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REVIEW ARTICLE

Imaging Modalities in Trauma and Emergency—a Review

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Abstract

Radiology plays a very important role in the management of acutely injured patients. As per the Advanced Trauma Life Support (ATLS) program, it has been made an integral part of primary and secondary surveys. The primary objective of the imaging during the primary survey is to identify immediately life-threatening injuries and to assist in resuscitation of the patient. While during the secondary survey, imaging modality is aimed to assist in definitive management of the trauma patient. However, imaging modality should never hamper the resuscitation process of the patient and should be used judiciously. This review is aimed to study the indications, advantages and disadvantages of these modalities and to guide the treating trauma surgeons about the utilization of imaging modalities in different aspects of the trauma care.

Keywords FAST · Interventional radiology · Trauma · CT scan

Abbreviations

ATLS	Advanced trauma life support
ACS	American College of Surgeons
CECT	Contrast enhanced computed tomography
CXR	Chest X-ray
CT	Computed tomography
e-FAST	Extended Focused Assessment by Sonography in Trauma
FAST	Focused Assessment by Sonography in Trauma
MRI	Magnetic resonance imaging
NCCT	Non-contrast computed tomography
NEXUS	National emergency X-radiography utilisation study
OR	Operating room
PXR	Pelvic X-ray
REBOA	Resuscitative endovascular balloon occlusion of aorta
WBCT	Whole body computed tomography

Introduction

The worldwide paradigm shift in the management of the trauma patients happened following the acceptance/assimilation of the Advanced Trauma Life Support (ATLS) program of American College of Surgeons (ACS) in trauma care [1]. Injury kills patients in a certain reproducible time frame. Survival and the functional recovery of the patients are directly dependent on the promptness in recognizing and treating the anatomical and physiological derangements, especially within the first few hours, i.e. the window of opportunity following trauma. Hence, time and the multidisciplinary team are two essential pillars in the holistic management of the trauma patients. Physiological status of a trauma patient is "Dynamic" and may deteriorate at any point of time. So, it is of paramount importance for the clinician to treat the greatest threat to life first based on clinical parameters without unnecessary radiological confirmation to avoid delay in the resuscitation process or in the transfer of patients for definitive care to higher center [2].

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The primary aim for radiology during primary survey and secondary survey differs. Imaging during primary survey aims to facilitate resuscitation while imaging during secondary survey aims to define injuries and to guide definitive management. It is essential to note that imaging should not hamper the resuscitation process. As such, if possible, during primary survey, imaging should be performed only in the resuscitation area of the emergency department, i.e. "Radiology should come to the patient" (Fig. 1). However, no life-saving intervention should be delayed for the want of radiology, especially when bedside radiology facility is not available and the patient is physiologically unstable. Furthermore, anatomical findings of radiology should be interpreted in terms of physiological aberrations it produces in an acutely injured patient. Keeping these points in mind, we will briefly highlight the pivot role of diagnostic and interventional radiology in the management of trauma patients primarily based on the concepts/principles of the Advanced Trauma Life Support (ATLS) of American College of Surgeons (ACS).

Radiology for Primary Survey

The following radiological investigations are the adjuncts to primary survey

a. Chest X-ray (CXR): anteroposterior (AP) view only.
b. Pelvic X-ray (PXR): anteroposterior (AP) view only.
c. FAST and e-FAST: Focused Assessment by Sonography in Trauma and extended Focused Assessment by Sonography in Trauma

Note: These radiological evaluations should be done in the resuscitation area only. Only anteroposterior view is recommended for CXR and PXR during the primary survey as the patient may be having a spine injury which may get aggravated in any other position. Hence, it is preferred to avoid any movement in the spine till it is cleared.

CXR AP View

It is one of the oldest imaging used in polytrauma patients. However, over the years, its utility has diminished in places where e-FAST and computed tomography (CT) scan facilities are available round the clock. This is due to the fact that e-FAST can easily identify most of the life-threatening injuries in the chest, and CT chest is the "gold standard" for further definitive imaging [3]. Wisbach et al. [4] in 2007 reviewed 1000 trauma patients over 7 months and concluded that CXR is unnecessary in stable trauma patient with a normal clinical examination. The comparison of CXR with CT scan in evaluating thoracic trauma has been studied in several studies (Table 1). It has been found that the sensitivity of CT scan is higher than CXR in thoracic trauma. However, Kea et al. [5] in 2013 in a study evaluated the clinical significance of chest CT scan when CXR was normal in patients with blunt trauma. They concluded that chest CT scan after a normal CXR result in patients with blunt trauma detects injuries, but most do not lead to changes in patients' management. In India being a developing country, 24-h CT scan facility might not be available at all the places. So, in such conditions, CXR still plays a major role. Also, in places where CT scan facility is available, its judicious use is required.

