International Imaging Course 07

Abstracts

Department of Diagnostic Radiology and Organ Imaging

The Chinese University of Hong Kong

Total Body Trauma Scanning with 64-Slice Scanner

By Robert A. Novelline, MD
Professor of Radiology, Harvard Medical School
Director of Emergency Radiology, Massachusetts General Hospital

In the USA trauma is the leading cause of death of for those under 40 years and the fourth cause of death for all ages. Last year there were over 39 million trauma related visits to USA emergency departments. Imaging examinations in multiple trauma patients should be fast, highly accurate, require minimum patient cooperation, enable careful patient monitoring and observation, provide a maximum of information in a single examination, use techniques that minimize radiation exposure, that are cost-effective, and that use imaging technologies which can be installed, readily available and convenient to emergency departments. All these features are currently possible with MDCT and improved with 64-slice scanners.

The specific features of the GE VCT 64-slice scanner for trauma imaging at our emergency center include 64 channels, 40mm of patient coverage per rotation gathering 64 slices at 0.625mm per rotation, a gantry speed of <375msec with approximately 2.5 to 3.0 rotations per second, direct multiplanar reformations constructed from 0.625mm slices, dose reduction with SmartmA or AutomA, cardiac gating, and an improved workstation for rapid post-processing. A longer table permits true total body single acquisition scanning. Trauma patients benefit from permit greater anatomical coverage per rotation, faster speed to decrease motion artifact, rapid total body single acquisition trauma scans and total body CTAs from the vertex through the lower extremities, a decrease in the volume of required IV contrast material, high resolution images, rapid multiplanar reformations and cardiac gating to decrease aortic and cardiac motion. High speed scanning is especially valuable in severely injures patients when time is critical.

In the multiple trauma patient routine coronal reformations are obtained on head CT scans and both routine coronal and sagittal reformations on face, cervical spine, chest, abdomen, pelvis and extremity CT scans. Curved plane, MIP, 3D and CTA reformations are obtained when indicated by clinical presentation or findings on the axial slices. The 0.625 axial slices are not sent to PACS but rather the viewing slices (2.5mm for head, 1.25mm for face, 2.5mm for cervical spine and 2.5mm or 5.0mm for chest, abdomen and pelvis, 1.25 slices of extremity joints and 2.5cm of extremity long bones). Multiplanar reformations of the chest and abdomen have eliminated the need for thoraco-lumbar spine clearance films after CT and have been extremely useful in providing better display of sternal and pelvic fractures, as well as soft tissue injuries of the parenchymal organs, diaphragm, bowel, mesentery and urinary bladder. CTA's have provided superb displays of injuries of the aorta, brachiocephalic arteries and other vascular structures. One of the current post-processing challenges in trauma imaging is providing high quality multiplanar, 3D and CTA reformations 24 hours a day, seven days a week

MDCT has positively affected the outcome of multiple trauma patients. By diagnosing injuries quickly and accurately, MDCT, now advanced with 64-slice scanning, can decrease patient morbidity and mortality, decrease non-therapeutic surgery, prevent unnecessary hospital admissions and decrease the costs of trauma evaluation.

Emergency musculoskeletal ultrasound

J F Griffith, Chinese University of Hong Kong

Urgent ultrasound of the musculoskeletal system can help with decision making and patient management in several clinical settings. These include:
Detection of foreign bodies
Assessment of soft tissue infection
Assessment of joint infection
Detection of occult fractures.
These entities will be discussed briefly.

Most non-vegetative foreign bodies are readily detected by ultrasound in the acute setting. This even applies to those foreign bodies which may not be visible radiographically such as certain types of glass or fish bone. Ultrasound allows one to determine the presence, and location of any foreign body as well as the degree of fragmentation. The sensitivity is such ultrasound it can be reliably used to exclude a foreign body in those patients with infection following penetrating injury though no retained foreign body. Vegetative foreign bodies such as bamboo or wood splints may occasionally be very difficult to detect on initial ultrasound examination. It is very important particularly in these situations to confer this information to the clinician and arrange a repeat ultrasound in 3-4 days if the initial ultrasound is negative and symptoms/ signs do not settle as expected. Once identified, foreign bodies may be removed under ultrasound guidance.

The value of ultrasound in the presence of clinically apparent acute soft tissue infection is to determine which tissues are infected and the form of this infection.

Is infection confined to the subcutaneous tissues, or does it involve tissues deep to the investing fascia? Are the tendon sheaths infected? Is this cellulitis alone or is there a phlegmon (pre-abscess) or abscess present? Is there necrotizing fascitis present? All of these questions, which can be difficult to answer clinically in the short term, can be readily assessed by urgent ultrasound examination.

Acute joint infection or septic arthritis is a diagnosis which should not be delayed. Bacterial infection within a joint can rapidly lead to an inflammatory cascade that erodes subchondral bone and articular cartilage. Delay in diagnosis allows infection to become entrenched and less readily eradicated. Ultrasound is helpful in several ways.

First, a negative ultrasound showing no joint effusion effectively excludes joint infection. Second, if an effusion is present, ultrasound-guided aspiration will allow confirmation and typing of infection enabling the use of appropriate antibiotic therapy. Likewise, therapy can be withheld in non-infective inflamed joints with no microbiological evidence of infection (inflammatory arthropathy, transient synovitis, crystal arthroapathy). Even prior to aspiration, ultrasound can show disease features indicative of a non-infectious etiology though of course more than one disease entity may occasionally co-exist.

Finally ultrasound is helpful in the detection of some radiographically occult fractures.

MDCT OF ABDOMINAL TRAUMA

By Robert A. Novelline, M.D.

