in ascites or substantial solid organ injury. Free fluid is typically located in Morrison’s pouch, perihepatic space, perisplenic space, paracolic gutters, and in the pelvis (55).

Focal mesenteric infiltration is also a frequently seen but nonspecific sign. A localized high attenuation mesenteric haematoma or intramural haematoma can help localize the site of injury. Mesenteric injuries are especially difficult to characterize before surgery, as the finding of focal mesenteric haematoma can be present in patients who require immediate surgery or in those that can be managed conservatively. Thickened bowel wall is seen in about 75% of cases with transmural laceration. Therefore, its absence does not exclude bowel injury (10). There has been controversy concerning the sensitivity of CT in detecting bowel and mesentery injuries. In their study, Rizzo et al (47) reported high sensitivity in detecting bowel and mesentery injuries, while other authors indicated that this diagnosis may be difficult with CT. This difficulty may be due in part to the subtlety of the findings and the fact that presentation of signs and symptoms may be delayed (56). The initial CT examination may be done before the clinical signs are manifested. The coordinated use of CT and peritoneal lavage for diagnosis of bowel and mesenteric injuries has been suggested (26).

As raised before, the usage of oral contrast in CT imaging in trauma patients has been controversial. For some authors, opacification of the bowel lumen by positive contrast medium is important for accurate diagnosis of bowel and pancreatic injuries. Recognition of extraluminal oral contrast material is an unequivocal sign of bowel laceration. Mural thickening is an indirect sign of bowel injury and is much more easily and accurately recognized when the bowel lumen is opacified. Peripancreatic oedema or haemorrhage is an important sign of pancreatic trauma but can be simulated by unopacified bowel loops. This is a well-recognized pitfall in the non trauma setting; suspected cases of pancreatitis from any aetiology are examined routinely following the use of intravenous and oral contrast material (26). On the other hand, though its usage has been shown to be useful for depicting bowel injuries of the duodenum and proximal jejunum, as well as mesenteric injuries, it is not without its complications.

In the trauma setting, the risk of vomiting and aspiration is sizeable, especially in patients with decreased consciousness. Other potential disadvantages include the theoretical risk of introducing barium into the peritoneal cavity through a lacerated bowel, and the tendency of barium to inspissate within the colon in patients who have delayed bowel transit time, frequently encountered in this group of patients. Furthermore, the potential delay in diagnosis and the lack of substantial benefits for detection of bowel and mesenteric injury are some of the underlying rationale explaining the protocol of performing CT scans without oral contrast in the trauma setting. And again newer studies using multi-detector CT scanners in which oral contrast was omitted show comparable results, indicating that administration of oral contrast can be avoided (16) (17) (18).

I.2.3.6. 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 (MVA) results in an avulsion of the small branches of major vessels (e.g. mesenteric tear). 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. Hemodynamically stable patients with blunt trauma and suspected abdominal vascular injuries may benefit from abdominal computed tomography (CT) scanning, which helps 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 (57).

Major retroperitoneal vascular structures include the abdominal aorta, IVC, renal vessels, proximal celiac axis and superior mesenteric arteries, superior mesenteric vein, lumbar arteries and veins, and iliac vessels within the pelvis. Several studies showed that blunt injury to the abdominal aorta is less common than thoracic aortic injuries with an estimated ration of 20:1. The infrequency with which blunt abdominal aortic injury occurs is likely due to the central protected position of the abdominal aorta. Most injuries result in damage to the intima, with creation of an intimal flap. The degree of injury may range from subtle intimal injuries to frank transection. Thrombus formation may occur with partial or total aortic occlusion. A mortality rate of up to 24% has been reported for these injuries. Injuries involve the infrarenal abdominal aorta in almost all cases (98%). Proposed mechanisms for traumatic rupture of the abdominal aorta include direct forces on the abdominal aorta, such as between a lap belt and the lumbar spine, as well as indirect forces generated by transmission of the pressure of the initiating force through adjacent organs to the aortic wall. Neurologic deficits ranging from sensory loss to paraplegia have also been associated with abdominal aortic injuries (58) (59).

Blunt injuries to IVC are also rare, with only a few published reports in the literature. CT findings of blunt IVC injury vary depending on the location of the injury. Retroperitoneal haematoma with a paracaval epicentre, irregular IVC contour, and extravasation of contrast material have been described with infrahepatic IVC injury. With retrohepatic IVC injuries, severe associated liver trauma is often seen. Signs that are suggestive of retrohepatic IVC injury include extensive liver laceration into the porta hepatis and retrohepatic IVC region or an irregular contour of the retrohepatic IVC. Blunt IVC injuries can be difficult to diagnose, since many of the reported cases lack contrast material extravasation as direct evidence of vascular injury. Other vascular injury signs that can help in diagnosis include the contrast blush near the origin of active bleeding, visceral organs infarctions and soft tissue density surrounding the blood vessels (20) (60).

I.2.3.7. INJURY TO THE URINARY BLADDER

Bladder injuries can be caused by blunt or penetrating trauma. It was reported that of all bladder injuries, 60-80% are from blunt trauma and 15-40% are from a penetrating injury, and that the most common mechanisms of blunt trauma are motor vehicle collisions (87%), falls (7%) and assaults (6%) (61).

The probability of bladder injury varies according to the degree of bladder distension; therefore, a full bladder is more likely to become injured than an empty one (62).

Although uniformly fatal in the past, a timely diagnosis with appropriate medical and surgical management now offers an excellent outcome. Early clinical suspicion, appropriate and reliable radiologic studies, and prompt surgical intervention when indicated, are the keys to successful diagnosis and management of bladder trauma (63).

In blunt trauma, deceleration injuries usually produce both bladder trauma (perforation) and pelvic fractures. Several studies showed that approximately 10% of patients with pelvic fractures also have significant bladder injuries, and that if there is a bladder rupture, there is almost always a pelvic fracture (20).

Gross haematuria is the hallmark of a bladder rupture. More than 98% of bladder ruptures are associated with gross haematuria, and 10% are associated with microscopic haematuria; conversely, 10% of patients with bladder ruptures have normal urinalysis results.

A number of studies showed that extraperitoneal bladder perforations account for 50-71%, intraperitoneal accounts for 25-43%, and a combined perforations account for 7-14% (64).

The incidence of intraperitoneal bladder rupture is significantly higher in children because of the predominantly intra-abdominal location of the bladder prior to puberty. The bladder usually descends into the pelvis by age of 20 years (64).

The CT scan of the pelvis provides information on the status of the pelvic organs and osseous pelvis and has replaced conventional cystography as the most sensitive test for bladder perforation. Subtle perforations are often revealed, and the intraperitoneal and extraperitoneal nature of these ruptures can be determined. Most patients with bladder trauma have multiple injuries and require abdominal or pelvic CT scans as part of the trauma evaluation. This does not preclude obtaining a separate contrast cystogram if the bladder findings of the CT scan are equivocal. The sensitivity and the specificity of CT cystography is very high. For extraperitoneal rupture it is respectively 100% and 99% and for intraperitoneal rupture it is 92% and 100% (20).

Bladder contusion is an incomplete or partial-thickness tear of the bladder mucosa. A segment of the bladder wall is bruised or contused, resulting in localized injury and haematoma. The bladder may appear normal or teardrop-shaped on cystography. Bladder contusions are relatively benign, are the most common form of blunt bladder trauma, and are usually a diagnosis of exclusion. They are self-limiting and require no specific therapy, except for short-term bed rest until haematuria resolves. Persistent haematuria or unexplained lower abdominal pain requires further investigation (20).

I.2.3.7.1. Extraperitoneal bladder ruptures

Traumatic extraperitoneal ruptures are usually associated with pelvic fractures (89-100%). Previously, the mechanism of injury was believed to be from a direct perforation by a bony fragment or a disruption of the pelvic girdle. It is now generally agreed that the pelvic fracture is likely coincidental and that the bladder rupture is most often due to a direct burst injury or the shearing force of the deforming pelvic ring (20). These ruptures are usually associated with fractures of the anterior pubic arch, and they may occur from a direct laceration of the bladder by the bony fragments of the osseous pelvis. The anterolateral aspect of the bladder is typically perforated by bony spicules. Forceful disruption of the bony pelvis and/or the puboprostatic ligaments also tears the wall of the bladder. The degree of bladder injury is directly related to the severity of the fracture (20).

I.2.3.7.2. Intraperitoneal bladder rupture

Classic intraperitoneal bladder ruptures are described as large horizontal tears in the dome of the bladder. The dome is the least supported area and the only portion of the adult bladder covered by peritoneum. The mechanism of injury is a sudden large increase in intravesical pressure in a full bladder. When full, the bladder's muscle fibers are widely separated and the entire bladder wall is relatively thin, offering relatively little resistance to perforation from sudden large changes in intravesical pressure. This type of injury is common among patients diagnosed with alcoholism or those sustaining a seatbelt or steering wheel injury. Intraperitoneal ruptures demonstrate contrast extravasation into the peritoneal cavity, often outlining loops of bowel, filling paracolic gutters, and pooling under the diaphragm. For the combination of intraperitoneal and extraperitoneal ruptures CT cystogram reveals contrast outlining the abdominal viscera and perivesical space (20).

I.2.3.8. INJURY TO THE OTHER ORGANS/MISCELLANEOUS ABDOMINAL TRAUMA

Injuries associated with intra-abdominal trauma include rib fractures, vertebral fractures, pelvic fractures, and injuries to the abdominal wall (2). Gallbladder injury after blunt abdominal trauma is uncommon, occurring in 2-3% of cases. Laceration or perforation, complete avulsion, or intramural contusion can occur. On CT, the gallbladder may contain high-density haemorrhage with associated peritoneal blood; low-density fluid associated with bile leakage also may be present. Haemobilia is likely if high-attenuation material is seen in the gallbladder, and other causes of increased density, such as stones, contrast material, and milk-of-calcium bile, can be excluded (65).

Diaphragmatic rupture occurs in 1-2% of patients after blunt abdominal trauma and almost always affects the left side. This injury is difficult to diagnose with any imaging technique and is often missed on CT. Herniation of abdominal contents through the diaphragm with a CT collar sign (waist in the stomach) may be seen occasionally. Other nonspecific signs of diaphragmatic injury include discontinuity of the crus, thickening of the diaphragm and dependent viscera sign (abdominal organs lying against the posterior thoracic wall) (20) (66).

