Resource Document 5: Roentgenographic Studies

The law of inverse proportionality: The number of x-ray films allowed in the emergency room must be inversely proportional to the severity of the injury.

Yoram Ben-Menachem, MD.

I. Introduction

Roentgenograms should be obtained judiciously and must not delay patient resuscitation or transfer. Three roentgenograms should be obtained during the secondary survey - cervical spine (c-spine), anterior/posterior (AP) chest, and AP pelvis. These films can be taken in the resuscitation area, usually with a portable x-ray unit, during hiatuses in the resuscitation process. Equipment in the resuscitation room should be restricted to the basic portable or overhead x-ray unit.

Radiology on the triage table must be limited to survey films. It may be necessary to transport the patient to the radiology department for repeated plain films, contrast studies, or computed tomography (CT) or ultrasound. Transport of the patient to the radiology department should be viewed as an intrahospital patient transfer. (See Chapter 12, Stabilization and Transport.) Care must be taken to ensure airway management, continuous fluid resuscitation, spinal immobilization, and stabilization of potential and recognized fractures. The patient must be accompanied at all times by trained medical personnel and the appropriate equipment to manage changes in the clinical condition of the patient.

All radiographs must be labeled with the date and time they are obtained and the patient's name. If the patient is transferred to another institution, all radiographs must accompany the patient.

This document includes an outline of roentgenograms obtained during the initial assessment and resuscitation of the multiple-trauma patient - spine, chest, pelvis, abdomen, head, and extremities. It does not include radiographic interpretation of CT of the abdomen and head, other contrast studies (including arteriography), sonography, nuclear scans, and magnetic resonance imaging (MRI).
II. Spine

A. Indication

A lateral c-spine roentgenogram should be obtained on every patient sustaining multiple trauma. In addition, a lateral c-spine film should be obtained on every patient sustaining an injury above the clavicle, and especially a head injury. Films of the thoracic and lumbar spine should be obtained on any patient suspected of sustaining multiple trauma, especially to the trunk. (See Chapter 7, Spine and Spinal Cord Trauma for specific spine injuries.)

B. When to Obtain

A lateral c-spine roentgenogram should be obtained as soon as life-threatening problems are identified and controlled. Thoracic and lumbar films should be obtained during or after the secondary survey.

C. How to Obtain

1. Cervical spine

The first and most important film to obtain of the c-spine is a well-positioned, adequately penetrating, crosstable, brow up, lateral projection of the c-spine in a neutral position. The base of the skull, all seven cervical vertebrae, and the first thoracic vertebra must be visualized. The patient's shoulders are routinely pulled down when obtaining the lateral c-spine film, preventing missed fractures or fracture-dislocations in the lower c-spine. If all seven cervical vertebrae are not visualized on the lateral roentgenograms, a lateral swimmer's view of the lower cervical and upper thoracic area may be obtained.

After adequate demonstration of all seven cervical and the first thoracic vertebrae, the physician can obtain chest and open-mouth odontoid films. Other roentgenograms that can be obtained after the first hour to further evaluate the c-spine include AP and oblique cervical views. These or more sophisticated studies should be done for any patient with a normal crosstable lateral roentgenogram who is suspected (by signs and symptoms or mechanism of injury) of having a cervical injury. Even the best portable films miss 5% to 15% of the injuries.

A CT scan may be needed to determine the presence of bone fragments in the spinal canal. Alternatively, tomograms may be obtained to confirm a c-spine injury and determine its stability. Lateral flexion and extension roentgenograms of the c-spine may be dangerous and should be done under the direct supervision and control of a knowledgeable physician.

2. Thoracic and lumbar spine

Ap films of the thoracic and lumbar areas of the spine are standard. Because the crosstable lateral diameter of the body is usually greater than the AP diameter, most portable x-ray equipment used in the emergency department provides better bony definition in the AP view. Subsequent films may be obtained in the more elective environment of the radiology
department. Oblique thoracic films seldom add further information. Lateral and oblique films of the lumbar spine are obtained if indicated.

d. Interpretation

(See Table 1, Spine Roentgenographic Suggestions.)