Professor of Radiology, Harvard Medical School

Director of Emergency Radiology, Massachusetts General Hospital

CT has made a significant impact on the diagnostic workup of patients who have suffered abdominal trauma. In a quickly performed single examination, CT can identify the presence of hemoperitoneum, as well as injuries of the liver, spleen, kidneys, pancreas, bowel, mesentery, abdominal wall and retroperitoneum. With CT, a significant percentage of abdominal trauma patients may be spared unnecessary diagnostic laparotomy and those patients requiring emergency surgery may more quickly be identified, and the extent of their injuries more accurately assessed. When abdominal trauma patients are treated conservatively, follow-up CT can document healing or identify complications. CT is indicated when abdominal injuries are suspected after blunt trauma, especially when the clinical findings support a diagnosis of intra-abdominal bleeding. In addition CT in indicated in penetrating trauma to differentiate those patients with peritoneal penetration requiring surgical exploration from those with superficial injuries that can be treated conservatively. CT can also be helpful in pinpointing the location and extent of penetrating injuries.

The following CT protocols are recommended. In the past both oral and intravenous contrast were routinely used. Today with the higher resolution images of MDCT, oral contrast may not be needed routinely, but is most helpful in cases of suspected bowel injury. A solution of 1/4 oz Gastrograffin in 10 oz of water, or other suitable liquid, is suggested. Two to three 10 oz. cups should be given orally or by injection down the nasogastric tube. The CT scan should not be delayed for the passage of oral contrast material, but should be performed as expediently as possible after oral contrast administration. For IV contrast material, 75 to 125cc of 370 concentration contrast material are injected at 3.5cc/second. Abdominal scanning is begun at 70 seconds and a delayed scan at 3 minutes is performed in patients with a parenchymal organ or other injury to search for delayed signs of active bleeding. Rectal contrast material (500 to 1000cc of 40cc 60% contrast material in 1000cc saline) should be administered in patients with penetrating injuries to opacify the large bowel.

The Foley bladder catheter should be clamped prior to scanning so the bladder will be better filled and bladder rupture may be identified. If the bladder is not shown to be filled on the initial CT scan of patients with a high likelihood of bladder rupture, due to the presence of gross hematuria or anterior pelvic fractures, then a repeat CT of the pelvis should be performed after unclamping the Foley catheter, draining the bladder and then instilling 300cc of bladder contrast material (40cc 60% contrast in 1000cc saline) into the Foley catheter.

Acquisitions should be obtained with the thinnest detector configuration (1.25mm for 4- and 16-slice scanners; 0.625mm for 64-slice scanners) The thin slices are used to produced high quality coronal, sagittal and volumetric reformations; thicker axial slices (2.5 or 5.0mm) are sent to PACS for interpretation. Routine coronal and sagittal reformations are performed on all abdominal trauma CT scans. CTA's of vascular injuries and volumetric reformations of spine and pelvic fractures may also be indicated. All axial slices and multiplanar images should be viewed at soft tissue, bone and lung windows.

CT can accurately identify and estimate the volume of intra-abdominal hemorrhage. Hemoperitoneum is usually seen in the subphrenic spaces, in Morrison's pouch between the liver and right kidney, in the paracolic gutters or in the pelvis. When free peritoneal fluid is identified at CT in a trauma patient, an

ROI should be obtained to verify that the fluid is actually blood (above 25 to 35 HU) and not water dense fluid (1-10 HU). In a trauma patient, water dense peritoneal fluid may represent urine from a ruptured bladder, bile from a ruptured gallbladder, intestinal contents from a ruptured segment of bowel or ascites. When blood is present, then the densest blood will be seen adjacent to the injury; this is called the *sentinel clot sign*, representing the denser blood clot adjacent to an injury that is attempting local hemostasis. If very bright blood is seen (measuring above 100 Hounds field units) then this represents blood mixed with the intravenously injected contrast materiel indicating active bleeding.

The most commonly injured organ with blunt abdominal trauma is the spleen. Subcapsular hematomas of the spleen appear as crescentic fluid collections immediately beneath the capsule, effacing the lateral or medial margins of the splenic parenchyma. They are often associated with lacerations of the spleen. Hematomas within splenic injuries appear as mottled, irregular regions of lower density than the contrast-enhanced adjacent splenic tissue.

Many splenic injuries are treated conservatively although intervention is usually indicated for active bleeding; age over 65 years, shattered spleen, splenic infarction or continued blood and fluid requirements.

Liver lacerations and hematomas are not only important to diagnose, but an estimation of the extent of injury is valuable in treatment planning. Lacerations of the liver may appear as linear or branching areas of decreased CT density. As with splenic injury, a subcapsular liver hematoma will appear as a crescentic fluid collection immediately beneath the liver capsule and there usually result from penetrating injuries including liver biopsy. Minor liver injuries, intraparenchymal lacerations with little or no hemoperitoneum, can usually be managed nonoperatively. Patients with severe liver injuries and active bleeding can often be treated with hepatic artery embolization as an alternative to surgery.

In patients with pancreatic trauma CT may demonstrate pancreatic hematomas, lacerations or fractures. Complete fractures usually require surgery with distal pancreatectomy. When lacerations are identified it is important to determine whether the pancreatic duct is patent or not and therefore the patient is often examined by ERCP or MRCP. If the duct is patent then the patient can usually be treated conservatively; if the duct is lacerated or interrupted than the patient will usually need a distal pancreatectomy.

With bowel injuries, CT may show signs of either bowel injury or bowel perforation. The signs of bowel injury include bowel wall thickening, bowel wall hyperemia, and free fluid in the peritoneal cavity. The signs of bowel rupture include intraperitoneal free air, extravasation of oral or rectal contrast material and an interruption in the bowel wall. Surgery is indicated when signs of rupture are present.

CT has proven helpful in the management of suspected renal trauma showing signs of renal contusion, renal laceration, renal fracture, subcapsular hematoma and urinoma with renal pelvis or ureteral injury. Extravasation of contrast enhanced urine from renal and ureteral lacerations, may be readily identified on CT but require a delayed scan for demonstration.