Traumatic adrenal haemorrhage occurs in up to 25% of patients after severe trauma. In 85% of cases haemorrhage is right-sided and in 20% of cases it is bilateral. On CT, adrenal haemorrhage appears as a hyperdense mass (50-75HU) with streaky infiltration into the peri-adrenal fat and thickening at the adjacent diaphragmatic crus. Abnormalities in the subcutaneous fat of the abdominal wall at the site of trauma also may be seen (67).

I.3. PROBLEM STATEMENT

Several previous studies have proven the usefulness of intravenous contrast medium in diagnostic blunt abdominal trauma CT scan, essentially for evaluating solid parenchymal and vascular injuries. It has been shown that without intravenous contrast enhancement, injuries of those organs can often be imperceptible, and also active arterial extravasation is only detectable with intravenous contrast material. Further, the success of contrast CT in staging abdominal injuries has contributed to the growing trend toward nonoperative management of traumatic abdominal injuries. Previous studies have shown that with CT, up to 85% of abdominal solid organ injuries are treated conservatively (4) (6) (7).

However, for some institutions, the usage of IV contrast for blunt abdominal trauma CT scan is not yet systematized, and Kenyatta National Hospital, our site of research, is one of them. Indeed, no local research has been done to find out the usefulness of intravenous contrast medium and hence adjust an appropriate protocol.

I.4. STUDY RATIONALE AND JUSTIFICATION

As seen earlier in the introduction of this research, CT is particularly useful when the physical examination is unreliable or equivocal or when nonoperative management is considered in the setting of stable patients with positive DPL or FAST exam. Several additional advantages of CT are that it is noninvasive, can define the location and extent of solid organ or retroperitoneal injuries, can detect ongoing bleeding when intravenous (IV) contrast is used, and does not require hemoperitoneum, as do DPL and FAST exams. For a large number of authors, IV contrast medium is the cornerstone in diagnostic blunt abdominal trauma CT scan. Unless contraindicated, IV contrast agent should be used when CT is obtained for evaluation of blunt abdominal trauma to examine renal function as to get a better definition of solid parenchymal injury, blood flow, and extravasation. Without intravenous contrast enhancement, injuries of those organs can often be imperceptible, and that has direct implications on management decisions and outcome.

However, CT scan without IV contrast for blunt abdominal trauma cases was still being done in KNH and there was no specific protocol for blunt abdominal trauma imaging in the department of Radiology. No similar study has been recorded locally, therefore we found this study very useful in our institution in order to adjust our protocol and improve patients' management. This study was to prove the usefulness of IV contrast medium in diagnostic blunt abdominal trauma CT scan at KNH; to help in adjustment of our institution's protocol and then improve the management of blunt abdominal trauma patients.

I.5. OBJECTIVES

I.5.1. BROAD OBJECTIVE

To assess the role and usefulness of IV contrast medium in diagnostic blunt abdominal trauma CT scan at Kenyatta National Hospital.

I.5.2. SPECIFIC OBJECTIVES

1. To determine the frequency of different mechanisms of trauma for patients enrolled in the study.
2. To determine the distribution of different intra-abdominal organs injury in blunt trauma at KNH.
3. To determine the pattern of CT findings in patients with abdominal injury.
4. To compare CT findings between precontrast and postcontrast scans.

CHAPTER II: STUDY METHODOLOGY

II. 1. STUDY DESIGN

This was a descriptive cross sectional study where a comparison was made between the findings of precontrast and post contrast abdominal CT scans for blunt abdominal trauma patients enrolled in this study. By comparing the CT findings from both the pre and post contrast scans for each participant and using appropriate statistical measurements we were able to determine the utility of IV contrast in blunt abdominal injury. The utility of IV contrast medium was confirmed by missing injuries on precontrast scans while are able to be seen on post contrast scans.

II.2. STUDY SITE

The study was conducted in the Department of Radiology, CT scan unit, at Kenyatta National Hospital (KNH), a level 6 National Referral and Teaching Hospital, located in Nairobi.

KNH is the oldest hospital in Kenya having been founded in 1901 as the Native Civil Hospital and then King George VI in 1952. It is currently the largest National referral, teaching and research hospital.

The hospital is organized into various specialized departments. Among these departments is the relatively well equipped Radiology department. The radiology department has a sixteen slice CT scanner among other modern imaging machines. The radiology department receives patient from different departments within the same hospital plus referrals from peripheral hospitals and private clinics in the country and from neighbouring countries. This department is run by a big number of consultant radiologists, registrars in radiology plus a team of registered radiographers.

The hospital serves mostly low and middle class social status patients, plus a few upper class patients.

In average in a month, the department of Radiology at KNH receives 30 patients with blunt abdominal trauma for FAST, 2/3 of them have FAST positive, and only a maximum of 4 patients are sent for abdominopelvic CT scan.

II.3. STUDY PERIOD

This study was carried out over a period of 12 months beginning the month of March 2013 to February 2014.

II.4. STUDY POPULATION

The study population consisted of blunt abdominal trauma patients sent by referring physicians to KNH for initial diagnostic abdominopelvic CT scan during the study period, and who could receive IV contrast medium and consent participation.

II.4.1. INCLUSION CRITERIA

All blunt abdominal trauma patients sent by referring physicians to KNH for initial diagnostic abdominopelvic CT scan during the study period and who could receive IV contrast medium were included in the study after obtaining participation informed consent. For unconscious patients, semi-conscious patients, and minors; the choice for participation in this study was made by their legal guardians.

II.4.2. EXCLUSION CRITERIA

Blunt abdominal trauma patients who could not receive IV contrast medium or did not consent participation were not included in the study. Unaccompanied minors and unaccompanied unconscious or semi-conscious patients were not also included in this study. Only one unconscious trauma patient was not accompanied and then excluded in our study.

II.5. RECRUITMENT PROCEDURE, DATA COLLECTION AND SAMPLING TECHNIQUE

Data was collected using data collection sheet over a period of 12 months, from March 2013 to February 2014. The study questionnaire was composed of three main questions: Patient’s biodata (study number, age in years and gender), mechanism of trauma and CT scan findings (pre and post contrast scans). For CT scan data, each finding was registered as whether it was detected on precontrast, postcontrast or both scans in order to facilitate the comparison between those scans. After consenting participation, all patients sent for initial diagnostic abdominopelvic CT scan with recent history of blunt abdominal trauma and who could receive IV contrast medium were recruited. Each participant underwent at least two consecutive scans, one scan without IV contrast medium and another one with IV contrast medium for comparison of findings. For IV contrast scans a portal venous phase scan at 65 seconds and a delayed phase scan at 5 minutes after starting IV contrast injection were acquired to every patient in our study. Oral contrast medium was not used in our study.

Socio-demographic information was obtained from patients request forms while data concerning CT scan results was obtained from CT scan machine after necessary reconstruction. The identification of the patient did not appear on the collection data sheet, only the study number was used and data link log was made. Data collection was done by the investigator himself assisted by qualified consultant radiologist/radiologists on duty, by filling a pre-established data collection form found in the appendix.

II.6. STANDARDIZATION OF RADIOLOGICAL RESULTS

The abdominopelvic CT scan images of the participants were firstly reviewed by the researcher himself for making initial diagnosis. The images were then presented to the qualified consultant radiologists on duty for their opinion. The registered CT findings in our study were the ones appearing in the final radiological CT scan report done by a consultant radiologist. This was what we entered as CT findings in the data collection forms. This process was to provide both standardization and reproducibility of the radiological results.

II.7. SAMPLE SIZE DETERMINATION

The sample was all blunt abdominal trauma patients sent to KNH for initial diagnostic abdominopelvic CT scan who could receive IV contrast medium and consent participation during the study period of 12 months. The formula for finite population correction was used to determine sample size because of the limited number of blunt abdominal CT imaging at KNH:

$$\boldsymbol{n = \frac{NZ^2P(1-P)}{d^2(N-1)+Z^2P(1-P)}}$$

Where **n** =sample size with finite population correction,

N=population size (approximately 4 blunt abdominal CT scans conducted in KNH monthly yielding a population size of 48 for the 12 months study period),

Z=Z statistic for a level of confidence (95% confidence=1.96)

P= expected proportion, and

d= precision (set at 0.05)

$$\boldsymbol{n = \frac{48 \times 1.96^2 \times 0.9(1-0.9)}{0.05^2(48-1) + 1.96^2 \times 0.9(1-0.9)}}$$

n = 36

The minimum sample size **n**=36

II.8. DATA MANAGEMENT

The data was recorded into a worksheet (appendix) and then entered into personal computer for analysis using statistical package for social science (SPSS) software version 19.0. This included demographic data, mechanism of injury and abdominal CT scan findings for both pre and post contrast medium. Results were presented in form of frequency distributions and descriptive statistics.

II.8.1. DATA ANALYSIS

Data was entered into Epidata sheet and then exported to SPSS version 19.0 statistical package for analysis. Frequencies, means and proportions were calculated. The primary analysis involved comparison of precontrast and post contrast investigation findings. These analyses were conducted by cross tabulation of investigation findings (presence of organ injury) versus investigation type (pre contract or post contrast). Results were presented in form of frequency tables, or charts as appropriate. The utility of post contrast findings for each type of organ injury was determined by calculating the proportion of injuries visualised on post contrast investigation which had been missed on precontrast investigation. The percentage was presented with the corresponding 95 % confidence interval. Discussions were made by comparing findings of this study with other similar studies done in other institutions or countries.

II.8.2. DISSEMINATION OF RESULTS

The results of this study will be strictly disseminated for educational purposes; copies of the study findings will be submitted to the department of Diagnostic Imaging and Radiation Medicine, Kenyatta National Hospital and University library for future reference and to facilitate any possible improvements in patient management. The results will also be presented in scientific conferences.

II.9. ETHICAL CONSIDERATION

- Permission to carry out this study was sought from Ethics and Research Committee of Kenyatta National Hospital and University of Nairobi through the Department of Radiology authorities. The study was hence commenced as soon as the study was approved by the committee.
- Only patients eligible for the study were included.