The findings of the chest X-ray should be interpreted quickly in the "DRS-ABCDE" way [2] (Fig. 2). The CXR should be interpreted to quickly identify life-threatening chest injuries in a trauma patient viz. hemothorax, pneumothorax, flail chest, tracheobronchial injury, aortic dissection, diaphragmatic injury and oesophageal injury.

PXR AP View

Pelvis is a major source of bleed and about 10% of the patients with pelvic fractures present with haemodynamic instability. The reported mortality ranges from 30 to 50%. Thus, as a clinician during initial assessment of an injured patient, the interpretation of the radiological findings of pelvic X-ray should focus on identifying fractures which are associated with significant blood loss. Furthermore, the utility of pelvic X-ray has also decreased where 24-h CT scan facility is available. Also, in paediatric population, the Royal College of Radiology recommends against getting a screening pelvic radiograph in all cases [9]. Lagisetty et al. [10] in 2012 found that GCS < 14 and pelvic tenderness were the best predictors for pelvic

Fig. 1 Bed side radiology. Red circles showing portable bedside ultrasound and X-ray machines

Table 1 Various studies comparing the efficacy of CXR versus CECT scan in thoracic trauma

Author	Year	Type	No. of centre	No. of cases	Comparison of modality	Conclusion
Kea et al. [5]	2014	Retrospective cohort	2	791	CXR vs. CECT	CT after a normal CXR rarely detected a clinically significant injury
Chapman et al. [6]	2016	Retrospective observational	1	399	CXR vs. CECT	CXR missed about 75% of Rib fractures
Schellenberg et al. [7]	2018	Retrospective Observational	1	1311	CXR + eFAST vs CECT	Sensitivity of eFAST + CXR is only 64%
Langdorf et al. [8]	2019	Prospective cohort	10	5912	CXR vs. CECT	24.6% of occult injuries were observed on CT only

fracture. However, they also found dangerous mechanism of injury such as unrestrained motor vehicle crash as an important predictor. The radiological landmarks to be assessed are (Fig. 3):

1. Width of pubic symphysis (Normal < 1 cm)
2. Three rings (C1, C2 and C3)
3. Two lines (L1 and L2)
4. The sacroiliac joints (S1 and S2)
5. Iliac crests (I1 and I2)

Anteroposterior compression fractures and vertical shear fractures are associated with significant blood loss. Pubic diastasis > 2.5 cm and sacroiliac joint disruption can lead to massive haemorrhage and shock. Lateral compression fractures are more associated with genitourinary and gastrointestinal tract injury.

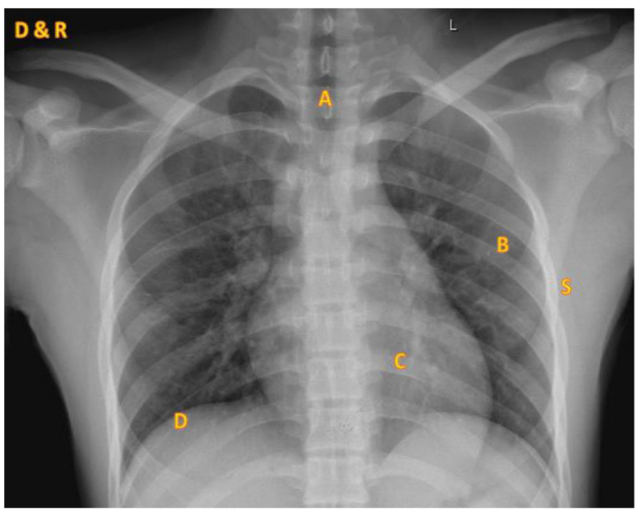

Fig. 2 Interpretation of X-ray chest: D: details (demographics, type of film, time and date); R: RIPE (assess image quality); S: soft tissue and bones: look for subcutaneous air and # of ribs, sternum, clavicle and scapulae. A: airway and mediastinum; B: breathing lung fields pneumothorax, pulmonary contusion, cavitation; C: circulation. Heart size, shape; D: diaphragm shape, angle, subdiaphragmatic air, gastric bubbles; E: extra. Endotracheal tube, central venous catheters, intercostal tubes

FAST and e-FAST

FAST was introduced to trauma evaluation, diagnosis and management in the 1990s. Since, then, it has replaced diagnostic peritoneal lavage from primary survey and continues to evolve. It has been extended from abdominal and pericardial cavity to pleural cavity (e-FAST) as well [11]. It is a very useful bedside tool which quickly detects free fluid in pericardial space, abdomen and fluid and free air in pleural cavity. For this reason, it is said to be the surgeon's stethoscope of trauma. It requires skill but can be acquired easily. FAST is not used to diagnose any solid organ injury or to quantify the amount or type of fluid present. It should preferably be done by the clinicians involved in the primary care of the trauma patients and not by the radiologists only (Fig. 4) [12]. It can detect as little as 200 ml of fluid in hepatorenal pouch, and as little as 20 ml fluid in pleural space. It is quick, cheap and has high accuracy. Various authors have reported a sensitivity of 70–95% and specificity of 90–99% [13, 14]. The sensitivity and specificity (~95%) are especially high in pericardial tamponade, where it is both diagnostic and