In reviewing abdominal trauma CT scans all images should be scrutinized for signs of lumbar spine and pelvic injuries as well as injuries of vascular structures and injuries of the abdominal wall. Multiplanar reformations are especially helpful for identification of spine and pelvic fractures. CTA’s and volumetric reformations may be especially useful for display when these injuries are present.

Emergency Musculoskeletal MRI

Gregory E Antonio, James F Griffith

Department of Diagnostic Radiology and Organ Imaging,

The Chinese University of Hong Kong

Abstract

With the increasing availability of MRI, its use for patients from the emergency room has seen a corresponding increase. This presentation will discuss the imaging findings of the diseases which would benefit from an urgent or semi-urgent MR scan.

For this presentation, musculoskeletal conditions will be classified as follows:

A. Axial skeleton:
- a. Fracture
  - i. Traumatic
  - ii. Pathological
- b. Mass
  - i. Infection
  - ii. Neoplasm

B. Appendicular skeleton:
- a. Fracture
  - i. Occult osseous
  - ii. Occult chondral
  - iii. Avascular complications
- b. Inflammation
  - i. Arthritides

ii. Osteitis
iii. Soft tissue inflammation

c. Soft tissue injury

i. Tendon
ii. Ligaments

The limitations, contra-indications and precautions with MRI in the emergency situation will also be discussed.

MDCT of Thoracic Trauma

Robert A. Novelline, MD

Professor of Radiology, Harvard Medical School

Director of Emergency Radiology, Massachusetts General Hospital

Introduction

Trauma is the third leading case of death in the USA and the leading cause of death for those under 40 years of age. And, approximately 25% of trauma deaths result from thoracic injuries. In the USA each year, more than 300,000 patients are hospitalized and more than 25,000 die as a consequence of chest trauma. Blunt trauma accounts for 90% of chest trauma and the most common cases of blunt trauma are motor vehicle collisions and falls.

The imaging workup of patients with suspected thoracic injuries usually begins with a supine, portable chest film taken on arrival to the emergency center. Many obvious thoracic injuries such as displaced rib fractures, as well as, large pneumothoraces and hemothoraces can be quickly detected with this exam. Also, the chest film may confirm proper positioning of an endotracheal tube or nasogastric tube. Other conditions such as small pneumothoraces, small hemothoraces, lung laceration, aortic trauma, tracheobronchial injury, cardiac injury, diaphragm rupture and thoracic spine injuries require further imaging with CT. Today multidetector CT (MDCT) scanners can quickly and accurately diagnosis and display with axial, multiplanar and volumetric images a wide variety of thoracic injuries. In the multiple trauma patient, chest CT can be included as part of a *single acquisition total body trauma scan* which also includes the patient's head, face, cervical spine, chest, abdomen and pelvis, and when indicated clinically, the scan can be continued downward to include the entire lower extremities

MDCT Protocol for Suspected Thoracic Injury

Chest CT scans for suspected thoracic trauma should be performed with intravenous contrast material in order to demonstrate any sites of active bleeding and to opacify the heart, aorta and thoracic blood vessels. Optimum vascular opacification may be obtained with an injection of 75 to 125cc of 370mg concentration at 3.0cc per second, beginning scanning after a 30 second delay. Scans should be acquired at thin detector configurations so that high quality multiplanar and volumetric reformations can produced from the thin axial images. Routine coronal and sagittal reformations of the chest are recommended on all chest trauma patients, and optional volumetric (3D), MIP (maximal intensity projection) and curved plane reformations are recommended in positive cases to better show trauma pathology. A detector configuration of 4x1.25mm would be recommended for 4-slice scanners and a detector configuration of 16x1.25mm for 16-slice scanners. 64-slice scanners would acquire axial slices having less than 1mm (sub-mm) thickness. These thin slices would be utilized to produce high quality routine coronal and sagittal reformations on the CT scanner, and in positive cases, they would be transmitted directly to a workstation for any indicated optional volumetric or other post-processing, such as 3D reformations of fractures and dislocations or CT arteriograms (CTA's) of vascular injuries. The thin slices would also be reformatted to 2.5 or 5.0mm viewing axial slices and transmitted to PACS along with the coronal and sagittal reformations for formal examination interpretation. All axial and multiplanar images should be reviewed on soft tissue, lung and bone windows.

Injures of the Thoracic Skeleton

Skeletal injuries of thorax may be apparent on the plain film examination, but nearly all are better-shown and more accurately diagnosed by CT. Upper rib fractures occur with severe chest trauma and may be associated with injuries of the aorta, great vessels and brachial plexus. Lower rib fractures may be associated with injuries of the liver, spleen and kidneys. Multiple fractures of the same rib involving three or more adjacent ribs may produce a flail segment of the chest wall with paradoxical motion during respiration, resulting in a 'flail chest", with ventilatory compromise. Other common injuries of the thoracic skeleton include scapular fractures, sternal fractures, sternoclavicular dislocation and thoracic spine injuries. Serious morbidity and even death have been associated with posterior dislocation of the clavicle at the sternoclavicular joint as the displaced clavicle head may impinge on, or injure the trachea, esophagus, great vessels or major nerves in the superior mediastinum. Sternoclavicular dislocation is well shown by CT. Sternal fractures are usually not seen on the AP portable chest film but are nearly all visible at CT, especially on sagittal reformations. CT will also show any associated retrosternal hematomas. Sternal fractures, however, be shown on the lateral chest film. Sternal fractures have a high association with both aortic and cardiac injuries.

Fractures of the thoracic spine account for 15-30% of all spine fractures. The most vulnerable segment of the thoracic spine is at the thoracoabdominal junction from T9 to T12. About 70% of thoracic spine fractures are visible on plain films but CT will show nearly all. With the superior spatial resolution of multidetector CT technology the axial, coronal and saggital thoracic spine reformations obtained from the chest trauma CT imaging protocol will show more fractures than AP and lateral thoracic spine plain films.