- The patients names did not appear anywhere on the data collection forms in order to maintain confidentiality. Instead the patients were coded with serial numbers. For referral purposes only patients IP/OP numbers were recorded.
- The ALARA principle that is keeping the radiation exposure As Low As Reasonably Achievable was maintained for all the patients. Only the standard radiological procedure for abdominal trauma CT scan has been applied to all patients. No additional examination was done on a patient other than the one requested by primary physician.

II.10. STUDY LIMITATIONS

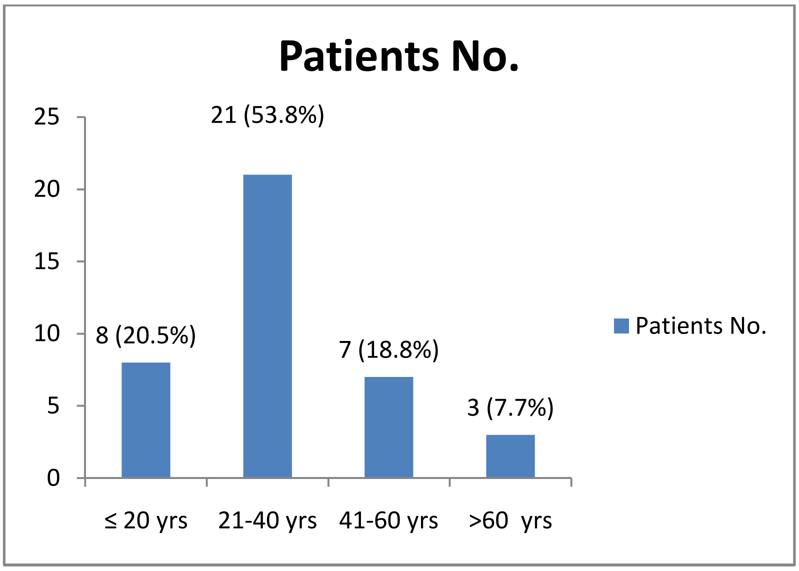
- Only IV contrast medium was given to patients in our study, even though oral contrast and CT cystogram have been said to be contributively useful to diagnostic blunt abdominal trauma CT scan by some authors.
- As CT scans were only performed in haemodynamically stable patients, the outcome of this study would not be a true reflection of all blunt abdominal injuries.
- No comparison between CT scan findings and operative findings was done to evaluate the accuracy of CT scan in the detection of blunt abdominal injuries in our set up.

CHAPTER III: STUDY RESULTS

A total of 39 patients participated in the study. Structured questionnaire was used to collect data and SPSS version 19.0 was used for analysis.

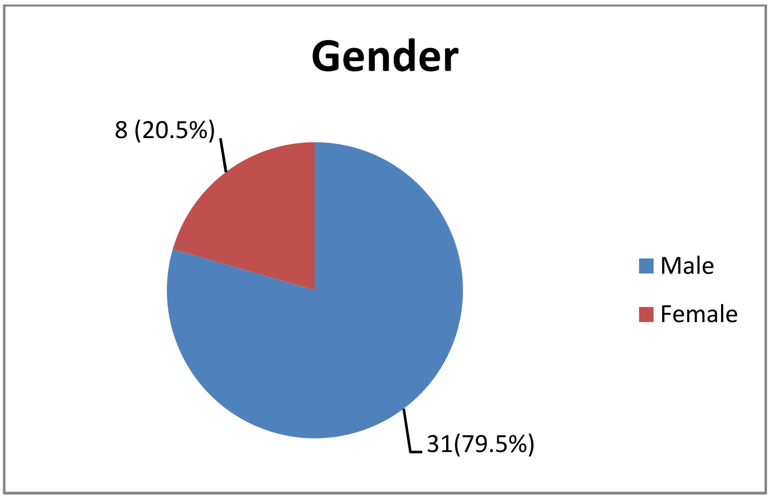
Socio-demographic characteristics of the study participants

Figure 1: Age distribution of study participants



The age range was 4 to 64 years with a median age of 31 and a mean age of 33 years. Twenty one patients (53.8 %) were in the age group of 21- 40 years. The mean ± SD was 33 ± 15.6 and the median (IQR) was 31 (22,41).

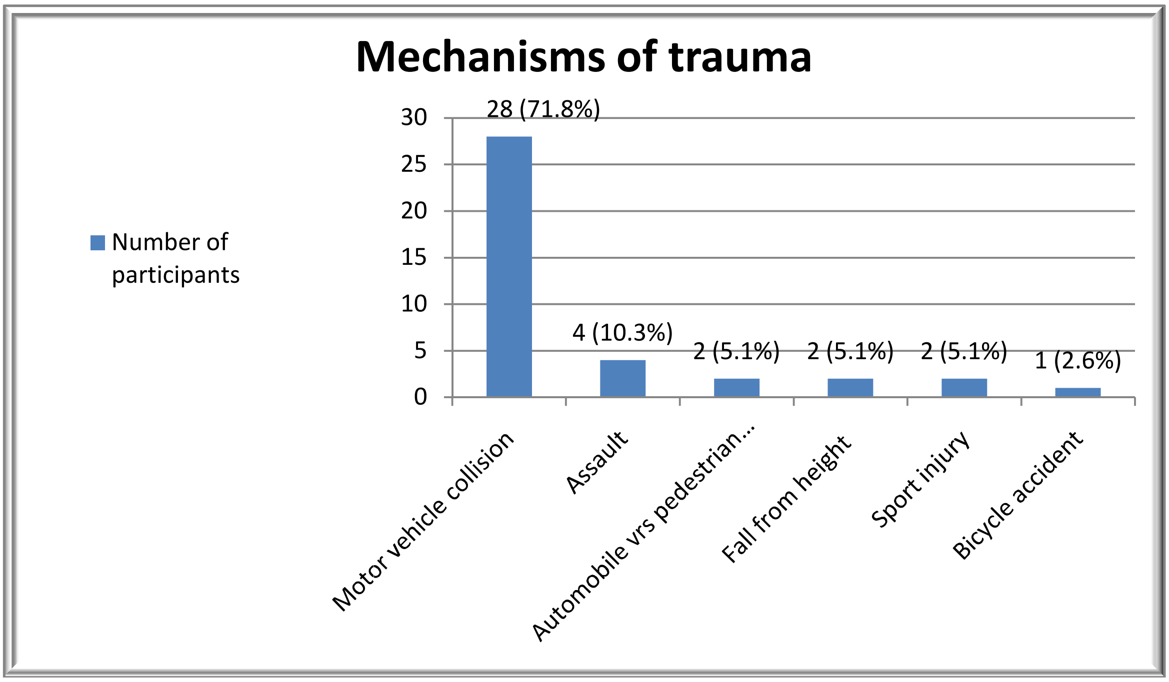
Figure 2: Sex distribution of study participants



Males were 31 (79.5%) and females were 8 (20.5%) with the male to female ratio of 3.8:1.

Results related to abdominal injury.

Figure 3: Mechanisms of trauma



The figure 3 shows that motor vehicle collision (MVC) was the most common cause of injury constituting 71.8% of cases. It was followed by assault represented by 10.3% of participants. The total cases of trauma from motor traffic accidents were 76.9 %, including automobile versus pedestrian accidents.

Table 4: Distribution of abdominal injuries

Abdominal organ involvement	Number	Percentage
Single organ	23	59.0
Two organs	13	33.3
Three organs	3	7.7
Spleen	16	41.0
Liver	15	38.5
Pancreas	2	5.1
Kidney	6	15.4
Bladder	2	5.1
Major blood vessels	1	2.6
Bowel and mesentery	5	12.8
Miscellaneous injuries	11	28.2

As shown in table 3, the majority of patients (59%) sustained injury to single organ. However a third (33.3%) of our participants had injuries of two intra-abdominal organs at the same time. Three organs were injured in 7.7% of our patients.

The spleen was found to be the most commonly injured organ constituting 41.0% of patients, followed by the liver (38.5%) and the kidneys (15.4%).Two patients had bladder injury, only one case of aortic intimal flap was seen and bowel and mesentery were considered injured in 5 cases. Miscellaneous injuries included four cases of rib fractures, two cases of vertebral fracture, one pelvic fracture, one adrenal hematoma and one lung contusion.

Table 5: CT findings on pre and post contrast scans

CT findings	**CT findings during:**				
	Total number	Pre contrast	Post contrast	Incremental utility of post contrast	
Hemoperitoneum	17	16	17	5.9%	1/17
Active intra-peritoneal hemorrhage	1	-	1	100.0%	1/1
Hemoretroperitoneum	8	8	8	-	-
LIVER					
Contusions	9	-	9	100%	9/9
Lacerations	10	-	10	100%	10/10
Intraparenchymal hematomas	3	1	3	66.7%	2/3
Subcaspular hematomas	2	2	2	-	-
Periportal tracking	3	-	3	100%	3/3
Active bleeding/contrast extravasation or blush	5	-	5	100%	5/5
SPLEEN					
Contusions	7	-	7	100%	7/7
Laceration	5	-	5	100%	5/5

Subcaspular hematoma	1	1	1	-	-
Fractures/ rupture of splenic parenchyma	2	1	2	50%	1/2
Splenic infarction/ necrosis	1	-	1	100%	1/1
Heterogeneous parenchyma with a mottled irregular enhancement	2	-	2	100%	2/2
Perisplenic clot	1	-	1	100%	1/1
Active bleeding/ contrast extravascation or blush	2	-	2	100%	2/2
PANCREAS					
Contusions	1	-	1	100%	1/1
Laceration	1	-	1	100%	1/1
Pancreatic duct disruption	1	-	1	100%	1/1
Fracture of the pancreas	1	-	1	100%	1/1
Peripancreatic hemorrhage	1	1	1	-	-
KIDNEYS					
Contusions	1	-	1	100%	1/1
Laceration that don’t communicate with the collecting system	2	-	2	100%	2/2
Laceration that communicate with the collecting system	1	-	1	100%	1/1
Shattered kidney	1	1	1	-	-
Intrarenal hematoma	1	1	1	-	-
Perirenal hematoma	1	1	1	-	-
Renal infarction	1	-	1	100%	1/1
Avulsion and laceration of the renal pelvis	1	-	1	100%	1/1
Extravasation of contrast-laden urine	1	-	1	100%	1/1
URINARY BLADDER					
Extraperitoneal bladder rupture	1	-	1	100%	1/1

Intraperitoneal bladder rupture	1	-	1	100%	1/1
BOWEL AND MESENTERY					
Extraluminal air or contrast material	2	2	2	-	-
Peritoneal / retroperitoneal fluid in the absence of solid organ injury	1	1	1	-	-
Interloop fluid	1	-	1	100%	1/1
Thickened bowel wall	3	-	3	100%	3/3
MAJOR BLOOD VESSELS					
Aortic intimal flap or transection	1	-	1	100%	1/1
MISCELLANEOUS INJURIES					
Rib fractures	4	4	4	-	
Vertebral fractures	2	2	2	-	
Pelvic fractures	1	1	1	-	
Injuries to the abdominal wall	2	2	2	-	
Adrenal haemorrhage	1	-	1	100%	1/1
Lung contusion	1	-	1	100%	1/1

Table 5 describes in detail the types of injuries sustained by the patients in our study with comparison of CT findings on pre and post contrast scan, which was the main objective of this study.