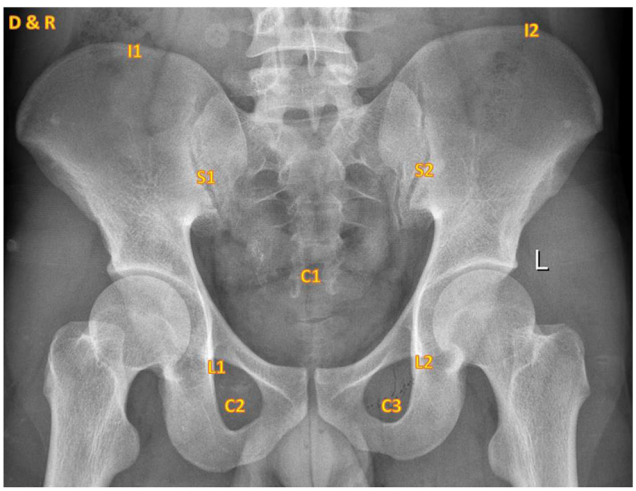

Fig. 3 Interpretation of X-ray pelvis. C1: pelvic ring; C2 and C3: obturator rings; L1 and L2: Shenton's line; S1 and S2: sacro-iliac joints; I1 and I2: iliac crest

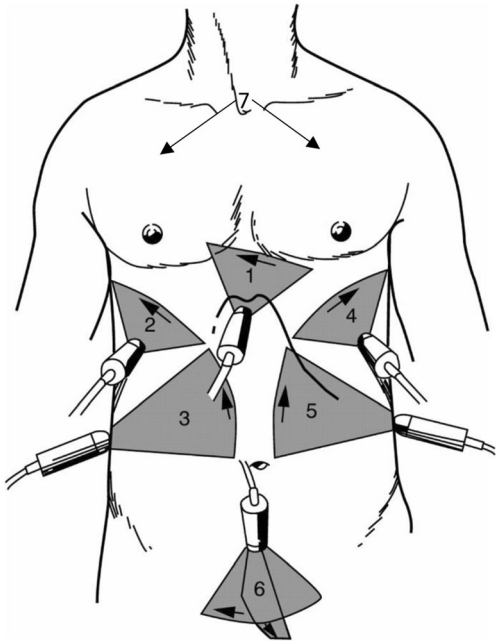

Fig. 4 Probe placement for e-FAST: (1) subxiphoid (pericardial window); (2) right pleural cavity; (3) hepatorenal pouch; (4) left pleural cavity; (5) splenorenal pouch; (6) pelvis; (7) mid-clavicular line 2nd intercostal space (for pneumothorax)

also assist in therapeutic pericardiocentesis. Further, it has to be kept in the mind that it is helpful in ruling in the injury and not ruling out the injury. However, its sensitivity is low in paediatric patients, with Liang et al. reporting a sensitivity of only 35% in a meta-analysis [15]. Further, the utility of FAST in haemodynamically stable patients has been questioned, as it is not useful for evaluating retroperitoneal, vascular, bowel and diaphragmatic injury. Also, it has its own limitations as it is operator dependent. It is also difficult to perform it in obese patients and in patients with excess bowel gas or subcutaneous emphysema. Moreover, it can be false positive when fluid filled bowel, gall bladder cysts, renal cysts or perinephric fat is misinterpreted as free fluid, while adhesions and bullae may be mistaken as pneumothorax [16, 17]. Nonetheless, e-FAST is a good bedside tool during primary survey of patients, especially in haemodynamically unstable patients in whom definitive imaging cannot be performed. A haemodynamically unstable patient who is FAST-positive should be quickly shifted to OR for damage control surgery. Further, ultrasonography has been useful in identifying musculoskeletal injuries, intracranial haemorrhage and raised intracranial pressure, laryngotracheal injuries and for guiding cardio-pulmonary resuscitation and instituting peripheral nerve blocks. However, this requires extensive training [18, 19]. Also, a greater number of comparative studies are required to establish the efficacy of ultrasound over other established imaging modalities.

Radiology for Secondary Survey

Secondary survey implies thorough head to toe and front to back examination of the patient. The clinical examination in secondary survey is supplemented by imaging adjuncts in the form of X-rays, fluoroscopic studies, computed tomography (CT) scan and magnetic resonance imaging (MRI). However, it is important to note that rushing the patient to a imaging modality needs to be done only after stabilizing the patient in primary survey [2]. Airway compromise, hypotension and ventilator malfunction are some of the noted adverse events that may occur, especially during CT or MRI. However, the concept of CT in haemodynamically stable patient only has been recently challenged. Tsutsumi et al. [20] in 2017 conducted a retrospective analysis of patients with trauma in shock who underwent CT scan. They observed that there was no clinically meaningful harmful effect of CT on survival for unstable blunt trauma patients. Few more studies have also supported their claim [21]. However, the topic is still under debate and it is better that best clinical judgement guides the need for imaging and patient is haemodynamically stabilised before shifting him/her for an imaging modality. Having said that, it is also important to recognize the importance of timely imaging which helps in early detection and management of injury.