1. Cervical spine

a. Roentgenograms of the c-spine should be examined for the following:

1) AP diameter of the spinal cord  
2) Contour and alignment of the vertebral bodies  
3) Displacement of bone fragments into the spinal canal  
4) Linear or comminuted fractures of the laminae, pedicles, or neural arches  
5) Soft-tissue swelling.

b. Anatomic assessment

1) Alignment - Identify and assess the four lordotic curves  
a) Anterior vertebral bodies  
b) Anterior spinal canal  
c) Posterior spinal canal  
d) Spinous process tips.  
2) Bone - Assess these areas:  
a) Vertebral body - contour and axial height  
b) Lateral bony mass  
   (1) Pedicles  
   (2) Facets  
   (3) Laminae  
   (4) Transverse processes.  
3) Cartilage - Assess these areas:  
a) Intervertebral discs  
b) Posterolateral facet joints  
4) Soft-tissue spaces - Assess for the following:  
a) Prevertebral space  
b) Prevertebral fat stripe  
c) Space between spinous processes.

c. Assessment guidelines for detecting abnormalities

1) Alignment  
a) Vertebral malignment > 3.0 mm - dislocation  
b) AP spinal canal space < 13 mm - spinal cord compression  
c) Angulation of intervertebral space > 11 degrees.
2) Bones
   a) Vertebral body
      (1) Anterior height < 3 mm posterior height - compression fractures
      (2) Lucency through the odontoid process of C-2 - fracture
   b) Lack of parallel facets of the lateral mass - possible lateral compression fracture
   c) Lucency through the tip of the spinous process - avulsion fracture
   d) Atlas and axis (C-1 and C-2)
      (1) Distance between posterior aspect of C-1 to anterior odontoid process > 3 mm - dislocation
      (2) Lucency through the odontoid process of C-2 - fracture.

3) Soft-tissue space
   a) Widening of the prevertebral space > 5 mm - hemorrhage accompanying spinal injury
   b) Obliteration of prevertebral fat strip - fracture at same level
   c) Widening of space between spinous processes - torn interspinous ligaments and likely spinal canal fracture anteriorly.

2. Thoracic and lumbar spine

During the early evaluation of the patient with suspected thoracic and/or lumbar vertebral injuries, it usually is sufficient to view only the AP film of the vertebral column. This film should be examined for the following:

a. Bilateral symmetry of the pedicles
b. Height of the intervertebral disc spaces
c. Central alignment of the spinous processes
d. Shape and contour of the vertebral bodies
e. Alignment of the vertebral bodies, if a lateral film is available.

Table. Spine Roentgenographic Suggestions

<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any c-spine bony abnormality</td>
<td>Cord compromise</td>
</tr>
<tr>
<td>C-spine injury</td>
<td>Airway compromise</td>
</tr>
<tr>
<td>Facial fracture</td>
<td>C-spine injury</td>
</tr>
<tr>
<td>Upper rib fracture</td>
<td>C-spine injury</td>
</tr>
<tr>
<td></td>
<td>Upper thoracic spine injury</td>
</tr>
<tr>
<td></td>
<td>Great vessel injury</td>
</tr>
<tr>
<td>Clavicular fracture</td>
<td>C-spine injury</td>
</tr>
<tr>
<td></td>
<td>Upper thoracic spine injury</td>
</tr>
<tr>
<td></td>
<td>Great vessel injury</td>
</tr>
<tr>
<td>Head injury</td>
<td>C-spine injury</td>
</tr>
<tr>
<td></td>
<td>Upper thoracic spine injury</td>
</tr>
<tr>
<td>Lower thoracic spine fracture</td>
<td>Pancreatic injury.</td>
</tr>
</tbody>
</table>
E. Roentgenographic Considerations in Children

A normal radiographic finding, in approximately 40% of children younger than seven years of age, is an anterior displacement of C-2 on C-3 (pseudosubluxation). Although radiographic finding is seen less commonly at C-3 to C-4, more than 3 mm of movement can be seen when these joints are studied by flexion and extension maneuvers.

Increased distance between the dens and the anterior arch of C-1 occurs in about 20% of young children. Gaps exceeding the upper limit of normal for the adult population are frequently seen.

Skeletal growth centers can resemble fractures. Basilar odontoid synchondrosis appears as a radiolucent area at the base of the dens, especially in children younger than five years of age. Apical odontoid epiphyses appear as separations on the odontoid roentgenogram and are usually seen between the ages of five and 11 years. The growth center of the spinous process may resemble fractures of the tip of the spinous process.