Pleural Manifestations of Trauma

Non-penetrating trauma may be associated with hemothorax and pneumothorax. Blood can flow into the pleural space from injuries of the chest wall, diaphragm, lung and mediastinal structures. CT can confirm a hemothorax when a pleural fluid collection in a trauma patient measures over 35-40HU. Air can enter the pleural space as a result of a lung injury, tracheobronchial injury or esophageal rupture. A pneumothorax may be seen in about 15 to 40% of patients with acute chest trauma. Many small and even moderate-sized pneumothoraces that are not visible on the supine chest film can be easily identified at CT. A pneumothorax seen at CT which cannot be identified on a supine chest film is referred to as an "occult" pneumothorax. A persistent pneumothorax after chest tube suction suggests either a malfunctioning chest tube or bronchial injury. A tension pneumothorax is an emergency condition resulting from a lung or airway injury associated with a one-way accumulation of air within the pleural space. As intrapleural pressure rises the mediastinal structures are compressed, decreasing venous return to the heart leading to hemodynamic instability. Radiography and CT will show mediastinal shift to the contralateral hemithorax, hyperexpansion of the ipsilateral thorax and depression of the ipsilateral hemidiaphragm.

Pulmonary Contusion

Pulmonary contusion represents traumatic extravasation of blood and edema fluid into the interstitium and air spaces of the lung as a result of small vessel trauma without significant parenchymal disruption. The injury is caused by energy transmitted directly to the lung from a blow to the overlying chest wall. On radiographs, contusion will appear as patchy areas of consolidation, which if extensive may show diffuse homogenous lung consolidation. Contusion may be absent on the initial chest film but is usually evident within 6 hours of injury, and resolves rapidly, within 3 to 10 days. CT will show non-segmental areas of consolidation often directly beneath the site of injury, and often sparing 1 to 2mm of the subpleural lung parenchyma. The opacities may be single or multiple, and both coup and contra-coup contusions may be identified. Contusion is often seen surrounding pulmonary lacerations

Pulmonary Laceration

Pulmonary lacerations are tears of the lung parenchyma, which fill with air, blood or both. When filled with air these injuries are called traumatic pneumatoceles, and when filled with blood they referred to as traumatic hematoceles or lung hematomas. If both air and fluid are present, an air-fluid level may be identified. On chest films lacerations may initially be obscured by surrounding lung contusion, but become revealed when the contusion clears, a few hours or days after the injury; however acute lung lacerations are nearly always detected by CT. Four types have been described with blunt trauma: compression rupture, compression shear, rib penetration injury and adhesion tears. They may also result from penetrating trauma, most frequently from stab wounds and gunshot wounds. Pulmonary lacerations are better shown and more extensively evaluated with CT than with plain films. Unlike pulmonary contusion, lung lacerations may take weeks or months to heal and may result in residual lung scarring

Tracheobroncheal Injury

Tracheobronchial injuries are uncommon and more than 80% occur within 2cm of the carina. There is an equal frequency of rupture of the left and right mainstem bronchi. The most common findings on chest films are pneumomediastinum and subcutaneous emphysema; leakage of air through the rupture flows into the surrounding mediastinal soft tissues with subsequent dissection up into the neck. Large amounts of pneumomedistatium are easy to identify on plain films, however small amounts may not be visible on the initial portable chest film. The majority of cases will have an associated pneumothorax. The clinical observation characteristic of this condition is a pneumothorax that does not resolve with chest tube suction due to continued leakage of air through the rupture. However resolution of a pneumothorax after chest tube placement does not exclude the diagnosis. Another pathognomonic finding is that of a "fallen lung", which occurs when there is complete disruption of a main-stem bronchus. On the supine chest film the lung falls laterally and posteriorly and in the upright position the lung falls inferiorly. This appearance contrasts with the usual situation in which a lung collapses toward the pulmonary hilus.

Other sign of tracheobronchial injury include a sharply angulated bronchus, bronchial discontinuity, or bronchial "cut-off". Abnormalities of an endotracheal tube balloon may also be noted with tracheal injury. The balloon may appear over inflated or more spherical as the balloon actually herniates through a vertical laceration of the trachea. All of these findings are better depicted at CT, which can show the actual tracheobronchial injury. In addition, CT will show more subtle secondary signs such as smaller amounts of pneumomediastinum than the chest film.

Esophageal Rupture

Esophageal injury is rare with blunt trauma and is far more common with penetrating trauma or iatrogenic trauma. Blunt trauma may involve the upper thoracic esophagus or the lower esophagus just above the gastroesophageal junction. Plain films of the chest may show pneumomediastinum and subcutaneous emphysema. CT may show focal air collections at the site of the tear or may show an esophageal wall hematoma. As lower injuries may rupture into the left pleural space one may also see a left pneumothorax, a left pleural fluid collection or left lower lobe atelectasis. The diagnosis is usually confirmed by the demonstration of oral contrast material extravasation at the site of injury.

Aortic and Great Vessel Injuries

Approximately 8,000 cases of thoracic aortic injury occur in the United States each year and traumatic aortic rupture is responsible for 15% to 20% of all fatalities associated with motor vehicle accidents. Approximately 90% of patients with traumatic aortic rupture die before emergency treatment can be instituted. Most aortic injuries involve the junction of the posterior aortic arch and descending aorta, just distal to the origin of the left subclavian artery. The proposed mechanism of injury is rapid deceleration, resulting in differential forces on the proximal descending aorta between fixed and more mobile segments.

A normal chest radiograph has a high negative predictive value (98%) but a low positive predictive value for aortic injury. The chest film findings suggestive of aortic injury include mediastinal widening greater than 8cm, loss of the normal aortic arch, a left apical pleural cap, displacement of the nasogastric tube to the right, widened paraspinal lines and loss of the descending aortic line. Most of the plain film findings of aortic injury are non-specific. The gold standard for the diagnosis of aortic injury has been aortography, however at most trauma centers today aortography has been replaced with MDCT.

