Radiographic Assessment of Tubes, Lines, Drains, and Other Devices - Normal Placement, Positioning Errors, Complications, and Indications for Radiological Evaluation

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Outline

• Endotracheal tubes
• Tracheostomy tubes
• Central venous catheters
• PA catheters
• Chest tubes
• Enteric tubes
• Cardiac pacemakers/defibrillators

1. Normal position
2. Abnormal position/complications
3. Indications of radiographic evaluation
Endotracheal Tubes – Normal Position

• Gold standard for determining placement in airway is end-tidal CO$_2$.*
  • Limited ability to detect some complications
  • Physical exam maneuvers also may be helpful

• Radiographic assessment of tube position based on visualizing radio-opaque line on ETT

*In patients with adequate tissue perfusion
Endotracheal Tubes – Normal Position

• ETT position dependent on neck flexion and extension:
  • Neck flexion (mandible @ T1-2): ETT tip can descend up to 2 cm
  • Neck extension (mandible @ C4): ETT tip can ascend up to 2 cm

• Acceptable positioning:
  • Proximal tube tip: level of medial heads of the clavicle
    • Too proximal – risk upper airway/vocal cord injury
  • Distal tube tip: 2 cm above carina
    • Too distal – mainstem bronchus intubation with neck flexion

• Tracheal cuff should fill tracheal wall (not bulge)
Endotracheal Tubes – Normal Position
Endotracheal Tubes – Normal Position
Endotracheal Tubes – Abnormal Position

• Potential Complications:
  • Increased risk of spontaneous extubation
  • Aspiration
  • Vocal cord injury
  • Gastric distension
Endotracheal Tubes – Abnormal Position
Endotracheal Tubes – Abnormal Position

• Potential Complications:
  • Left lobe (R main stem bronchus) or right upper lobe (R inferior intermediate bronchus) collapse/atelectasis
  • Tension pneumothorax

*Right main stem bronchus intubation is most common positioning error

Uncomplicated right main stem bronchus intubation
Endotracheal Tubes – Complications
Endotracheal Tubes – Complications

Right main stem bronchus intubation with left lung collapse (thin black arrows)
Endotracheal Tubes – Complications

Esophageal intubation with marked gastric distension
Endotracheal Tubes – Indications for Studies

• ACR Appropriateness Criteria

• Rating scale:
  • 1-3: Usually not appropriate
  • 4-6: May be appropriate
  • 7-9: Usually appropriate

• Takes into account clinical usefulness and potential costs/harms (i.e. radiation dose, etc.)
Endotracheal Tubes – Indications for Studies

• Radiographic evaluation indicated:
  • After ETT insertion (appropriateness score = 9)
    • Higher rate of detecting malpositioned tubes with chest x-rays than physical exam
    • Patient with ETT in place – clinical indications only (9)

• Radiographic evaluation NOT indicated:
  • Daily, routine follow-up (3)
    • Minimal benefit in cardiothoracic patients(?)

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate
Tracheostomy Tubes – Normal Position

• Similar distal tip positioning rules as ETTs

• Tip position should NOT vary with neck flexion/extension

• At least 2/3 of “smooth” portion should lie within the trachea
Tracheostomy Tubes – Normal Position
Tracheostomy Tubes – Normal Position
Tracheostomy Tubes – Complications
Tracheostomy Tubes – Complications

• Potential complications
  • Tracheal injury
    • Subcutaneous emphysema/pneumomediastinum*
  • Pneumothorax
  • Hemorrhage
  • Late complications:
    • Tracheal stenosis
    • Tracheomalacia
    • Vascular erosions
    • Tracheobronchial fistula

*Small amount of subcutaneous emphysema may be normal post-insertion

Tracheostomy tube with subcutaneous emphysema (thick arrow), pneumomediastinum (curved), and left pneumothorax (thin)
Central Venous Catheters – Normal Position

- Central venous catheter may be central (IJ, subclavian) or peripheral (PICC)

- Catheter tip should terminate in SVC or cavo-atrial junction
  - “OK to use” varies with intended function

- Placement borders:
  - Brachiocephalic/IJ junction – 1st anterior intercostal space
    - Last venous valve
  - Cavo-atrial junction – inferior border of right bronchus intermedius (+2.5 cm below)
    - Prevent cardiac chamber insertion
Central Venous Catheters – Normal Position
Central Venous Catheters – Normal Position

- Subclavian veins
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava
- Right atrium
Central Venous Catheters – Normal Position

- Subclavian veins
- Internal jugular veins
- Brachiocephalic veins
- Superior vena cava
- Right atrium
- Right ventricle
Central Venous Catheters – Normal Position
Central Venous Catheters – Normal Position
Central Venous Catheters – Abnormal Position