Children may sustain spinal cord injury without radiographic abnormality more commonly than adults. A normal spine series can be found in up to two-thirds of children sustaining spinal cord injury. Therefore, if spinal cord injury is suspected, based on history or the results of neurologic examination, normal spine roentgenograms do not exclude significant spinal cord injury. When in doubt about the integrity of the c-spine, assume that an unstable injury exists, maintain immobilization of the child's head and neck, and obtain appropriate consultation.

III. Chest Roentgenogram

A. Indications

A chest roentgenogram should be obtained on all patients who have sustained torso trauma - blunt or penetrating, and who are unconscious, going to the operating room, and/or are in respiratory distress.

B. When to Obtain

A chest roentgenogram should be obtained during the primary survey / resuscitation phase or the secondary survey.

C. How to Obtain

An AP film should be obtained with the patient in a supine position. An AP film may be obtained with the patient in an upright position; however, adequate immobilization of the patient's spine, particularly c-spine, must be maintained.

D. Interpretation

(See Table 2, Chest Roentgenographic Suggestions.)
1. Soft tissues - chest wall

The soft tissues may be contused, lacerated, perforated, or avulsed. The physician should examine the film for displacement or disruption of the tissue planes and for evidence of subcutaneous emphysema.

2. Bony thorax

   a. Ribs

   Rib fractures are the most common injury seen on a chest film. However, 50% are missed due to the position or lack of the fracture displacement.

   Fractures of the upper three ribs indicate severe trauma and require careful evaluation of the patient and the chest film for evidence of bronchial or aortic injury. Ribs four through nine are fractured most commonly. Two rib fractures in two or more places result in an unstable chest wall (flail chest). Fractures of the lower two ribs should cause the examiner to suspect an intra-abdominal injury, eg, spleen, liver, and/or kidney.

   b. Scapula

   Scapular fractures are associated with significant mortality due to associated injuries. Most scapular fractures are difficult to detect on a chest film. A high index of suspicion and knowledge of the mechanism of injury are required when examining chest films for scapular fractures. Special views are often required to identify such an injury.

   c. Sternum

   Most sternal fractures involve the sternomandibular junction or sternal body, and are often confused on the AP film as a mediastinal hematoma. A coned-down view, overpenetrated film, lateral film, or CT scan clarify this. The forces required to fracture the sternum also may produce myocardial contusion.

3. Pleural space

Abnormal accumulation of fluid may represent a hemothorax or chylothorax. On an upright or frontal chest film, a pneumothorax is seen usually as an apical lucent area absent of bronchial or vascular markings. This area separates the superior and lateral margins of the lung from the chest wall. Films obtained on full expiration may assist in identifying a small pneumothorax. Abnormal accumulations there constitute a pneumothorax.

The pneumothorax may progress to a tension pneumothorax, which can collapse more lung tissue. The increase in pleural pressure can restrict the inflow and outflow hemodynamics of the heart resulting in hypotension. Tension pneumothorax is not a radiographic diagnosis.

Pulmonary contusion appears as air space consolidation that can be irregular and patchy or homogeneous, diffuse, or extensive. Lacerations appear as a hematoma, vary according to the magnitude of the injury, and appear as areas of consolidation.
Roentgenographic findings of inhalation injury appear late.

**4. Trachea, bronchi**

Tracheal lacerations present as pneumomediastinum, pneumothorax, and subcutaneous and interstitial emphysema of the neck or pneumoperitoneum. Bronchial fractures with free pleural communication produce a massive pneumothorax with a persistent air leak that is not responsive to thoracostomy.

**5. Diaphragm**

The diagnosis of a diaphragmatic rupture requires a high index of suspicion. An elevated, irregular, or obscure hemidiaphragm in a patient with multiple trauma requires close observation and further studies to evaluate the diaphragmatic integrity. The roentgenographic changes listed herein suggest diaphragmatic injury:

- a. Elevation, irregularity, or obliteration of the diaphragm - segmental or total
- b. Mass-like density above the diaphragm due to a fluid-filled bowel, omentum, liver, kidney, spleen, or pancreas - may appear as a "loculated pneumothorax"
- c. Air- or contrast-containing stomach or bowel above the diaphragm
- d. Contralateral mediastinal shift
- e. Widening of the cardiac silhouette if the peritoneal contents herniate into the pericardial sac
- f. Pleural effusion
- g. The inferior border of the liver may appear higher than expected. Lower rib fractures, pulmonary contusions, and the appearance of foreign bodies in the chest cavity may be associated with diaphragmatic injury. Splenic, pancreatic, renal, and liver injuries also may be associated with diaphragmatic injury.
- h. A nasogastric tube coiled in the chest may represent a stomach herniated into the chest or a hole in the esophagus.