The sensitivity of CT has been reported to be 92%-100% and specificity 62% to 100% for the detection of aortic injury. The CT findings include both indirect signs, such as mediastinal hematoma surrounding the posterior aortic arch and proximal descending aorta, as well as the direct signs of intimal tear/flap, aortic contour abnormality, thrombus protruding into the aortic lumen, false aneurysm formation, pseudocoarctation and extravasation of intravenous contrast material. If only direct signs are utilized, the sensitive and negative predictive value remains at 100% but the specificity increases to 96%. The accuracy of aortic trauma detection with CT has been improving in parallel with technologic improvements in CT scanning. Current fast scanners decrease motion artifact and provide higher quality two and three-dimensional reformations for diagnosis and surgical planning. Also, current generation scanners can also scan the chest with cardiac gating during diastole to eliminate aortic pulsatile motion artifact that may be confused with an acute aortic injury. Today patients with no direct evidence of aortic injury at CT and no mediastinal hematoma around the expected site of injury do not require further imaging workup to rule out aortic trauma.

Cardiac Injuries

Cardiac and pericardial injuries are uncommon with blunt thoracic trauma but due occur with severe blows to the anterior chest. They include cardiac contusion, cardiac rupture, pneumopericardium, hemopericardium, cardiac tamponade, and cardiac valve injury. Hemopericardium from a cardiac injury or cardiac rupture can quickly produce cardiac tamponade with hemodynamic compromise. Cardiomegaly will be shown on the plain chest film; CT or cardiac ultrasound can confirm hemopericardium.

Diaphragmatic Injury

Diaphragmatic rupture is seen in about 5% of patients undergoing laparotomy or thoracotomy for trauma. The postulated mechanism is a sudden increase in either intrathoracic or intra-abdominal pressure against a fixed diaphragm. Left-sided injuries are more common having a reported left-to-right ratio of 3:1, with 4.5% having bilateral rupture.

The chest film may show a hemothorax, a pneumothorax, loss of the visualized hemidiaphragm, apparent elevation of the hemidiaphragm, visualization of herniated abdominal organs into the thorax and cephalad extension of a nasogastric tube into the thorax. Today, MDCT axial scans combined with high quality coronal and sagittal reformations can show both large and small ruptures of the diaphragm, in addition to showing any abdominal organs herniated across the rupture.

MDCT of Spine Trauma

Robert A. Novelline, MD

Professor of Radiology, Harvard Medical School

Director of Emergency Radiology, Massachusetts General Hospital

Because of the possibility of spinal cord paralysis, spine fractures are dreaded injuries in trauma patients. And, spine trauma is a common traumatic condition. Each year in the USA there are approximately 10,000 cervical spine fractures and 4000 thoracolumbar spine fractures diagnosed. Approximately 20% of trauma deaths are associated with spine trauma. However the majority of patients with spine fracture, including those with spinal cord damage, survive their injuries. Almost one out of 1000 USA residents are currently being cared for partial or complete spinal paralysis. Consequently the evaluation for suspected spine fracture is top priority consideration in multiple trauma patients. The consequences of a missed or untreated spine fracture are so devastating that an extremely high index of suspicion is required. In multiple trauma patients the existence of a spine fracture should be assumed to be present until such an injury is ruled out. Fortunately, today we have the benefit of MDCT which can quickly and accurately identify spine fractures and evaluate their extent in exquisite detail on axial and multiplanar images. In addition, volumetric reformations can provide outstanding and informative displays of complex injuries such as fracture-dislocations.

In most trauma centers today, suspected cervical spine trauma is imaged with MDCT rather than cervical spine radiographs. CT is faster and more accurate than radiography, requires less patient positioning and provides a superior display of injuries. Also CT has cost benefits. Because it is faster and requires less manpower, at our medical center, it is actually less costly to perform a cervical spine CT scan (6 second scan) than cervical spine radiography (average case takes 25 to 30 minutes); on and off the table time would be the same for both exams. Our MDCT protocol is to scan non-contrast with the thinnest detector configuration (1.25mm for 4- and 16-slice scanners; 0625mm for 64-slice scanners). Axial images in bone and soft tissue algorithms are sent to PACS at 2.5mm viewing slices. Routine coronal and sagittal reformations are obtained on every case. Volumetric reformations are performed for displaced fractures, dislocations and subluxations. In patients with a demonstrated fracture, a repeat cervical spine and head CT are performed with IV contrast material to produce a cerebrovascular CTA in search of possible associated vascular injury.

In patients with clinically apparent cerebral ischemia associated with trauma, the initial cervical spine CT could be performed with IV contrast to evaluate both the bones and vascular structures in a single MDCT examination.

Thoracolumbar spine trauma is usually suspected in patients with multiple trauma in whom there are concerns for both thoracic and abdominal injuries. It is most fortunate today to be able to post-process MDCT trauma scans of the chest and abdomen into outstanding axial, coronal and sagittal images of the thoracolumbar spine. Several investigations have shown that reformatted spine images of chest-abdomen MDCT scans can demonstrate nearly 100% of thoracolumbar spine fractures, as compared with thoracolumbar spine radiographs which show only 50 to 70% of fractures. MDCT images better display the extent and configuration of thoracolumbar spine fractures including the presence of fragments in the spinal canal with burst fractures. Volumetric displays can provide outstanding displays of complex fractures and fracture-dislocations.

Global Anatomy of the Extracranial H & N

Professor Ric H. Harnsberger

Understanding the complex anatomy of the soft tissue of the extracranial head & neck is the key to meaningful reporting of diseases that affect this area. On a global level, the neck can be divided into suprahyoid, infrahyoid and oral cavity components. Three layers of deep cervical fascia cleave the area into “spaces” that can be named. In the axial plane the soft tissues can be completely viewed by its spatial subunits.

Many of the spaces of the suprahyoid neck travel into the infrahyoid neck including the pharyngeal mucosal, carotid, retropharyngeal, perivertebral and posterior cervical spaces. The parapharyngeal, masticator and parotid spaces are the only spaces confined to the suprahyoid neck while the visceral space is the only space confined to the infrahyoid neck.