CT scan has come up as a major modality in management of trauma. It has helped in augmenting non-operative management by grading the injuries and ruling out injuries which would require exploration. Also, it has an added advantage of being quick, non-invasive and operator independent. The use of CT scan in trauma has increased so much that the concept of "whole body CT (WBCT)" was given in Sweden in 1990s [22]. They utilized it as a standard protocol in severe injuries (injury severity score > 15). WBCT included NCCT head and C-spine followed by contrast-enhanced CT (CECT) chest, abdomen and pelvis. It included whole spine series. WBCT has shown to be effective in identifying occult injuries and increasing probability of survival in polytrauma patients as was shown by Wagner et al. [23] in 2009. However, it was a retrospective study. Sierink et al. [24] in 2016 did a randomized controlled trial comparing WBCT with conventional selective imaging (REACT-2 trial). However, they could not find any significant difference in the in-hospital mortality in two groups. Furthermore, they also found that dose of radiation was higher in WBCT group. In paediatric population, Miglioretti et al. [25] quantified the risk of malignancy on the basis of a child's age. They found that 1 in every 570–5130 scans would lead to malignancy in children less than 10 years of age, depending on age, sex and type of CT scan. Furthermore, caution should be practiced in getting a CECT scan done for patients with renal failure and pregnant females. The treating surgeon should try to utilise other imaging modalities in these patients. A thorough clinical examination

assisted by ultrasonography (USG) may be helpful in this group of patients. At the same time, it is worth mentioning that the fear of radiation hazard from CT scans or nephrotoxicity from contrast agents should never influence our decision regarding appropriate radiologic evaluation of a trauma patient. It should be done by taking desired precautions and after obtaining an informed consent from patient or his relatives. At the same time, the authors do not advocate non-judicious use of CT scan in trauma setting. In the following section, we would be discussing the imaging in a head to toe fashion.

Dangerous Mechanism of Injury

This is an important concept as patients with normal physical examination but with certain types of mechanism of injury may still harbour significant life-threatening injuries like head injury, diaphragmatic injury, major vascular injury, hollow viscus injury or solid organ injury [26–28]. This is based on field triage system [29]. Indications with specific mechanisms of injury who are at high risk for major trauma and qualify to undergo a WBCT are described in Table 2.

Non-Contrast CT Head and C-Spine

Non-contrast CT (NCCT) head has proven its efficacy in diagnosing both extra- and intra-axial haemorrhage. Other parameters which affect the management issues, i.e. mass effect and midline shift, are also delineated well. Apart from it, it is helpful in diagnosing other bony injuries and soft tissue injuries. Interpretation of NCCT head requires assessment of bone window and brain parenchymal window. A major limitation of NCCT head in trauma patient is in diagnosing diffuse axonal injury, in which small petechial haemorrhages may be seen at grey matter—white matter junction, but is not mandatory. The indications for NCCT head in trauma are summarised in Table 3. In a head injury patient, the incidence of cervical spine injury is about 5% [2]. The correct assessment of spine injury in a head injury patient is also difficult. Every trauma patient should be suspected to have a C-spine injury unless proven otherwise by either clinical examination (Canadian C-spine rule/NEXUS criteria) and/or radiological evaluation [30–32]. Hence, NCCT head and C-spine should be done in conjunction.

NCCT C-spine has a sensitivity and specificity of about 90–95% for bony injuries [33]. However, it has limitations in detecting disc herniation and cord oedema, for which MRI Spine is preferred. Other indications for C-spine imaging include:

- Neurological deficit
- Neurogenic shock
- C-spine injury not ruled out by Canadian C-spine rule or NEXUS criteria.

Table 2 Indications for WBCT in patients with the dangerous mechanism of injuries

1) Road traffic injuries:
Pedestrian hit by 4-wheeler
2-wheeler/ 4-wheeler hit by a high speed 4-wheeler
Death of a co-passenger
Car overturned
Ejection from a car
Intrusion > 12 in. on occupant side and 18 in. on any other side
2) Unknown mechanism of injury
3) Fall from height:
5 m in adults (> 12 years)
3× height in children (< 12 years)
4) Blast injuries

Intrusion here means interior compartment intrusion and not to deformation which refers to exterior damage

Table 3 Indications for NCCT head in suspected head injury

• GCS <15
• Suspected open/depressed/skull base fracture
• Post-traumatic seizure
• Focal neurological deficit
• > 1 episode vomiting
• > 65 years old
• Coagulopathy
• Dangerous mechanism of injury
• > 30-min retrograde amnesia