Initial chest roentgenograms may not suggest clearly a diaphragmatic injury, and sequential films may be needed to assist in this determination. Additional studies include oral barium, barium enema, or CT. Magnetic resonance imaging can show the diaphragm; however, the study is usually time consuming and is not indicated for a patient in respiratory distress. Ultrasonography also may be used to confirm the diagnosis of diaphragmatic injury.

**6. Mediastinum**

Mediastinal structures may be displaced by air or blood and may dissect out along the bronchial structures, either displacing those structures or blurring the demarcation between
tissue planes or outlining them with radiolucency. Air or blood in the pericardium appears to enlarge the cardiac silhouette. Progressive changes in the cardiac size may represent an expanding pneumopericardium or hemopericardium. Radiologic signs that suggest aortic rupture include:

a. Widened mediastinum - most reliable finding
b. Fractures of the first and second ribs
c. Obliteration of the aortic knob
d. Deviation of the trachea to the right
e. Presence of a pleural cap
f. Elevation and rightward shift of the right mainstem bronchus
g. Depression of the left mainstem bronchus
h. Obliteration of the space between the pulmonary artery and the aorta
i. Deviation of the esophagus (nasogastric tube to the right).

Arteriography is the appropriate modality to make the definitive diagnosis.

**Table 2. Chest Roentgenographic Suggestions**

<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any rib fracture</td>
<td>Pneumothorax</td>
</tr>
<tr>
<td>Fracture, first 3 ribs</td>
<td>Airway or great vessel injury</td>
</tr>
<tr>
<td>Lower ribs, 9 to 12</td>
<td>Abdominal injury</td>
</tr>
<tr>
<td>Two or more rib fractures in two or more places</td>
<td>Flail chest, pulmonary contusion</td>
</tr>
<tr>
<td>GI gas pattern in the chest (Loculated air)</td>
<td>Diaphragmatic rupture</td>
</tr>
<tr>
<td>NG tube in the chest</td>
<td>Diaphragmatic rupture or ruptured esophagus</td>
</tr>
<tr>
<td>Air fluid level in the chest</td>
<td>Hemothorax or diaphragmatic rupture</td>
</tr>
<tr>
<td>Loss of diaphragmatic contour</td>
<td>Diaphragmatic rupture</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>Myocardial contusion, head injury, c-spine injury</td>
</tr>
<tr>
<td>Mediastinal hematoma</td>
<td>Great vessel injury, sternal fracture</td>
</tr>
<tr>
<td>Disrupted diaphragm</td>
<td>Prompt celiotomy</td>
</tr>
<tr>
<td>Respiratory distress without roentgenographic findings</td>
<td>CNS injury, aspiration</td>
</tr>
<tr>
<td>Persistent large pneumothorax after chest tube insertion</td>
<td>Bronchial tear, esophageal disruption</td>
</tr>
<tr>
<td>Mediastinal air</td>
<td>Esophageal disruption, pneumoperitoneum,</td>
</tr>
<tr>
<td>Tracheal injury</td>
<td>Airway or great vessel injury, or pulmonary contusion</td>
</tr>
<tr>
<td>Scapular fracture</td>
<td>Ruptured hollow abdominal viscus.</td>
</tr>
<tr>
<td>Free air under the diaphragm</td>
<td></td>
</tr>
</tbody>
</table>
IV. Pelvis

A. Indications

Indications for pelvic roentgenograms include patients with significant blunt trauma to the torso, pelvic instability, gross blood and/or disrupted prostate on rectal examination, gross blood on vaginal examination, gross hematuria, and unexplained hypotension.

B. When to Obtain

Pelvic films are obtained during secondary survey.

C. How to Obtain

An AP pelvic film is obtained with the patient in a supine position. All bones of the pelvis must be visualized. A lateral view rarely is used and is difficult to obtain in the trauma patient. Oblique or angulated views are used to evaluate the sacroiliac joints and to further define fractures, particularly of the rami. Other imaging techniques used to delineate the pelvic anatomy include retrograde urethrogram and cystogram, intravenous pyelogram (IVP), ultrasonography, and CT.