The oral cavity is made up of the oral mucosal, sublingual and submandibular spaces. Only the submandibular space is a true fascia-lined space. The sublingual and submandibular spaces communicate at the posterior margin of the mylohyoid muscle. The parapharyngeal space empties inferiorly into this same area.

When the radiologist possesses spatial knowledge of the extracranial head and neck, they may assign a lesion to a specific space, and then compare it against a space-specific differential diagnosis list. In the radiologic report the precise anatomic context and short differential diagnosis list can be offered to referring clinician.

Thyroid Cancer Imaging

Ann D King

The four most common thyroid cancers, papillary (PC), follicular (FC), medullary (MC), and anaplastic (AC) carcinoma, will be discussed with the emphasis on PC which accounts for up to 80% of thyroid cancers. Papillary carcinoma usually takes an indolent course but there are a small number of patients in whom it takes a more aggressive course. As a result there has been controversy in management and staging of thyroid cancer.

Imaging for staging and management of thyroid cancer will be discussed in relationship to the primary cancer, nodal metastases and distant metastases.

Primary Tumour: Ultrasound displays features that are highly suggestive of cancer, particularly for PC where punctate calcification is frequent. Ultrasound and ultrasound guided fine needle aspiration cytology (FNAC) are used to detect cancer and ultrasound is used to stage cancer confined to the gland (stage T1 and T2). Multifocal disease is common but deposits may be very small and difficult to characterize. Extrathyroidal tumour spread (stage T3 and T4) requires further imaging, usually by MRI which avoids CT iodinated contrast agents that may interfere with subsequent use of ^{131}iodine. Imaging is used to alert the surgeon to invasion into structures such as the trachea and oesophagus which require major reconstructive surgery (T4a), as well as to identify inoperable disease (T4b). *Nodal metastases:* staged by ultrasound (± FNAC). Nodes from PC are frequently small and therefore abnormalities of internal architecture are even more important. In addition to the usual internal abnormalities associated with malignant nodes, those from PC may be hyperechoic and show calcification and cysts. Nodal metastases usually spread to the central compartment (N1a) and lateral compartment (N1b) of the neck. Identification of nodal metastases guides the extent of neck dissection especially for nodes in the paratracheal region inferior to the thyroid, and in the lateral compartment of the neck. Superior mediastinal nodes (N1b) require further imaging with MRI/CT but the indications for scanning this region are not well established. *Distant metastases:* The most common sites for distant metastases are the lung and bone. *C*hest radiograph and post operative ^{131}I whole body scan are employed in most patients with PC and FC. CT thorax and^{18} F -FDG PET are finding a role for staging metastases in patients with iodine-negative tumours (less well differentiated FC and PC with persistently raised serum thyroglobulin levels and a negative ^{131}I whole body scan, and patients with MC and AC). ^{111}In-DTPA-octreotide and $^{131/123}$I-MIBG are used in some centers to stage MC. The use of other modalities is dependant on specific clinical indications.

The role of imaging for planning post-operative radiation treatment (including IMRT) will be discussed.

Yearly Ultrasound of the neck is advocated for surveillance of patients with no clinical or biochemical evidence of recurrent differentiated carcinoma.

The Normal T-Bone: EAC to IAC

H. Ric Harnsberger M.D.

The normal T-bone discussion is best organized into embryology, external auditory canal (EAC), middle ear, facial nerve, petrous apex and inner ear segments. The embryological subunits of the T-bone include the EAC (1^{st} branchial cleft), middle ear (1^{st} pharyngeal pouch), ossicles (1^{st} & 2^{nd} branchial arches), membranous labyrinth (otocyst) and the IAC. The phases of inner ear embryology are made up of the endolymphatic (otic) phase between 3-8 weeks where the membranous labyrinth forms and the perilymphatic (periotic) phase between 6 and 9 weeks where the fluid, cartilage and osseous capsule form.

The EAC is made up of fibrocartilage laterally, bone medially with the tympanic membrane comprising its medial border. The tympanic membrane attaches to the scutum superiorly and the tympanic annulus inferiorly. The EAC and adjacent skin lymphatic drainage is into the parotid nodal group.

The middle ear has many critical features including the 3 ossicles (malleus, incus, & stapes), tympanic and mastoid portions of CN7, facial nerve recess, pyramidal eminence and sinus tympani. Middle ear subdivisions include the epitympanum (tegmen tympani to scutum), mesotympanum (scutum to tympanic annulus) and hypotympanum (tympanic annulus to floor of middle ear cavity). The epitympanum contains the malleus head, body & short process of incus and Prussak space. The mesotympanum contains the manubrium of the malleus, long process of incus, stapes and the tensor tympani and stapedius muscles. The hypotympanum contains no vital structures. The medial wall of the middle ear cavity is made up of the cochlear promontory, lateral semicircular canal, tympanic segment CN7, oval window and round window.

A complete understanding of the facial nerve anatomy, branches and functions is critical to anyone doing T-bone imaging. CN7 is best thought of in segments including the CPA, IAC, labyrinthine, geniculate ganglion, tympanic, mastoid and extracranial (parotid) segments. Whenever a CT or MR case of the temporal bone is under review, the facial nerve must be inspected and declared normal or abnormal.

Because the petrous apex may be both pneumatized or marrow filled, air space diseases and marrow space diseases may be found here. The petrous apex is located between lateral clivus & inner ear. It contains the horizontal petrous internal carotid artery, foramen lacerum, bone marrow and mucosal-lined pneumatized air cells. 33% people have a pneumatized petrous apex.

The inner ear is made up of membranous labyrinth and bony labyrinth and receives CN7 & CN8 from the internal auditory canal. The labyrinth components include the endolymphatic chambers and organs, the perilymphatic surrounding fluid space and the osseous encasement. Normal structures of the inner ear include the cochlea, vestibule, endolymphatic duct and sac and the labyrinthine segment of CN7. Cochlear features include the cochlear aperture, modiolus, spiral turns (scala tympani, scala vestibuli, scala media) and the spiral lamina. The vestibular system is made up of the macula cribrosa, vestibule and the semicircular canals.