NCCT Face

In a polytrauma patient, maxillofacial injuries range from 15% to 20%, thus forming a significant proportion. They are often associated with other injuries, head injury being the commonest. However, accurate anatomical delineation of maxillofacial injury in acute trauma is not essential. At the same time, it is important to recognise maxillofacial injury as airway and circulation may be in jeopardy. Clinical examination is very sensitive in identifying which patient would require further imaging. X-ray series is effective in identifying isolated bone fractures. However, in cases of suspected panfacial injuries or patient undergoing CT for other injuries, NCCT face holds an advantage [34].

CECT Neck

Soft tissue injuries in neck may include vascular, aerodigestive or neural injuries. Imaging in neck injuries is guided by mechanism of injuries (Fig. 5). With the evolution of "No-Zone" approach in penetrating neck injuries, CECT neck is now being advocated in all penetrating injuries with platysmal

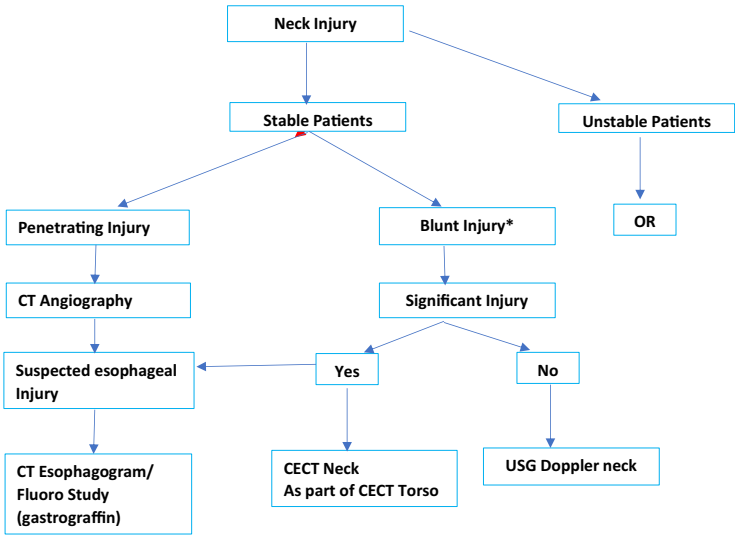

Fig. 5 Algorithm for imaging in neck injuries

*Blunt injury to the neck:
i) *Suspected Cerebro-vascular injuries*[34] -
Signs and symptoms: Arterial Haemorrhage, Cervical Bruit, Neurologic examination incongruous with head CT scan findings, Focal neurologic deficit, Expanding cervical hematoma
Risk factors: High-energy transfer mechanism with LeFort II or III fracture, Basilar skull fracture with carotid canal involvement, Petrous bone fracture, Diffuse axonal injury, Cervical-spine fracture patterns: subluxation, fractures extending into the transverse foramen, and fractures of C1–C3, Near hanging with anoxic brain injury
ii) *Suspected laryngotracheal injuries*: Stridor, Subcutaneous emphysema in neck, Hoarseness of voice, Bony crepitus
iii) *Suspected cervical oesophageal injuries*: (CT esophagogram is required): Subcutaneous emphysema in neck, Dysphagia

breach [36]. However, in blunt injuries, the indications are mentioned in Fig. 5. CECT neck has been found to be useful in detecting cervical aero-digestive and vascular injuries. In equivocal cases of cervical oesophageal injury, a CT esophagogram with oral contrast can be performed. Indirect evidence of cervical aero-digestive injuries includes mediastinal air or mediastinal hematoma; more in peritracheal or periesophageal space [37].

CECT Torso

It includes CECT chest, abdomen and pelvis. This concept is based on the fact that there is a high association of injuries to these areas subsequent to blunt trauma. Hence, it is suggested that while contemplating CECT of either of these areas, a full series of torso should be done in blunt trauma patients. In the next section, individual indications are being discussed.

CECT Chest Contrast CT chest should be performed in an acute trauma patient, unless a specific contraindication for contrast occurs. It improves tissue differentiation and also helps to evaluate any subtle vascular injuries which may not be evident on clinical examination. CECT chest is important in identifying injuries to sternum, spine, mediastinal structures and lung hernias which may be missed on a plain X-ray chest [38]. Chapman et al. [7] showed that X-rays missed 75% of rib fractures which were seen on chest CT. Traub et al. [39] suggested that in the presence of chest wall tenderness, reduced air entry and/or abnormal respiratory effort, a CT chest needs to be done even if the chest X-ray is normal. He reported that CT chest is more effective in identifying lung contusions, pneumothorax, mediastinal haematomas and fractures of ribs, scapula, sternum and spine. The indications for CECT chest are summarised in Fig. 6.