Hemoperitoneum was the commonest CT finding. It was seen in 17 cases and only one case of very minimal hemoperitoneum was missed on precontrast scan. Hemoretroperitoneum was found in 8 cases on both the pre and post contrast scans. Only one case of active intra-peritoneal haemorrhage occurred and could not be recognized without contrast injection.

The commonest injury findings in the liver were lacerations in 10 patients followed by contusions in 9 cases. All liver contusions and lacerations were missed on precontrast scan. One of the two cases of intraparenchymal hematoma was missed without contrast injection, while the total of 3 cases of periportal tracking and 5 cases of liver active bleeding were only seen on post contrast scans. Two cases of hepatic subcapsular hematoma could be seen even on precontrast scans.

As mentioned above, the spleen was the commonest injured organ in our study with 7 cases of contusion, 5 cases of laceration, one case of subcapsular hematoma, 2 cases of splenic fracture, one case of splenic infarction, one case of perisplenic clot, one case of active bleeding and 2 cases of heterogeneous parenchyma with a mottled irregular enhancement. Among all those splenic lesions, only one case of subcapsular hematoma and one splenic fracture were detected on precontrast scans. Others were missed without contrast.

The pancreas was injured in 2 patients. The lesions that could only be detected on postcontrast scans were one case of contusion, one laceration, one pancreatic duct disruption, and one fracture of the pancreas. Only a case of peripancreatic hemorrhage could be seen on precontrast scans.

Kidneys were the third commonly injured organ in this study. One case of contusion, one laceration that didn’t communicate with the collecting system, one laceration that communicates with the collecting system, on renal infarction, one avulsion and laceration of the renal pelvis, and one extravasation of contrast-laden urine were all missed on precontrast scans. Only a case of shattered kidney, intrarenal hematoma, and perirenal hematoma could be detected on precontrast scans. Even though the shattered kidney could not be clearly defined on precontrast scans, there was evidence of injured kidney.

Only two cases of urinary bladder injury were seen in this study; one extraperitoneal bladder rupture and one intraperitoneal bladder rupture. Both were missed on precontrast scans.

In our study, bowel and mesentery injuries were considered in case of extraluminal air (2 cases), peritoneal fluid in the absence of solid organ injury (1 case), interloop fluid (1 case), and thickened bowel wall (3 cases). One case with interloop fluid and three cases with thickened bowel wall were missed on precontrast scans.

Only one case of major blood vessels injury was registered. That was an abdominal aortic intimal flap and was only seen on post contrast scans.

One case of adrenal hematoma was counted in our study and was only detected on post contrast scans. Registered associated extra-abdominal injuries were rib fracture (4 cases), vertebral fracture (2 cases), pelvic fracture (1 case), abdominal wall injury (2 cases), and one case of lung contusion.

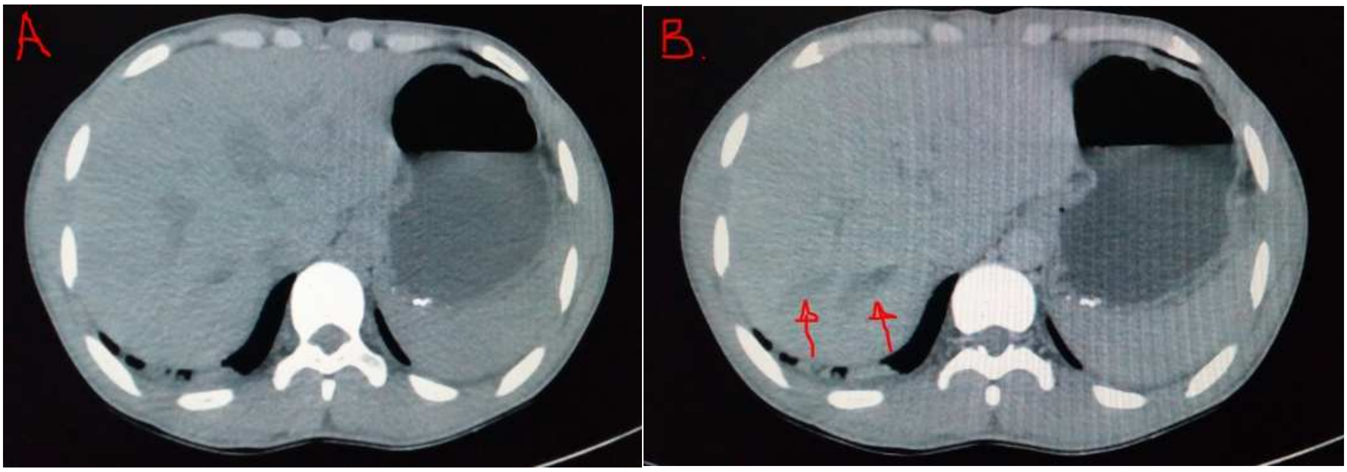
In summary, out of 115 injuries registered in our study, pre contrast scans could only detect 45 injuries which correspond to 39.1% (95 % CI 30.2 – 48.7). This means that 60.9% (95% CI 51.3 – 69.8) of injuries were missed on precontrast scans.

A certain number of our CT findings were considered more clinically significant than others. These include one case of active intraperitoneal haemorrhage, five cases of active intrahepatic bleeding, one active splenic bleeding, one splenic fracture, one pancreatic duct disruption, one fracture of pancreas, one laceration and avulsion of renal pelvis, one shattered kidney, two cases of bladder rupture, three cases of bowel and mesentery injury, one intraabdominal aortic dissection, 2 cases of vertebral fracture and one pelvic fracture.

However, the type of management and clinical or surgical outcome were not registered in out study, and it was mentioned to be one of the limitations of this study.

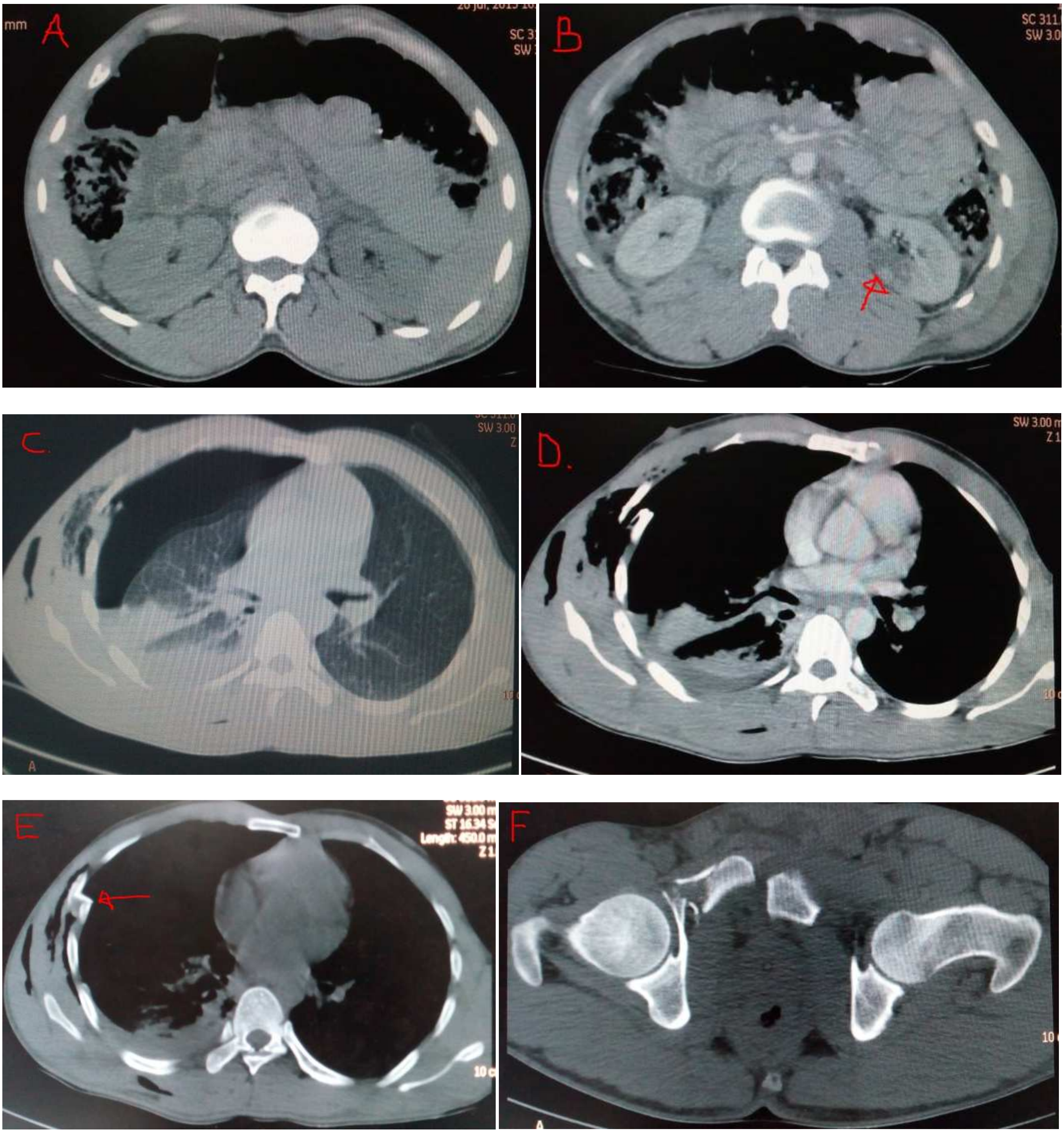
Representative images from our study:

Figure 4: Liver laceration



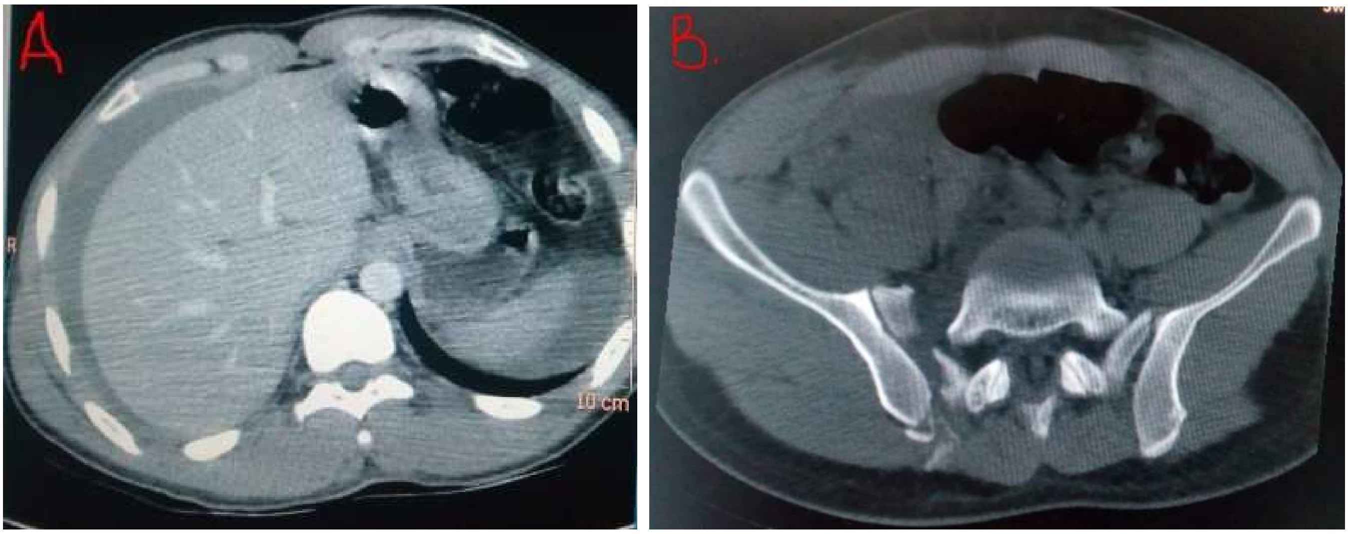
Axial CT scan of abdomen in a 21-year-old man who was involved in a motor vehicle accident (MVA) showing small lacerations in right lobe of the liver (arrows in image B). The lesions could be visualized on post contrast scans (image B) and easily missed on pre-contrast images (image A).

Figure 5: Multiple injuries



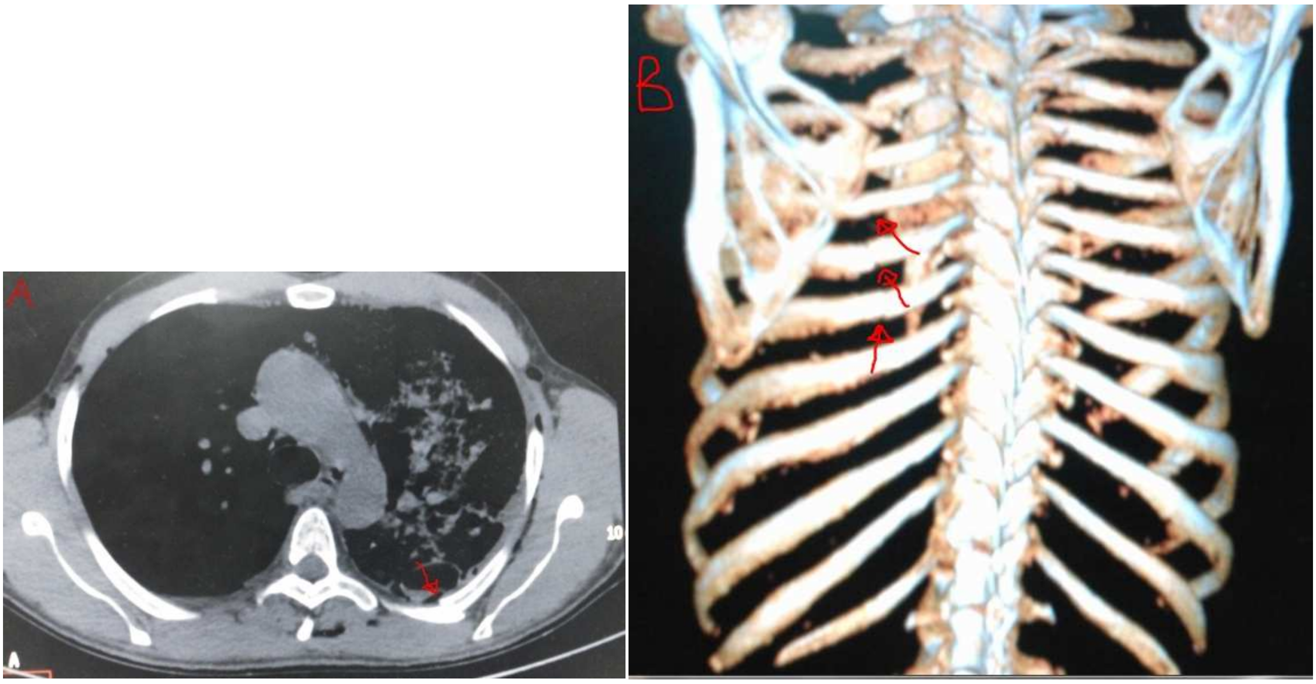
CT scan images (A-F) in 37-year-old-male patient demonstrating multiple injuries due to road traffic accident (RTA). A post contrast image B shows a grade I left renal contusion (arrow) which could not be detected on precontrast scans (image A). Other images demonstrate a right sided pneumothorax (image C), a right sided hemothorax (image D), rib fractures (image E, arrow) and multiple pelvic fractures (image F). In this patient the urinary bladder was not injured.

Figure 6: Peritoneal fluid in the absence of solid organ injury



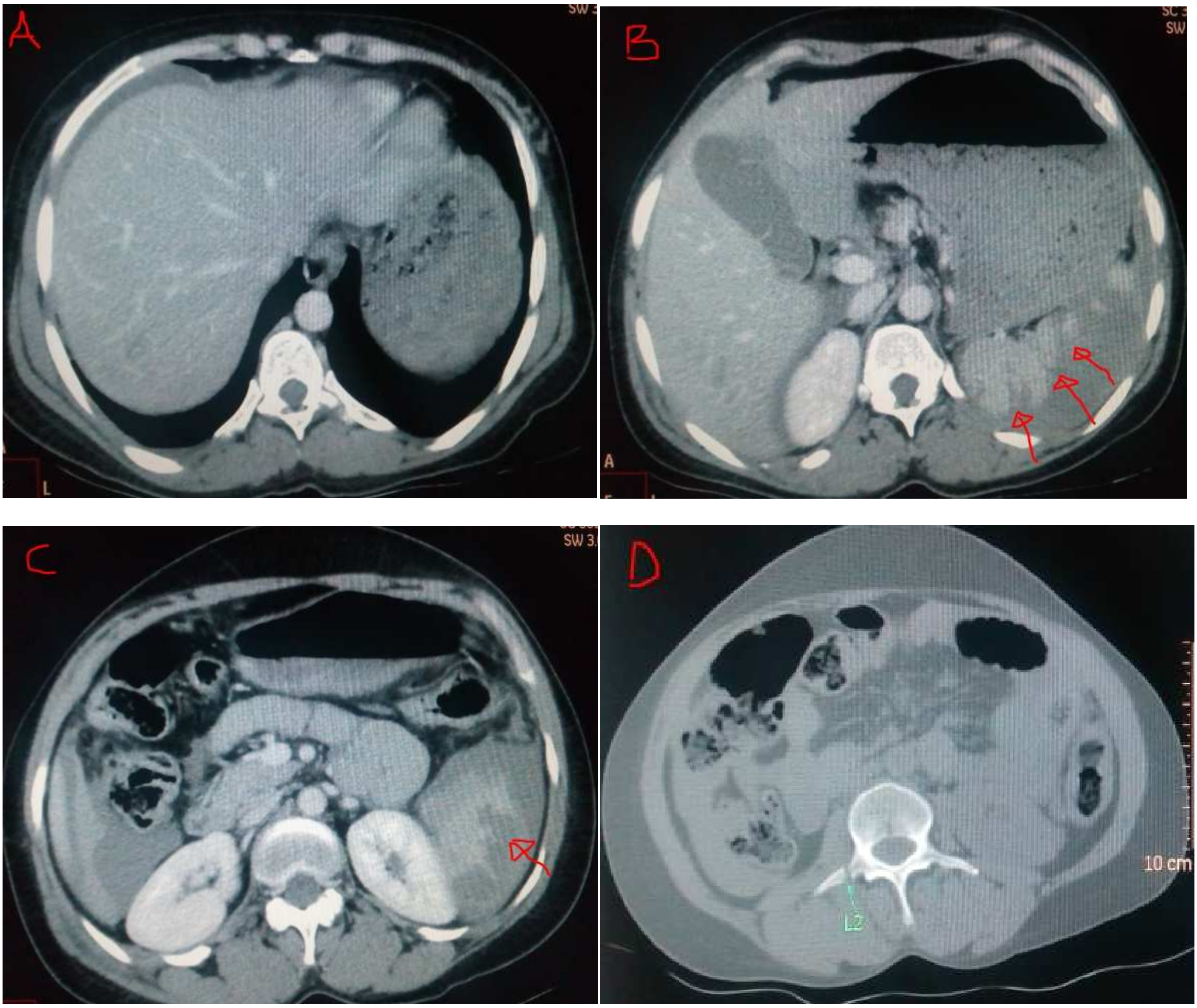
CT scans in a 28-year-old patient after involvement in an MVA. Image A shows an intraperitoneal fluid without solid organ injury. The findings were suspicious of bowel injury that was not clearly detected on CT scans. Associated multiple pelvic fractures are seen on image B.