• Positioning errors:
  - Ipsilateral IJ
  - Contralateral brachiocephalic vein
  - Right atrium/ventricle
  - Increased risk of arrhythmias
  - Reduced dilution of administered medications
  - Azygous vein
    - Internal thoracic vein
    - Difficult to detect on routine AP imaging – may require lateral imaging if suspicious
Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ vein

Left subclavian line terminating in left IJ
Central Venous Catheters – Abnormal Position

• Positioning errors:
  • Ipsilateral IJ vein

*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious
Central Venous Catheters – Abnormal Position

• Positioning errors:
  • Ipsilateral IJ vein
  • Contralateral brachiocephalic vein

Right subclavian line terminating in left brachiocephalic
Central Venous Catheters – Abnormal Position

• Positioning errors:
  • Ipsilateral IJ
  • Contralateral brachiocephalic vein
  • Right atrium/ventricle
    • Increased risk of arrhythmias
    • Reduced dilution of administered medications

*Difficult to detect on routine AP imaging — may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

Right arm PICC terminating in right atrium
Central Venous Catheters – Abnormal Position

• Positioning errors:
  • Ipsilateral IJ
  • Contralateral brachiocephalic vein
  • Right atrium/ventricle
    • Increased risk of arrhythmias
    • Reduced dilution of administered medications
  • Azygous vein*

*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

Left arm PICC terminating in azygos vein
Central Venous Catheters – Abnormal Position

- Positioning errors:
  - Ipsilateral IJ
  - Contralateral brachiocephalic vein
  - Right atrium/ventricle
    - Increased risk of arrhythmias
    - Reduced dilution of administered medications
  - Azygous vein*
  - Internal thoracic vein*

*Difficult to detect on routine AP imaging – may require lateral imaging if suspicious; more common in SVC thrombus and/or volume overload

Left arm PICC terminating in azygos vein
Central Venous Catheters – Anatomic Variants

• Anatomic variants:
  • Persistent left SVC (0.3% of population)
    • Left SVC → coronary sinus → RA
    • More common in CHD

Left IJ catheter terminating within proximal left-sided SVC
Central Venous Catheters – Anatomic Variants

- Anatomic variants:
  - Persistent left SVC (0.3% of population)
    - Left SVC $\rightarrow$ coronary sinus $\rightarrow$ RA
    - More common in CHD
  - Ventricular septal defect
  - Atrial septal defect
  - Anomalous pulmonary vein

Left IJ catheter terminating within proximal left-sided SVC
Central Venous Catheters – Complications
Central Venous Catheters – Complications

Left subclavian line with tip in SVC; Left pneumothorax
Central Venous Catheters – Complications
Central Venous Catheters – Complications

• Signs of perforation:
  • Unusual catheter trajectory
  • New apical density ("apical cap")
    • Extrapleural hematoma
  • New pleural effusion
    • Hemothorax
  • Mediastinal widening
    • Mediastinal hematoma

Right IJ catheter with venous perforation and right mediastinal hematoma
Central line placement into left common carotid artery
Central Venous Catheters—Indications for Studies

• Radiographic evaluation indicated:
  • After CVC insertion (appropriateness score = 9)
  • Patient with CVC in place – clinical indications only (9)

• Radiographic evaluation NOT indicated:
  • Daily, routine follow-up (1)

• Radiographic evaluation after failed CVC insertion?
  • Insertion site hematoma, pneumothorax
  • No clear evidence or guidelines

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate
Pulmonary Artery Catheters – Normal Position

• Inserted via subclavian, jugular, or femoral veins

• “Resting” position dependent on its intended function
  • RV, pulmonary trunk, right/left PA, etc

• Ideal catheter tip position no farther than proximal interlobar pulmonary arteries
  • Within 1-2 cm of hilum/mediastinal shadow

*Catheter balloon tip should only be inflated during pressure measurements!
Pulmonary Artery Catheters – Normal Position

Left subclavian PA catheter terminating in main pulmonary artery
Pulmonary Artery Catheters – Complications
Pulmonary Artery Catheters – Complications

• Potential Complications:
  • Pulmonary artery infarction
    • Tip too distal
    • Persistent balloon inflation
    • Clot around distal catheter tip
  • Complications of CVCs
    • Looping/coiling
    • Pneumothorax
    • Hematoma
    • Perforation
Pulmonary Artery Catheters – Complications

• Potential Complications:
  • Pulmonary artery infarction
    • Tip too distal
    • Persistent balloon inflation
    • Clot around distal catheter tip
  • Pulmonary artery rupture
  • Pulmonary artery dissection

• Complications of CVCs
  • Looping/coiling
  • Pneumothorax
  • Hematoma
  • Perforation