CECT Abdomen and Pelvis CT abdomen is an important entity in imaging of abdominal trauma as it helps to identify and delineate the injuries both hollow viscus and solid organ. The indications for imaging differ on the mechanism of injury (Fig. 7). Penetrating injury to anterior abdominal wall mandates local wound exploration or diagnostic laparoscopy. However, a few studies also advocate CT scan for decision making in anterior abdominal wall penetrating injury. In posterior abdominal wall and flank penetrating injury, primary management is dependent on CT findings with utilisation of rectal contrast depending on site of injury. A CECT in penetrating trauma helps in identifying the associated injuries as well as helping in assisting selective non-operative

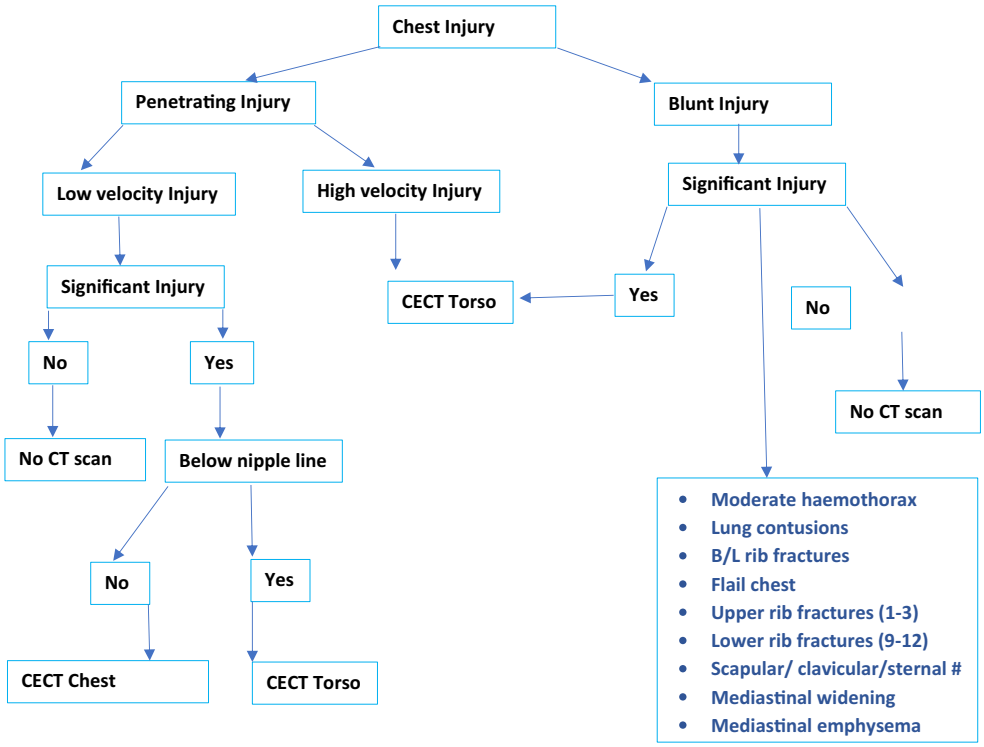

Fig. 6 Algorithm for imaging in thoracic injuries

management in cases of solid organ injuries [40]. In blunt trauma abdomen, the primary indication is a haemodynamically stable patient who is FAST positive. Secondary indications include dangerous mechanism of injury, associated chest trauma, suspicion of pancreatic injury (blow to epigastrium in the form of handle bar injuries, etc.) and suspicion of upper urinary tract injury (haematuria, flank tenderness or hematoma).