Figure 7: Multiple rib fractures.



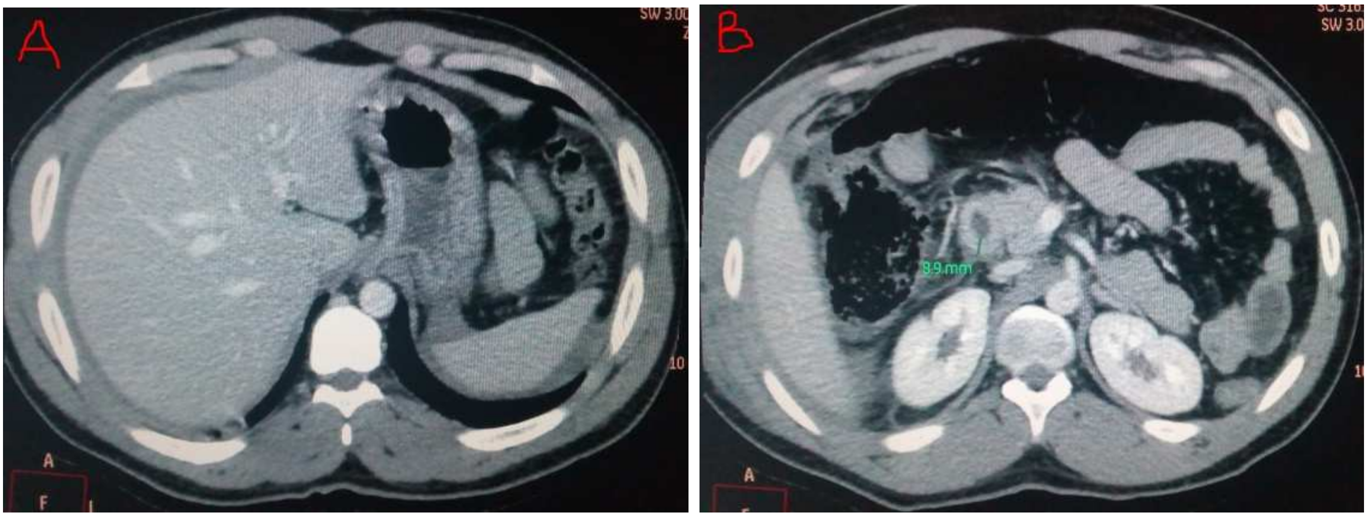
CT scans in 45-year-old male patients after a fall from height. Both bone window (image A) and 3D reconstruction (image B) demonstrate left sided multiple rib fractures (arrows). Lesions seen in lung fields (image A) were due to chronic lung disease, not related to the accident.

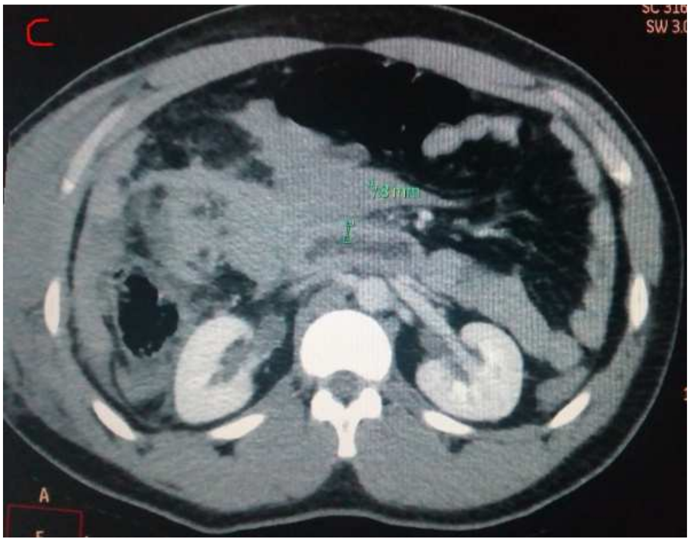
Figure 8: Splenic rupture/fracture



Abdominal axial CT scans in a 35-year-old female patient involved in a road traffic accident (RTA). Image A shows a peri-hepatic hemoretroperitoneum. Images B and C demonstrate multiple splenic ruptures with peri-splenic hematoma (arrows) and image D shows an associated fracture of right transverse process of L2 vertebral body.

Figure 9: Bowel/mesenteric injury





Axial CT scans of abdomen in a 27-year-old patient after MVA. The images A, B and C show peritoneal free fluid with thickened bowel walls in absence of intra-abdominal solid organ injury. The findings are suggestive of bowel/mesenteric injury.

CHAPTER IV: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

IV.1. DISCUSION

Abdominal trauma is most common in the active segment of the population globally and the incidence is highest in the 21-40 year age group (68). In this study 53.9 % of patients were in this age group. These were due to motor traffic crashes, occupational hazards and interpersonal violence or assault. The age range of patients was 4 to 64 years and the mean age being 33 years. This study supports the findings of others that the young economically active segment of the population is very vulnerable to injuries including abdominal trauma (68) (69).

Males were more involved compared to females in a ratio of 3.8:1.The predominance of males has been also documented in the study done by Musau et al at Kenyatta National Hospital (2006) in which the male to female ratio was 12.3:1 (70). Another study on the Pattern and outcome of abdominal injuries at Muhimbili National Hospital, Dar Es salaam, Tanzania revealed that abdominal injuries predominantly involve the male gender, with male to female ratio of 7.4:1 (69).This is also supported by another regional study done in Uganda, at Mbarara regional referral Hospital in 2008 that recorded a male to female ratio of 5:1 (71).The large proportion of male involvement can be attributed to occupational hazards and other socio-economical activities men do that predispose them to injuries. They are more likely to have reasons for moving from one place to another. In most African countries, males also represent the active group in any society that takes part in high risk activities. However, these last years, there is an evident increase of female involvement in income productive activities in Africa. This would explain the low male to female ratio in our study compared to the cited studies done some years ago.

The motor traffic crash was found to be the commonest cause of blunt abdominal trauma as found elsewhere worldwide. In this study 30 out of 39 patients (76.9%) with blunt abdominal injury sustained their injuries from motor traffic accidents as passengers, drivers or pedestrians.

This concurs with the findings of a prospective study on abdominal injury that was done at Mbarara in Uganda (71), where most injuries were a result of road traffic accidents (47.1%)

and assault. Another study done in Dar Es Salaam, Tanzania found the same results (57.7%) (69).

The spleen was found to be the most commonly injured intra-abdominal organ in our study with 41% of cases, followed by the liver in 38.5% and kidneys in 15.4% of cases.
This is in agreement with two studies done at Muhimbili National Hospital, Dar Es salaam, Tanzania at different periods of time which found the spleen to be the commonest organ injured in abdominal trauma, followed by the liver (69) (72).
Almost a third of cases (28.2%) had associated extra-abdominal injuries in our study and this agrees with other studies done in the region (69), (70).

Hemoperitoneum was found to be the most common CT finding in our study with 17 cases. Similar studies on injuries from other areas show a similar trend (73).
The majority of injuries found in our study were lacerations and contusions for the spleen and the liver. The same tendency was demonstrated by E. Kailidou at al. (74).

In our study, bowel and mesentery injuries were considered in case of extraluminal air seen in two cases, peritoneal / retroperitoneal fluid in the absence of solid organ injury (1 case), interloop fluid (1 case) and 3 cases of thickened bowel wall. A comparison with findings at surgery would have been of great importance for us to confirm the gravity of these injuries.

CT cystography for suspected bladder injuries, oral contrast for suspected bowel injuries and endoscopic retrograde cholangiopancreatography (ERCP) for pancreatic injuries were not done during our study.

In our study, 60.9% of injuries were missed on precontrast scans. The majority of the missed lesions were clinically significant. This explains the key role of IV contrast medium in diagnostic CT scan of blunt abdominal trauma. Without IV contrast injection the majority of life-threatening injuries are not perceptible on CT scan. The protocol for diagnostic blunt abdominal trauma CT scan should include the use of IV contrast medium.

The same remark was made by many different authors, from both old and more recent studies. E. Kailidou et al, in their study done in 2005 in Greece, found that in 82.4% of participants the use of IV contrast medium assisted in the demonstration of active arterial or venous haemorrhage, the size of the haematomas or the morphology and severity of visceral trauma (12).

Also A. Luana Stanescu et al in their study done in 2006, made the same conclusion that intravenously contrast-enhanced CT remains the most common and efficacious means of correctly diagnosing and categorizing patients into those likely manageable with nonoperative techniques and those who need surgery (76).

The usage of IV contrast medium in CT evaluation of blunt abdominal trauma is currently a universal recommendation.

IV.2. CONCLUSIONS

The spleen was the most commonly injured organ in our study. It was followed by the liver and the kidneys. Motor traffic accidents were the commonest cause of injury, there was a male predominance and most patients were in their 3^{rd} and 4^{th} decades. The use of IV contrast medium assisted in the demonstration of 60.9% of injuries that would have been missed without contrast injection. Our study results were in agreement with other different studies done elsewhere.

IV.3. RECOMMENDATIONS

- In order to reach definite conclusions larger series are needed. However, contrast enhanced spiral CT remains a valuable method for diagnosis and grading of abdominal trauma.
- Diagnostic protocol for management of patients with blunt abdominal injuries should be made at KNH and be available for guiding radiologists and surgeons on management of patients with abdominal injuries.
- A study to evaluate the accuracy of CT scan in the detection of blunt abdominal injuries by comparing CT findings and surgery findings is needed.

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APPENDIX

A. DATA COLLECTION SHEET

"The role of IV contrast medium in diagnostic blunt abdominal trauma CT scan at KNH"

1. PATIENT'S BIODATA

Study number…………..Age in years….......... Gender: Male Female

2. MODE OF TRAUMA

Mechanism of trauma…………………………………………..