D. Interpretation

(See Table 3, Pelvic Roentgenographic Suggestions.)

The anatomy of the pelvis is arranged primarily as a ring. If a fracture in any one portion is identified, there is generally a second disruption of the ring. The examining physician should be alerted to any disruption in the symmetry of the pelvic ring and the possibility of a fracture or significant soft-tissue injury. Avulsed fragments and comminuted wing fractures may be difficult to identify as well as fractures of the coccyx and sacroiliac joints.

Table 3. Pelvic Roentgenographic Suggestions

<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any fracture of the pelvis</td>
<td>Hemorrhage, urethral trauma, bladder trauma, rectal injury</td>
</tr>
<tr>
<td>Pelvic fracture in a pregnant woman</td>
<td>Abruptio placenta, uterine hematoma, or fetal distress</td>
</tr>
<tr>
<td>Widening of the sacroiliac joint</td>
<td>Urethral injury</td>
</tr>
<tr>
<td>Pubic diastasis</td>
<td>Urethral injury</td>
</tr>
<tr>
<td>Posterior hip dislocation</td>
<td>Sciatic nerve injury</td>
</tr>
<tr>
<td>Anterior hip dislocation</td>
<td>Vascular compromise</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>Intra-abdominal visceral injuries, life-threatening thoracic injuries, diaphragmatic rupture, retroperitoneal vascular injury</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>Femoral shaft fracture.</td>
</tr>
</tbody>
</table>
V. Abdomen

A. Indications

Plain films of the abdomen are of limited use when evaluating the trauma patient. Remember, the information obtained on a roentgenogram is, for the most part, limited to the bony structures. Given the wide impact of blunt or penetrating trauma and the range of possible soft-tissue injuries in the abdomen, the limitations of the plain abdominal film must be recognized.

Plain films are useful in looking for foreign bodies, free air, and bony abnormalities. The interluminal gas pattern for the abdominal structures and the outline of solid soft-tissue organs are unreliable in the patient with multiple trauma. The air and soft-tissue patterns may be of indirect help in the assessment of structures contained in the peritoneum, retroperitoneum, and pelvis.

Abdominal films should be obtained on patients with (1) penetrating or blunt abdominal trauma who have suspected intra-abdominal injuries, (2) an altered sensorium and who are unable to provide a reliable history or responses to a physical examination, or (3) findings referable to the abdomen.

B. When to Obtain

Abdominal roentgenograms should be obtained during the secondary survey.

C. How to Obtain

1. Abdominal roentgenograms

AP plain or crosstable lateral decubitus films may be appropriate. Projection must include the top of the diaphragm and the entire pelvis. A chest film is an essential companion to the abdominal film. Repeated roentgenograms may be useful to detect shifts in fluid or air in the abdomen.

2. Contrast studies

a. Urethrogram

Urethrogram should be performed before inserting an indwelling urinary catheter when a urethral tear is suspected. The urethrogram can be performed with a #12-French urinary catheter secured in the meatal fossa by balloon inflation to 3 mL. Undiluted contrast material is instilled with gentle pressure.

b. Cystography

Bladder rupture is established with a gravity flow cystograms. A bulb syringe attached to the indwelling bladder catheter is held 15 cm above the patient, and 250 to 300 mL of water-soluble contrast is allowed to flow into the bladder. Anteroposterior, oblique, and
postdrainage views are essential to definitively exclude injury. The order of an IVP versus cystography is governed by the index of suspicion for upper versus lower tract injury.

c. **Excretory urogram**

An IVP may be valuable for initial renal evaluation. High-dose intravenous bolus injection should provide evidence of relative kidney function at 5 to 10 minutes. In the stable patient, CT is preferable to the IVP if there is the suspicion of other intra-abdominal and/or retroperitoneal injuries. Intravenous contrast studies should not be performed in the hypotensive, unstable patient.

d. **Computed tomography**

Diagnostic peritoneal lavage can be performed rapidly and without delay in the emergency department. By comparison, CT requires transport of the patient to the scan area and time to perform the examination. A complete CT examination, usually using both intravenous and oral contrast material, must include the upper abdomen and pelvis. Therefore, the CT scan should be performed only on stable patients in whom there is no apparent indication for immediate operation. The CT scan, which provides information relative to specific organ injury and its extent, also can diagnose retroperitoneal and pelvic organ injuries that are difficult to assess by a physical examination or peritoneal lavage.