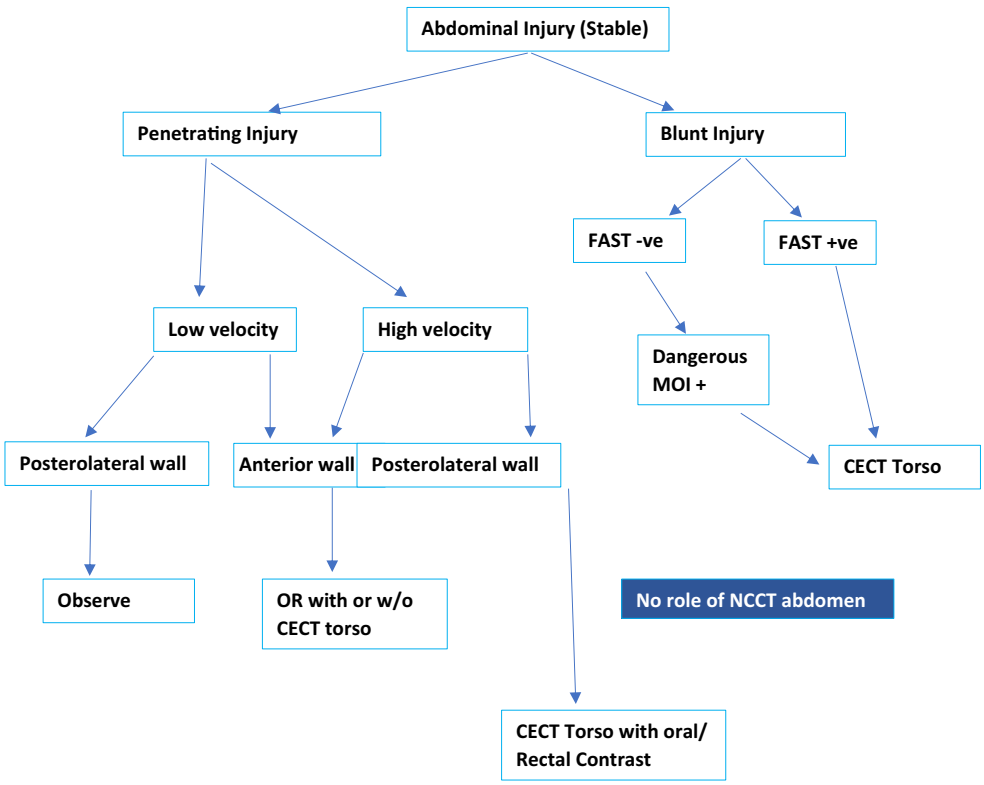

Fig. 7 Algorithm for imaging in abdominal injuries

In cases of solid organ injuries, CT abdomen helps to grade the injuries as per AAST guidelines. The way to perform CT scan is also important. Single-phase CT (venous phase) is indicated in FAST negative patient, while dual-phase CT (both arterial and venous phase) is recommended in other conditions. Dual phase CT has an advantage of characterising vascular injuries, i.e. pseudoaneurysm and active contrast extravasation [40, 41]. A delayed phase is recommended in cases of suspected renal trauma. The delayed phase is important to identify urinary extravasation. A 9-min delay was recommended between the early and excretory phase by Kiehani et al. [42] in a study of 326 patients.

In pelvic injuries, the indication of CT is preoperative surgical planning and delineation of any vascular, genitourinary or rectal injury. It is usually combined with CECT abdomen in acute trauma setting.

CT cystography is utilised in identification of bladder injuries. The primary indication for CT cystogram is haematuria. It is done by distending the bladder with 300–350 ml of contrast through a bladder catheter and then doing the scan. Contrast extravasation freely into peritoneum or in the extraperitoneal space is seen in the bladder injuries. CT cystogram can also delineate the site of bladder perforation [43]. Another important finding to be noted on CT is diaphragmatic anatomy. CT has an added advantage over X-ray in identifying diaphragmatic injuries, and has a sensitivity of close to 80–85% and a specificity of greater than 95%.

a) CT Angiography

Imaging in peripheral vascular injuries is guided by soft signs and hard signs [44]. Whenever exploration for vascular injury is contemplated, it is advised to get a CT angiography (Fig. 8). The sensitivity and specificity of CT angiography in peripheral vascular injuries has been reported to be as high as 100% [45]. CT angiography helps to delineate the vascular anatomy and provides a road map for exploration. At the same time, in patients with soft signs, i.e. who do not have an upfront indication for exploration, screening by duplex imaging can be done [46]. The reported sensitivity of duplex imaging in identifying vascular injuries is 95% while specificity for excluding vascular injury is 99% [4]. Having said that, it is important to understand that it is operator dependent, time consuming and an open injury may preclude proper assessment, in which case CT angiography is needed. Vascular injuries identified on CT angiography are (a) thrombus, (b) dissection, (c) pseudoaneurysm, (d) transection, (e) active bleeding and (f) arterio-venous fistula. In equivocal cases, catheter angiography needs to be done [47]. The indications for CT angiography depend on soft and hard signs of vascular injuries which are enumerated in Fig. 8.

Other Imaging Modalities

Retrograde Urethrography

It is indicated in cases of suspicious urethral injury. Blood at urethral meatus, inability to void with palpable bladder and perineal hematoma are suggestive of urethral injury. RGU is performed by placing a Foley catheter just at the meatus with inflating a balloon by 2–3 ml of saline. About 25–30 ml of contrast is then injected through Foley and images are taken. Contrast extravasation with filling of bladder suggests partial rupture, while complete rupture is suggested by extravasation of all the contrast without any contrast reaching the bladder [48].

X-Rays for Bony Injuries

It is indicated in cases of obvious extremity deformity, palpable crepitus, pain and swelling. Minimum two X-rays are required in different planes for accurate assessment of injuries. Apart from that, at few sites, different views of X-rays are required which should be done in consultation with the orthopaedic surgeon.