3. CT SCAN FINDINGS

CT SCAN FINDINGS	**Precontrast**		**Postcontrast**	
	YES	**NO**	**YES**	**NO**
Hemoperitoneum				
Active intra-abdominal haemorrhage				
Hemoretroperitoneum				
Liver				
Contusions				
Lacerations				
Intraparenchymal hematomas/central hematomas				
Subcapsular hematomas				
Disruption of the hepatic capsule				
Bile leakage				
Fractures/rupture of hepatic parenchyma				
Hepatic infarction or necrosis				
Liver maceration or devascularisation				
Hepatic subcapsular or parenchymal gas				
Periportal tracking				
Juxtahepatic venous injuries				
Avulsion of the hepatic pedicle				
Active Bleeding/contrast extravasation or blush				
Spleen				
Contusions				
Lacerations				
Intraparenchymal hematomas/central hematomas				
Subcapsular hematomas				
Disruption of the splenic capsule				
Fractures/rupture of splenic parenchyma				
Splenic infarction or necrosis				
Heterogenous parenchyma with a mottled irregular enhancement				
Perisplenic clot				

Splenic maceration or devascularisation				
Active Bleeding/contrast extravasation or blush				
Pancreas				
Contusions				
Lacerations				
Pancreatic duct disruption				
Pancreatic duct dilatation				
Fracture of the pancreas				
Traumatic pancreatitis				
Focal or diffuse enlargement of the pancreas				
Areas of decreased attenuation / Inhomogeneous enhancement				
Peripancreatic oedema and fluid collections				
Acute pseudocyst formation				
Peripancreatic haemorrhage				
Peripancreatic fat stranding				
Thickening of the left anterior renal fascia				
Kidneys				
Contusions				
Lacerations that don't communicate with the collecting system				
Lacerations that communicate with the collecting system				
Shattered kidney				
Renal fractures				
Subcapsular hematomas				
Intrarenal hematomas				
Perirenal hematomas				
Leakage of urine into the abdomen/urinoma				
Renal infarction				
Renal pedicle injuries				
Renal maceration or devascularisation				
Avulsion and laceration of the renal pelvis				
Extravasation of contrast-laden urine				
Active Bleeding/contrast extravasation or blush				
Renal arterial or venous occlusion				
Urinary bladder				
Bladder contusion (incomplete tear of the bladder mucosa)				
Extraperitoneal bladder rupture/contrast extravasation at the base				
Intraperitoneal bladder rupture/contrast extravasation at the dome				
Both extra and intraperitoneal bladder rupture				
Bowel and mesentery				
Extraluminal air(pneumoperitoneum)or contrast material				
Peritoneal/retroperitoneal fluid in the absence of solid organ injury				
Interloop fluid				
Thickened bowel wall (>3mm).				
Transmural laceration				

Disruption of the bowel wall or mesentery				
Intramural hematoma				
Bowel ischemia or necrosis / pneumatosis				
Sentinel clot adjacent to the involved bowel				
Mesenteric haemorrhage/hematoma				
Mesenteric fat stranding				
Focal mesenteric infiltration or streaking				
Active intavenous contrast extravasation				
Abrupt termination of mesenteric vessel(s)				
Major blood vessels				
Aortic intimal flap or transection				
Visceral organs infarctions				
Thrombus formation				
Soft tissue density surrounding the aorta				
Retroperitoneal hematoma with a paracavalepicenter				
Irregular IVC contour				
Extravasation of contrast material near the origin of active bleeding				
Hypovolemic shock				
Small aorta				
Collapsed/flat inferior vena cava				
Marked enhancement of the kidneys				
Initially diminished density of spleen compared with liver after contrast enhancement				
Marked,diffuse dilatation of the intestine by fluid				
Abnormally intense contrast enhancement of the bowel wall				
Abnormally intense contrast enhancement of the mesentary				
Abnormally intense contrast enhancement of the pancreas				
Miscellaneous abdominal trauma				
Rib fractures				
Vertebral fractures				
Pelvic fractures				
Injuries to the abdominal wall				
Gallbladder injury				
Diaphragmatic rupture				
Adrenal injury/haemorrhage				
Other CT findings (not quoted above)				

Radiologists' name: ***Date:………/………./……………***

B. PATIENT'S CONSENT FORM (ENGLISH)

Study participation consent form

The study: The role of IV contrast medium in diagnostic blunt abdominal trauma CT scan at Kenyatta National Hospital.

Investigator:

Dr. Fidens Dusabeyezu, MB.ChB, Student M.Med Diagnostic imaging and radiation medicine, University of Nairobi.

Emergency telephone number

Dr. Fidens Dusabeyezu, +254720561583

Investigators' statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study. Please read this form carefully. You may ask questions about what we will ask you to do, the risks, the benefits and your rights as a volunteer, or anything about the research or in this form that is not clear. When all your questions have been answered, you can decide if you want to be in this study or not. This process is called "informed consent".

Purpose and benefits

This study will help us to know the importance of giving intravenous contrast medium when we are doing abdominopelvic CT scans for the patients who had blunt abdominal trauma. This study will benefit the society by providing information that can be used to improve services to ensure that patients with blunt abdominal trauma are managed correctly and a better management protocol is implemented in the routine care of such trauma patients. At a personal level, participation in the study will provide not only a better diagnosis but also a better management decisions by surgeons.

Procedures

This study involves reviewing your CT scan together with your clinical notes to gather information about your condition after abdominal trauma for which your doctor would like to have you scanned. The information from your report will be analysed together with that of other patients in order to generate an overall impression of the results that are encountered whenever this procedure is carried out. This is what will happen if you decide to participate in this study. I will ask you some questions about yourself and your accident, and after answering these questions you will be scanned first without contrast and then, through a catheter introduced into one of your veins, you will be given an IV contrast medium before the second scan.

Risks, stress, or discomfort

You may become embarrassed, worried, or anxious when answering some of the questions as they may remind you about the accident endured. You may also feel pain when we will be looking for an IV line. Even though very rare, the contrast medium we will inject in your vein may cause you some unintended reactions. If it is the case we will assist you properly. The CT scanning uses radiation, but the radiation dose for these scans are known to be not harmful. During the scan you will not feel anything. This procedure will take between 10 and 20 minutes. However, we will try to serve you as quick as possible.

Other information

We will keep your identity as a research subject confidential. Only the principal investigator will have access to information about you. The information about you will be identified by the study number and will not be linked to your name in any records. Your name will not be used in any published reports about this study. Although we will make every effort to keep your information confidential, no system for protecting your confidentiality can be completely secure.

Please note that your participation is voluntary and you have a right to decline or withdraw from the study at any time during the procedure without loss of benefit or penalty. No incentives will be given to the study subjects. If you have any questions regarding the study you can contact the investigator listed above. You are free to refuse to participate in the study, if you decide not to participate in the study; you will receive a similar care to that provided to patients with blunt abdominal trauma participating in the study. Note that for unconscious patients and minors, the decision for participating in the study will be made by a medico-legal companion if available. Otherwise they will not be included in the study.

Signature of investigator__________________________Date_____________________________

Name of investigator ____

Subject’s statement:

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later on about the research I can ask the investigator listed above. If I have questions about my rights as a research subject, I can address myself to the KNH/UoN-Ethics and Research Committee. I will receive a copy of this consent form.

Signature of the subject______________________Date________________________________

Left thumbprint of the subject__________________Date_______________________________

Name of subject____

Signature of witness (if thumbprint used)____

Name of witness____

ETHICS AND RESEARCH COMMITTEE

KNH/UoN-ERC

P.O. Box 20723, Nairobi.

C. KIBALI CHA KUSHIRIKI KATIKA UTAFIKI

Utafiti unahusu:

Matumizi ya dawa ya kuongeza ubora wa picha za CT scan wakati wa kuchunguza majeraha ya tumbo katika Hospitali Kuu ya Kenyatta.

Kiongozi wa utafiti:

Dkt. Fidens Dusabeyezu, MB.ChB**,** Mwanafunzi wa shahada la M.Med Diagnostic imaging and radiation medicine, Chuo Kikuu cha Nairobi.

Namba ya simu ya dharura:

Dkt. Fidens Dusabeyezu**,** +254720561583

Maelezo ya kiongozi wa utafiki

Tunakuomba ushiriki katika utafiki. Sababu ya kibali hiki ni kukupa wewe maelezo ambayo yatakuwezesha kuamua ikiwa ungependa kushiriki katika utafiti huu. Tafadhali soma kwa makini. Unaweza kuuliza maswali kuhusu maagizo utakayopewa, athari, faida na haki zako ikiwa utajitoa kwa hiari; ama lolote kuhusu utafiti au kibali hiki ambalo hujafahamu vizuri. Maswali yako yakishajibiwa, unaweza kuamua ikiwa utashiriki katika utafiti au la. Utaratibu huu unaitwa “kutoa kibali kwa ufahamu.”

Kusudi na manufaa

Utafiti huu utatusaidia kujua umuhimu wa kutumia dawa ya kuongeza ubora wa picha wakati wa kuchunguza majeraha ya tumbo.

Jamii itanufaika ikiwa kutapatikana ujumbe ambao utatumika kuboresha huduma kwa wagonjwa walio na majeraha ya tumbo.

Kwa kushiriki katika utafiti huu, wewe mwenyewe utapata kuchunguzwa vizuri zaidi ili madaktari wapate kukuhudumia inavyostahili.

Utaratibu:

Utafiti huu utahusika na usomaji wa picha zako pamoja na maandishi ya daktari kuhusu majeraha ulionayo.

Ujumbe unaokuhusu wewe pamoja na wengine wanaoshiriki utafiti utachunguzwa kwa jumla, ili kutoa matokeo yanayo tarajiwa.

Ikiwa utajitolea kushiriki katika utafiti, nitakuuliza maswali kuhusu juu yako na ajali ulioipata. Baada ya kujibu maswali, utapigwa picha kwanza bila dawa halafu picha itarudiwa tena ukiwa ushapewa dawa kupitia mishipa wa damu.

Athari na dhiki:

Unaweza kupata wasiwasi au fedheha wakati unapojibu maswali kwa sababu utakumbuka ajali uliokumbana nayo.

Unaweza kusikia uchungu wakati wa kutafuta mshipa wa damu utakaotumiwa kukupa dawa. Mara nyingine dawa utakayo pewa inaweza kuleta matokeo yasiokusudiwa lakini ni nadra sana; kasha utapewa usaidizi utakaohitaji.