**D. Interpretation**

(See Table 4, Abdominal Roentgenographic Suggestions.)

1. **Spleen**

Intrasplenic hemorrhage, subcapsular hematoma, visceral fragments, and blood accumulation in the splenic fossa may appear as a radio-opaque mass in the left upper quadrant. Displacement or obliteration of the left kidney medially or the left transverse colon interiorly may be further signs. An upright roentgenogram with the patient in the right posterior oblique position may assist in the demonstration of the splenic mass and visceral displacement. Atelectasis, pleural effusion, irregularity, or prominence of gastric mucosal folds are additional signs. CT scan may provide more direct information. Radionucleotide scans and abdominal ultrasound also have been employed.

2. **Hemoperitoneum**

As blood fills the peritoneal cavity, the blood collects in the pelvis which constitutes approximately one third of the volume of the peritoneal cavity. Initially, perirectal and, later, perivesicle and perirectal pouches fill with blood, displacing the small intestine cephalad. This may appear as a homogenous density superior and lateral to the bladder. Free-flowing blood or other fluid in the lateral gutter displaces the colon medially and replaces the sacculations formed by the colonic haustra. Blood in the posterior subhepatic space (Morrison's pouch) may obscure the outlines of the undersurface of the liver. CT demonstrates some of the anatomic subtleties of hemoperitoneum accurately.
3. Gastrointestinal tract

Bowel lacerations allow air, fluid, and food residue to escape into the bowel wall, peritoneum, and extraperitoneal spaces revealing itself as extraluminal air and alterations in the normal crisp outlines of the bowel air patterns. An upright chest film provides the best means of demonstrating free intraperitoneal air. A lateral decubitus of the abdomen is a second best plain film. Oral or rectally-administered water-soluble contrast material may assist in demonstrating perforation at either ends of the gastrointestinal tract. Barium is not used as its presence in the free peritoneal cavity increases the morbidity of perforation. Additional signs of free air under the diaphragm include the following:

a. Double wall sign, ie, intraluminal and extraluminal air outside the mucosal and serosal surfaces

b. A cap of air forming a lucency over fluid areas in the abdomen

c. Visualization of the falciform ligament as it is outlined by air

d. Subhepatic air

e. An accumulation of air in the central tendon of the diaphragm providing a curved, sharp interface with the inferior mediastinum

f. Subpulmonic pneumothorax with air apparently loculated between the base of the lung and the diaphragm

g. Mediastinal air that has dissected from the abdomen

h. An apparent large diverticulum arising from a subdiaphragmatic esophagus, the stomach, or the duodenum.

4. Duodenum and pancreas

Duodenal and pancreatic injuries are difficult to diagnose. Intramural hematoma and air outlining retroperitoneal structures are suspicious of these problems. Extraluminal retroperitoneal gas may tend to the anatomic spaces outlined by fascial planes. Air surrounding the right kidney may be an additional sign. Pancreatic injury is even less specific with elevation of the left hemidiaphragm, and basal atelectasis, pleural fluid, scoliosis, adynamic ileus, and loss of roentgenographic visualization of the normal retroperitoneal structures and fascial planes are suggestive of this problem. Intramural duodenal hematomas are more common in children as their abdominal walls are less protective of the abdominal viscera.

5. Liver

There are few reliable signs of hepatic trauma. On a plain film, rib fractures in the area are of some assistance; however, CT scan is a more definitive imaging technique. Subscapular hematomas may distort the liver outline and change the hepatic angle and
displace the hepatic flexure of the colon interiorly. Additional measures include nuclear scanning and ultrasonography.

6. Kidney

Intravenous pyelogram is the most frequently performed contrast study in the patient with acute trauma. Renal injuries are divided as indicated herein:

a. Minor injury - compression of a collecting system; displacement by retroperitoneal hematoma; some delay in excretion

b. Major injury - contrast leakage from the collecting system; tear in the renal capsule; perinephric hematoma; obliteration of the renal outline or psoas muscle

c. Catastrophic injury - appears as the shattered kidney with extensive hemorrhage and displacement and disruption of the renal parenchyma.