X-Ray Skull and Abdomen

These X-rays are usually not required in acute trauma setting. X-ray skull has been replaced by NCCT head as X-rays does not provide information about brain parenchymal injury. It is now recommended in cases of foreign body impaction at a centre where NCCT facilities are not available. The role of X-ray abdomen has decreased because they do not provide information about solid organ injuries. Moreover, they cannot detect mesenteric injuries. Also, there are frequent instances when there is a bowel injury but no pneumoperitoneum is present even on CT. In such cases, bowel injury is indicated by subtle signs which are clearly evident only on CT and not on X-ray abdomen. Moreover, since a polytrauma patient lies supine till his spine injury is ruled out, obtaining an erect abdominal film may be difficult. However, in centres where CT facility is not available, a combination of clinical examination, USG and X-ray can help the surgeon to identify majority of the immediately life-threatening injuries in a polytrauma patient.

MRI

In acute trauma setting, MRI is usually not required. It is mainly required in identifying pancreatic ductal injuries in equivocal cases of pancreatic injury with pancreatic duct identification rate up to 97% [49, 50]. Other than it, it is required in spine injuries for preoperative planning and in cases of spinal cord injury without radiographic abnormalities (SCIWORA) [51].

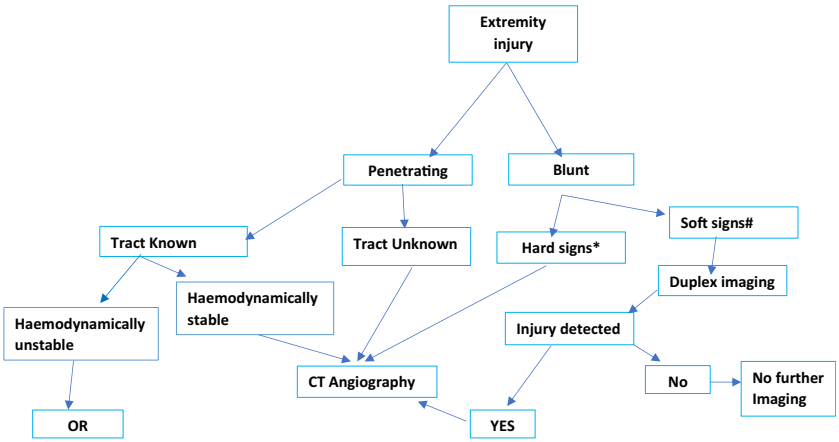

Fig. 8 Algorithm for imaging in peripheral vascular injuries

#Soft Signs [45]): Proximity of injury to vascular structures, Major single nerve deficit (e.g. sciatic, femoral, median, ulna or radial), Non-expanding hematoma, Reduced pulse, Posterior knee or anterior elbow dislocation, Hypotension or moderate blood loss at the scene

***Hard signs:** Absent pulses, Bruit or thrill, Active or pulsatile hemorrhage, Signs of limb ischemia/ compartment syndrome (6 Ps), Pulsatile or expanding hematoma

Role of Interventional Radiology in Trauma

IR has become an integral part in trauma management. It supplements non-operative management in trauma and is also helpful in managing injuries of difficult to access areas like thoracic aorta. However, they are not a substitute to surgical exploration if the clinical condition of the patient demands it.

Its uses in trauma settings are divided as follows.

During Primary Survey

Resuscitative endovascular balloon occlusion of aorta (REBOA) is a novel technique in management of patients in shock and is an alternative to resuscitative thoracotomy. In this technique, a special catheter is placed inside aorta under fluoroscopic guidance as per the site of bleeding. It is a temporary time-buying measure for achieving definitive bleeding control. However, it is associated with a number of complications. Hence, judicious use is recommended [52].

Hybrid OR

An upcoming concept in management of trauma patients in which interventional radiology and operation room are combined in the same place which allows single stage endovascular management and open procedure [53].

During Secondary/Tertiary Survey

In cases of high grade splenic or liver injuries, they are useful for prophylactic or therapeutic angioembolisation. Thus, it plays a key role in non-operative management of these high-grade injuries. It is also utilised to angioembolise other actively bleeding sites when and where required. It is being utilised extensively for other endovascular procedures in the form of stenting or thrombolysis. Further, it is helpful in guiding percutaneous interventions in the form of image guided drainage of collections or abscesses.

Damage Control IR

Recently, the use of IR has been extended to haemodyanmically unstable patients for control of bleeding. It is important in cases where the bleeding vessel may be difficult to access surgically [54]. However, the decision for damage control IR should be taken in a centre where technical expertise is available and that the IR procedure does not become too much time consuming. Furthermore, it is important that the resuscitation of the patient is continued throughout the procedure and an OR facility should be at standby in case the procedure fails.

Conclusion

Radiology plays a major role in trauma management and at times it is a lifesaving tool especially in vascular and solid

organ injuries. However, it should be used judiciously to your advantage during both primary survey and secondary survey. Treatment decision should not be based on the radiological findings alone. Clinico-radiological findings should dictate the management of a trauma patient.

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Compliance with Ethical Standards

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