Contemporary Imaging Issues in Conductive Hearing Loss

Professor Ric H. Harnsberger

In this presentation we will discuss the important anatomy in the work-up of conductive hearing loss (CHL), the imaging approach and the lesions that may cause this symptom. The anatomic issues in CHL are straight forward. The external auditory canal, tympanic membrane, middle ear (ossicles) and oval window must all be visualized when imaging in CHL. T-bone CT alone is usually all that is necessary to image patients with CHL. No contrast is necessary. Multi-slice CT has significantly increased what can be seen on CT in patients with CHL. If a lesion is found that affects adjacent structures, focused T1 enhanced fat-saturated MR is employed in addition to CT.

Pediatric-congenital causes of CHL where the diagnosis is clinically obvious include EAC atresia (syndromal or sporadic) and congenital cholesteatoma. Imaging issues in EAC atresia include thickness and type of atresia plate, middle ear size, ossicles status, facial nerve position (especially mastoid segment), and oval or round window atresia. Congenital cholesteatoma presents with intact tympanic membrane and relative sparing of the facial nerve and ossicles. Inner ear fistula is rare with preservation of the tegmen tympani.

Causes of congenital CHL that are clinically occult include oval window atresia-stapedial fixation and congenital ossicular anomalies. Isolated oval window atresia presents with CHL but normal otoscopic examination. CT shows the stapes shape to be abnormal associated oval window bony covering and ectopic tympanic segment of facial nerve. Congenital ossicular anomalies involve all ossicles with fusion to each other, to the middle ear wall or absence altogether all possible.

Adult lesions of the temporal bone that may cause CHL can be grouped by location as found in the external auditory canal (EAC) or middle ear. EAC causes include cold water (surfer's) ear, EAC cholesteatoma, keratosis obturans and medial canal fibrosis. Cold water ear is a reaction of the ear to repeated exposure to cold water. CT shows bilateral EAC narrowing secondary to exostoses with cerumen & epithelial debris clogging the medial EAC.

EAC cholesteatoma is usually a unilateral lesion the cholesteatoma presenting as a submucosal lesion in the medial EAC. It may be post-traumatic but is usually spontaneous. CT shows a unilateral EAC mass with bony scalloping and ossific flecks within lesion secondary to necrotic bone. Keratosis obturans is a rare lesion found in patients with history of sinusitis and/or bronchectasis. Acute otalgia with CHL is typical. CT shows bilateral opacification of the EAC with an epithelial plug. Diffuse widening of EAC secondary to pressure from plug may occur. Post-inflammatory medial canal fibrosis presents as chronic otitis externa or chronic dermatitis of the EAC with CT showing thick fibrous plug in the medial EAC.

Adult middle ear causes of CHL include acquired cholesteatoma, cholesterol granuloma, tympanosclerosis with chronic otitis media and fenestral otosclerosis. Acquired cholesteatoma secondary to tympanic membrane rupture or retraction is seen on CT as a middle ear mass with destruction of ossicles and scalloping of the middle ear bony walls.

Middle ear cholesterol granuloma presents with a blue-black tympanic membrane and CHL. CT shows a middle ear mass usually without significant ossicles destruction or bony scalloping. MR reveals high T1 & T2 signal. Post-inflammatory ossicular fixation (tympanosclerosis) presents with history of chronic otitis media and CHL. CT demonstrates punctuate osteoneogenesis in the middle ear cavity sometimes looking like "extra ossicles".

Fenestral otosclerosis is an otodystrophy that involves the medial wall of the middle ear around the margins of the oval and round windows. Pathologically otosclerosis is otospongiosis of enchondral bone. CT shows focal radiolucent lesions beginning in the fissula antefenestrum. The lesions may spread to involve the bone surrounding both the oval and the round windows. Late, chronic finding of heaped up healing bone may be seen.

Imaging of Salivary Glands

KT Wong, Yolanda YP Lee, Ann D King, Anil T Ahuja

Salivary gland diseases may present clinically as facial / neck lump, diffuse swelling or pain. After a detailed history and physical examination, high-resolution ultrasound is the ideal initial imaging investigation of choice for (a) characterization of the lesion; (b) delineate the extent of lesion. In most circumstances, salivary gland abnormalities are adequately assessed by ultrasound supplemented by fine needle aspiration cytology (FNAC). Cross-sectional imaging including computed tomography (CT) and magnetic resonance imaging (MRI) add further important information in selected cases.

The aim of this presentation is to discuss imaging features of the commonly encountered salivary gland lesions including salivary gland tumours, calculi, acute / chronic inflammatory conditions and miscellaneous "parotid" lesions.

Contemporary Imaging Issues in Sensorineural

Hearing Loss in the Adult Population

H. Ric Harnsberger, MD

Adult sensorineural hearing loss (SNHL) critical anatomy, imaging strategies and causes will be discussed in this presentation. Critical normal anatomy necessary to evaluate CT & MR in patients with SNHL includes the fine details of the inner ear, CPA-IAC and the brainstem.

Cochlear anatomy of import includes the scalar chambers, modiolus and cochlear aperture. Other areas of the inner ear of interest include the vestibule, semicircular canals and the endolymphatic sac & duct. In the CPA-IAC the cochlear nerve, superior & inferior vestibular nerves and the facial nerve must all be appreciated. The cochlear nuclei reside on the lateral margin of the inferior cerebellar peduncle.

Imaging issues in SNHL can be divided into the imaging of simple, uncomplicated, unilateral SNHL with a screening high-resolution T2 protocol and the imaging of complex SNHL with full enhanced brain-CPA MR protocol.