Hutasikia lolote wakati wa kupigwa picha. Utaratibu huu utachukua dakika 10 hadi 20 lakini tutajaribu kukuhudumia haraka iwezekanavyo.

Maelezo ya ziada:

Kushiriki kwako katika utafiti kutawekwa siri. Kiongozi wa utafiti ndie atakaye kuwa na ujumbe juu yako. Ujumbe utakaotoa utatambulishwa kwa nambari tu, na wala hautahusishwa na jina lako katika nakala yoyote. Jina lako halite tambulishwa katika chapa ya ripoti yoyote kuhusu utafiti huu.

Unahitaji kufahamu kuwa hakuna njia ya kuweka siri kikamilifu.

Kumbuka kua unashikiri kwa hiari yako na unaweza kujiondoa kwenye utafiti wakati wowote bila adhabu wala hasara yoyote.

Washirika hawatapewa chochote ilikuwashawishi washirik iutafiti.

Elekeza maswali yako kwake kiongozi wa utafiti aliyetajwa hapo awali.

Kibali cha watoto au wagonjwa waliopoteza fahamu kitatolewa na mwengine anayeruhusiwa kisheria, la si hivyo hawezi kushiriki utafiti.

Sahihi yakiongozi wa utafiti______________________tarehe___________________________

Jina la kiongozi wa utafiti____

Kibali cha mshirika:

Nimeelezwa kuhusu utafiti huu. Najitolea kushiriki. Nimepewa fursa ya kuuliza maswali. Ikiwa nitakuwa na maswali zaidi baadaye, nitamuuliza kiongozi wa utafiti hapo juu. Ikiwa nina maswali kuhusu haki zangu kama mshirika, ninaweza kuasiliana na “KNH/UoN-Ethics and Research committee”. Nitapokea chapa yahiki kibali.

Sahihi ya mshiriki________________________________tarehe______________________

Au

Alama ya kidole cha mkono wa kushoto wa shirika_____________tarehe_______________

Jina la mshirika____

Sahihi ya shahidi (ikiwa alama ya kidole metumika)_______________________________

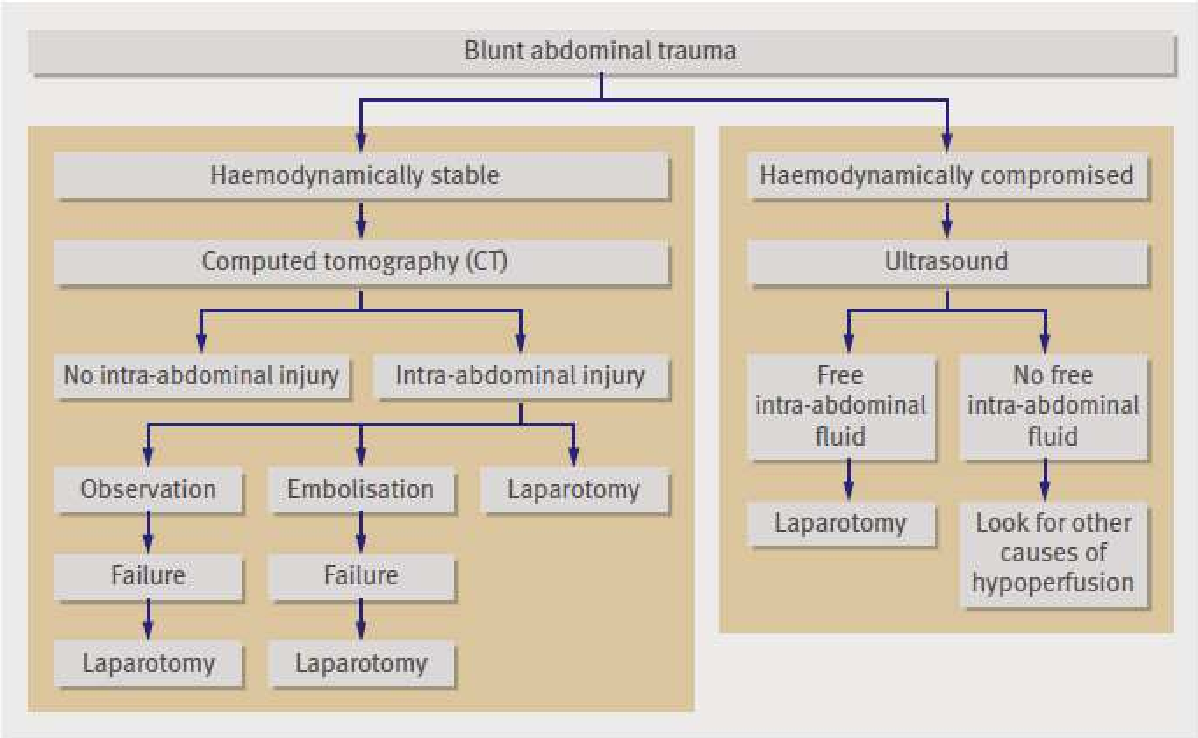
Jina la shahidi____

ETHICS AND RESEARCH COMMITTEE

KNH/UoN-ERC

S.L.P 20723, Nairobi.

Figure 10: Algorithm for the investigation of blunt abdominal trauma (75).



A practical approach

The algorithm above is widely accepted and applicable in hospitals with access to ultrasonography and computed tomography.

How should I investigate haemodynamically unstable patients?

The main aim in haemodynamically unstable patients with blunt trauma is to stop the bleeding. This will usually require laparotomy if the source of the haemorrhage is intra-abdominal, and investigation will serve just to localise the site of haemorrhage to the abdomen.9 The investigation of choice is ultrasound, which can be performed quickly and without moving the patient from the resuscitation area. If free fluid is detected, the patient should proceed to laparotomy.

How should I investigate haemodynamically stable patients?

The aims of investigation in haemodynamically stable patients are to demonstrate or exclude intra-abdominal injury. This requires a test that is sensitive and specific.

The decision to operate does not depend solely on the presence or absence of injury, because many injuries to solid organs can be managed non-operatively. Focused abdominal sonography for trauma will miss injuries not associated with intra-abdominal fluid and is therefore not useful in haemodynamically stable patients,7 and even formal abdominal ultrasonography lacks the sensitivity and specificity needed in this context. Computed tomography is therefore the investigation of choice in haemodynamically stable patients.

How should I manage a stable patient with isolated free fluid on computed tomography?

Free intra-abdominal fluid without solid organ injury is a concern, particularly in neurologically compromised patients, and must be placed in the clinical context with regard to injury patterns and signs of high risk, such as abdominal seat belt marks. In most cases, the fluid is blood and of no further consequence, but occasionally it may be gastrointestinal content from an undetected hollow viscus injury. Such patients should be managed by a surgeon. A recent systematic review reported that only 27% of these patients will need a therapeutic laparotomy and recommended that awake patients should be managed according to findings of the clinical examination, whereas neurologically compromised patients should undergo diagnostic peritoneal lavage to clarify the nature of the fluid.

Does a normal computed tomography scan rule out abdominal injury?

Patients without discernible injuries despite a major mechanism of injury are usually admitted to hospital for observation. A systematic review confirmed that a normal ultrasound scan does not exclude injury and should be followed by a period of observation or further investigation. In contrast, a large prospective multicentre study showed that a normal abdominal computed tomography scan has a high negative predictive value (99.63%), and it concluded that admission for observation may not be necessary. Such a strategy has obvious health economic appeal but requires further study.

What should I do if an initially unstable patient becomes “stable” during ultrasound?

Some initially unstable patients may respond to resuscitation during the time taken to complete the ultrasound scan. If no other indication for immediate laparotomy exists, such patients should then undergo computed tomography. Patients who transiently respond to resuscitation should be managed as unstable patients. The decision to obtain a computed tomography scan in such patients should be made only by experienced staff, after careful appraisal of the risks and potential benefits, and only if the results are likely to alter management.

Does the initial investigation of patients with major pelvic fractures differ?

The management of patients with pelvic fractures, particularly in the face of haemodynamic instability, is controversial, and a detailed discussion is outside the scope of this article. In broad terms, investigation should proceed along similar lines to other patients with major blunt abdominal trauma, albeit with attention to stabilization of the pelvis. Despite limitations, a recent systematic review identified focused abdominal sonography for trauma as the initial investigation of choice in haemodynamically compromised patients. Diagnostic peritoneal lavage in the presence of a pelvic fracture is associated with a high false positive rate.10 Haemodynamically stable patients with pelvic fractures should be evaluated by computed tomography.

Conclusion

The investigation of blunt abdominal trauma is a challenging and contentious subject with a limited evidence base. The algorithm proposed here is widely accepted and should help doctors in emergency departments decide on the most appropriate form of investigation pending the arrival of a specialist.

TIMEFRAME

The following is a proposed time-frame of the study process:

Number	ACTIVITY	ESTIMATED TIME
1	Proposal development	October - December 2012
2	Proposal submission to the department for marking	January 2013
3	Submission of proposal for ethical approval	February 2013
4	Data collection	March - December 2013
5	Data analysis	January 2014
6	Dissertation writing	February 2014
7	Dissertation submission	March 2014

D. STUDY BUDGET

Category	Remarks	Quantity	Unit cost (KShs)	Total(Kshs)
Proposal development	Literature review via internet (hours)	40	125	5,000
	Ethics Fee	1	2,000	2,000
	Laptop Computer	1	50,000	50,000
	Computer software	3	2,000	6,000
	Printer and catridges	1	8,000	8,000
	SPSS software	1	2,000	2,000
	Flash disk	1	1,000	1,000
	Reams printing paper	2	1,000	2,000
Data collection	Photocopy of data collection forms	1	500	500
	Biro pens	5	50	250
	Communication fees for 10 months	10	3,000	30,000
	Registration of data to Epidata (Assistant)	1	20,000	20,000
	Folders	5	200	1,000
Data analysis	Statistician	1	35,000	35,000
Thesis write up	Transport cost			10,000
	Typist fees			10,000
	Photocopy	10	200	2,000
	Binding	10	300	3,000
Subtotal				187,750
Contingencies at 5%				9,387.5
Grand total				197,137.5

The above expenses will be met by the researcher himself.