Roentgenographic signs include:

1) Loss of the psoas margin on the side of the injury

2) Concomitant fracture of the ribs, pelvis, or spine - suggestive of severe abdominal trauma

3) Concavity of the spine on the side of the trauma

4) Unilateral hypoconcentration

5) Absence or delayed function

6) Filling defects in the renal pelvis, parenchyma, ureter, or bladder suggesting blood clots

7) A flank mass with displacement of the bowel loops

8) Fluid collection above the renal calyces representing a subcapsular collection

9) Hemorrhage into the perirenal fat

10) A striated nephrogram

11) Extravasation of contrast.
Table 4. Abdominal Roentgenographic Suggestions

<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower rib fractures</td>
<td>Hepatic or splenic trauma</td>
</tr>
<tr>
<td>Pelvic fracture</td>
<td>Rectal laceration, diaphragmatic rupture, hemorrhage</td>
</tr>
<tr>
<td>Lumbar spine fracture</td>
<td>Renal injury</td>
</tr>
<tr>
<td>Free air</td>
<td>Ruptured hollow viscus</td>
</tr>
<tr>
<td>Apparent displacement of bowel gas patterns, eg, stomach or small bowel</td>
<td>Hemoperitoneum</td>
</tr>
<tr>
<td>Effacement of mucosal folds of the duodenum</td>
<td>Intramural hematoma of the duodenum</td>
</tr>
<tr>
<td>Loss of psoas shadow</td>
<td>Retroperitoneal hematoma</td>
</tr>
<tr>
<td>Retroperitoneal air</td>
<td>Duodenal rupture</td>
</tr>
<tr>
<td>Lower thoracic spine injuries</td>
<td>Pancreatic injury</td>
</tr>
<tr>
<td>Extraluminal air</td>
<td>Prompt celiotomy</td>
</tr>
<tr>
<td>Intraperitoneal perforation of urinary bladder</td>
<td>Prompt celiotomy</td>
</tr>
</tbody>
</table>

VI. Head Trauma

A. Skull Roentgenograms

Skulls roentgenograms are of little value in the early management of patients with obvious head injuries, except in cases of penetrating injuries. The unconscious patient should have skull roentgenograms only if precise care of the cardiorespiratory system and continuing reassessment can be assured. Physical examination is usually more valuable than skull roentgenograms. Clinical signs of basal fractures are more useful than radiographs of the skull base in diagnosing fracture. Increasingly, skull films are not being obtained on patients with minor head injuries because the information obtained is rarely helpful. When in doubt about the patient's condition, the physicians should obtain neurosurgical consultation.

B. Computed Tomography

The CT scan has revolutionized diagnosis in patients with head injuries and is the diagnostic procedure of choice for patients who have or are suspected of having a serious head injury. Although not perfect, the CT scan is capable of showing the exact location and size of most lesions. Specific diagnosis allows more precise planning of definitive care, including operation. The CT scan has supplanted less specific and more invasive tests such as cerebral angiography.

Except for patients with trivial head injuries, all head-injured patients require CT scanning at some time. The more serious the injury, the earlier and more emergent is the need for the scan. Consequently, injured patients seen first at facilities without CT capability may require transfer to a trauma center.

Once initial resuscitation has been undertaken and the need for a CT scan determined, care must be taken to (1) maintain adequate resuscitation during the scan, and (2) assure the best possible quality of the scan. The patient must be attended constantly in the CT suite to
monitor his vital signs closely, and immediate treatment must be initiated should the patient's status deteriorate.

Patient movement results in artifacts and a poor-quality scan. This artifact may mask significant intracranial lesions requiring urgent surgical intervention. Movement artifact can be eliminated by sedating restless or uncooperative patients. However, extreme caution must be exercised to avoid sedating patients whose restlessness or lack of cooperation is a clinical manifestation of hypoxia. Often endotracheal intubation with controlled ventilation becomes necessary if the scan is considered mandatory and the patient can be rendered motionless only with paralyzing drugs. Ideally, the neurosurgeon should examine the patient before the patient is iatrogenically paralyzed or has a CT scan. However, efficient and correct management of the patient in certain situations may dictate otherwise.

C. Isotope Scan

Isotope scanning has no role in the early management of head trauma.

VII. Extremities

A. Indications

Indications for obtaining extremity roentgenograms on the trauma patient include blunt or penetrating trauma to the extremity, extremity deformity, or evidence of vascular or neurologic compromise of the extremity.