Acquired adult SNHL causes in the inner ear include labyrinthitis, intralabyrinthine schwannoma and cochlear otosclerosis. Membranous labyrinthitis can occur at any age and is usually secondary to viral infection of the labyrinth. Rapid onset of complex SNHL is the rule with facial nerve paralysis sometimes present. Imaging finding may include enhancement of the membranous labyrinth, facial and vestibulocochlear nerves.

Labyrinthine schwannoma presents with a long history of progressive SNHL. Intractable dizziness and/or growth of the tumor into the IAC may force surgical treatment, otherwise no treatment is applied. The preferred terminology for this tumor is anatomically based. The terms intracochlear, intravestibular, vestibulocochlear, transmodiolar, transmacular and transotic are applied in describing labyrinthine schwannoma.

Cochlear otosclerosis is also referred to as cochlear otospongiosis. It usually presents with mixed conductive and sensorineural hearing loss. Concomitant fenestral otosclerosis may be present. Treatment may include high dose fluoride. CT findings include gray-radiolucent areas in otic capsule. MR may show focal enhancing areas in otic capsule, especially in the pericochlear bony labyrinth.

Congenital lesions that may cause adult SNHL include epidermoid cyst, arachnoid cyst and CPA-IAC lipoma. CPA epidermoid is a slow growing and may be clinically silent for years. Peak age at presentation is 40 years. Presenting symptoms include headache, tic douloureux, hemifacial spasm and SNHL. MR shows CPA epidermoid to be an insinuating lesion that does not contrast enhancement. T1 signal = or > CSF while T2 signal = CSF signal. FLAIR shows no or incomplete attenuation with diffusion weighted imaging showing diffusion restriction.

CPA arachnoid cyst presents as an incidental finding on MR. This lesion has been linked to dizziness, SNHL, tic douloureux and hemifacial spasm. MR findings of arachnoid cyst include smooth, sharp margins on a "pushing lesion" that shows no contrast enhancement with T1 & T2 signal = CSF and FLAIR showing complete suppression with diffusion weighted imaging revealing no restriction.

CPA lipoma usually presents with SNHL and dizziness. This lesion is a congenital rest of normal fatty tissue within the CPA or IAC cistern. Cranial nerves 7 & 8 often traverse the lipoma, making surgical cure worse than the disease. Do not operate on this lesion and do not mistake it for an enhancing acoustic schwannoma.

Adult acquired causes in the CPA-IAC of SNHL include acoustic schwannoma, meningioma, facial schwannoma and aneurysm. Acoustic schwannoma is the most common CPA mass. Presenting symptoms of unilateral SNHL and tinnitus (ringing) are most commonly reported. The tumor most commonly arises from the vestibular nerve sheath. Imaging features include an enhancing mass on T1 contrast-enhanced MR. T2 MR shows a filling defect in the high signal CSF. Uncommonly intramural cysts (~15%), associated arachnoid cyst (<1%) and intratumoral hemorrhage (<1%) are seen.

CPA meningioma is the 2nd most common CPA mass lesion. Unilateral SNHL and tinnitus (ringing) are the most common presenting symptoms. The tumor arises from "arachnoid cap cells". MR findings reported include flat, dural based lesion of with a dural "tail sign". The tumor is commonly asymmetric to porus acusticus with a CSF-vascular cleft between the tumor and the adjacent brainstem and cerebellum. Associated brain edema signals surgical problems and recurrence potential.

CPA-IAC facial nerve schwannoma can appear identical to acoustic schwannoma on MR if no "tail" along the labyrinthine segment of the facial nerve is present. The tumor presents as commonly with SNHL as it does with facial nerve paresis. It should be looked for on all cases of suspected acoustic schwannoma.

CPA aneurysm is the 3rd most common finding in unilateral SNHL screening. They may present with SNHL. On MR imaging it may be seen as a CPA mass with complex MR signals. Posterior inferior cerebellar artery, vertebral artery and anterior inferior cerebellar artery all can be the site of origination of CPA aneurysm.

Other uncommon causes of adult acquired SNHL include other schwannoma, Ramsay-Hunt syndrome, neurosarcoidosis, siderosis, metastases, NHL and leukemia.

Resident's experience in head and neck ultrasound

Dr Yolanda YP Lee

Resident, Department of Diagnostic Radiology and Organ Imaging,

Prince of Wales Hospital

Ultrasound is a useful tool in assessment of the nature of most head and neck lesions. The areas of interest are often superficial and image resolution and tissue characterization are excellent using high resolution ultrasound machine. Characteristic features are defined in most of the lesions.

For lesions with similar appearances, an ultrasound guided fine needle aspiration cytology (FNAC) could be readily performed to facilitate diagnosis, management plan and patient counseling.

In cases of deep tissue extension, an MRI or CT scan would be required to define complete anatomical extent.

This presentation outlines the basic scanning regions in head and neck ultrasound. A few interesting cases relating to each scanning regions are introduced. Their similarity and differentiating features are demonstrated.

The Central & Posterior Skull Base

Prof Ric H Harnsberger

In this presentation we will review the radiologic issues surrounding the central and posterior skull base. Imaging techniques and goals will be covered first. A combination of focused, thin-section enhanced skull base MR and unenhanced, bone-only CT creates a complete imaging perspective of most skull base lesions.

CT and MR normal anatomy required for complete image interpretation of skull base lesions in next presented. A careful look at the anatomy of the basi-sphenoid, basi-occiput, petrous apex and jugular foramen is completed. Armed with this anatomic foundation, classic anatomy-based imaging differential diagnoses will be covered. These include differential diagnoses of clival, petro-occipital fissure, jugular foramen and petrous apex lesions.

Principal lesions discussed in this talk include clival chordoma, petro-occipital fissure chondrosarcoma. In the area of the jugular foramen, flow pseudolesions, jugular bulb venous variants and jugular foramen paraganglioma, schwannoma & meningioma will be highlighted. Finally, in the petrous apex trapped fluid, cephalocele, apical petrositis, cholesterol granuloma, Langerhans cell histiocytosis and metastatic tumor will be presented.