B. When to Obtain

Roentgenograms of the extremities are obtained during the secondary survey.

C. How to Obtain

Anterior, posterior, and lateral extremity films may be obtained. Comparison views visualizing the contralateral extremity are helpful, particularly in children. Patterns of bone injury may be helpful in predicting associated extremity injuries other than the one that is first seen, eg, a suspected fracture of the tibia with a less obvious fracture of the fibula or dislocation of a joint proximal or distal to an obvious long bone fracture. Because of the three-dimensional nature of the extremity, views in at least two projections, preferably at right angles, are desirable. These may be supplemented by oblique views. Specific anatomic areas include the shoulder, scapula, clavicle, elbow, forearm, wrist, hand, knee, leg, ankle, and foot. Special imaging may be necessary for smaller bones such as the wrist, patella, foot, and hand. Stress fractures or small fracture lines may be best visualized in days or weeks after the injury incident.
When obtaining and viewing extremity roentgenograms, these items should be reviewed:

1. Is this the correct patient and the correct side to be filmed?
2. Do the roentgenograms cover the entire area of injury, including one joint above and one joint below the injury?
3. Have proper projections been obtained?
4. Are the roentgenograms properly exposed?
5. Is the detail adequate?
6. Are the contours of the bones in the cortical surfaces?
7. Inspect the cortical margins of each bone completely as the bones may be superimposed. Look for secondary soft-tissue signs.
8. If there is an obvious lesion, disregard it until you have looked at the remainder of the film.

D. Roentgenographic Considerations in Children

1. General

Roentgenographic diagnoses of fractures and dislocations in the younger child are difficult because of the lack of mineralization around the epiphysis and the presence of a physis (growth plate). Information about the magnitude, mechanism, and time of injury facilitates better correlation of the physical findings and roentgenograms. Radiographic evidence of fractures of different ages should alert the physician to possible child abuse.

2. Physeal (growth plate) fractures

Bones lengthen as new bone is laid down by the physis near the articular surfaces. Injuries to or adjacent to this area before the physis has closed can potentially retard the normal growth or alter the development of the bone in an abnormal way. Crush injuries, which are often difficult to recognize roentgenographically, have the worst prognosis.

3. Unique fractures

The immature, pliable nature of bones in children may lead to a so-called "greenstick" fracture. Such fractures are incomplete, with angulation maintained by cortical splinters on the concave surface. The torus or "buckle" fracture, seen in small children, involves angulation due to cortical impaction with a radiolucent fracture line. Supracondylar fractures at the elbow or knee have a high propensity for vascular injury as well as injury to the growth plate.
<table>
<thead>
<tr>
<th>Abnormal Findings</th>
<th>Diagnoses to Consider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremity fracture</td>
<td>Arterial injury</td>
</tr>
<tr>
<td></td>
<td>Nerve injury</td>
</tr>
<tr>
<td></td>
<td>Hemorrhage with or without shock</td>
</tr>
<tr>
<td></td>
<td>Compartment syndrome</td>
</tr>
<tr>
<td></td>
<td>Fat embolization</td>
</tr>
<tr>
<td></td>
<td>Some anaerobic soft-tissue infections</td>
</tr>
<tr>
<td></td>
<td>Fracture fragments within the joint</td>
</tr>
<tr>
<td></td>
<td>Thromboembolism</td>
</tr>
<tr>
<td></td>
<td>Continued soft-tissue injury</td>
</tr>
<tr>
<td></td>
<td>Joint dislocation above and below fracture site</td>
</tr>
<tr>
<td></td>
<td>Growth plate injury</td>
</tr>
<tr>
<td>Femoral fracture</td>
<td>Acetabular fracture, hip dislocation, pelvic ring fracture</td>
</tr>
<tr>
<td>Calcaneal fracture</td>
<td>Vertebral column injuries</td>
</tr>
<tr>
<td>Shoulder girdle fracture</td>
<td>Thoracic injuries</td>
</tr>
<tr>
<td>Soft-tissue signs without fracture</td>
<td>Ligamentous injury</td>
</tr>
<tr>
<td>Multiple long-bone fractures in a child</td>
<td>Child abuse</td>
</tr>
<tr>
<td>Multiple fractures of different ages</td>
<td>Child abuse</td>
</tr>
</tbody>
</table>