Right IJ PA catheter (straight arrows) distally placed with pulmonary infarction (curved)
Pulmonary Artery Catheters—Indications for Studies

• Radiographic evaluation indicated:
  • After PAC insertion (appropriateness score = 9)
    • Characteristic pressure tracings alone are NOT sufficient to verify position
    • Patient with PAC in place – clinical indications only (9)

• Radiographic evaluation NOT indicated:
  • Daily, routine follow-up (1)

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate
Chest Tubes – Normal Position

• Assessment based on identification of radiopaque lines and side holes

• All side holes must be within pleural space and completely visualized
  • Side holes = interruption of radiopaque line
  • Position medial to inner margin of ribs

• Tube direction depends on indication:
  • Air removal (PTX) – anterior and superior
  • Fluid removal (effusion)– posterior and inferior
    • Tube should not “float” on top of effusion

• Lateral films also helpful in confirming position (i.e. anterior-posterior)
  • Non-contrast CT scan if still uncertain
Chest Tubes – Normal Position

Right apical chest tube

Bilateral pigtail chest tubes
Chest Tubes – Abnormal Position

• Positioning errors:
  • Incomplete insertion
    • Side hole outside of pleural cavity

Incomplete tube placement with subcutaneous emphysema
Chest Tubes – Abnormal Position

• Positioning errors:
  • Incomplete insertion
    • Side hole outside of pleural cavity
  • Tube kinking
    • Tube angulations

[Image: Multiple chest tube kinks]
Chest Tubes – Abnormal Position

- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations
  - Soft tissue/chest wall

Left chest tube appears in proper position

CT demonstrating chest tube within chest wall

*May appear normal on AP imaging and may require lateral imaging or CT (non-contrast)
Chest Tubes – Abnormal Position

• Positioning errors:
  • Incomplete insertion
    • Side hole outside of pleural cavity
  • Tube kinking
    • Tube angulations
  • Soft tissue/ chest wall
  • Lung fissures*
    • Poor drainage
    • Horizontal projection
    • Herniation into tube \(\rightarrow\) infarction

*May appear normal on AP imaging. May require lateral imaging or CT (non-contrast).

Right chest tube projecting horizontally

Right chest tube (axial) within right minor fissure
Chest Tubes – Abnormal Position

- Positioning errors:
  - Incomplete insertion
    - Side hole outside of pleural cavity
  - Tube kinking
    - Tube angulations
  - Soft tissue/chest wall
  - Lung fissures*
    - Poor drainage
    - Horizontal projection
    - Herniation into tube → infarction

*May appear normal on frontal chest X ray
Chest Tubes – Complications

• Reexpansion pulmonary edema
  • Rapid removal of air/fluid from pleural space
    • Prolonged atelectasis
  • Also: s/p thoracentesis
• Clinical manifestations:
  • <2 hours after lung reexpansion
  • Hypoxia → respiratory distress
  • Lasts 1-2 days
• Unilateral airspace opacity

Right pleural effusion prior to drainage

Interval resolution of right pleural effusion; new airspace opacity in RLL
Chest Tubes—Indications for Studies

- Radiographic evaluation indicated:
  - After chest tube insertion (appropriateness score = 9)
  - Patient with chest tube in place – clinical indications only (9)
    - Also: newly malfunctioning chest tubes

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate
Enteric Tubes – Normal Position

- **NGT/OGT**
  - Larger diameter
  - Stiffer
  - Used for feeding or suction
  - More easily placed
  - Increased aspiration risk
    - Large feeding volumes
    - Impaired gastric motility
  - May measure gastric residuals
  - May contain side holes

- **Flexible/Dobhoff tube (DHT)**
  - Small diameter
  - More flexible
  - Used for feeding only (no suction)
  - More difficult to place
    - Weight (radiopaque) tip
  - Decreased aspiration risk
    - Antral/post-pyloric placement
  - May contain side holes
Enteric Tubes – Normal Position

• Optimal position depends on tube type
  • NGT/OGT:
    • Feeding – distal/antral stomach placement
      • Tip directed towards midline
      • Tip at least 10cm distal to GE junction
      • GE junction - just below level of the left cardiophrenic angle
    • Decompression – gastric placement
      • Tip distal to GE junction
  • Dobhoff:
    • Feeding – 2nd portion of duodenum
      • Tip crosses midline; tip oriented caudally

• “Optimal” position ≠ “acceptable” position

• “OK to use” criteria:
  • Tube follows midline course down the chest without coils
  • Tip and all side holes are below GE junction
Enteric Tubes – Normal Position

NGT terminating in gastric body

DHT terminating in gastric antrum
Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
Enteric Tubes – Abnormal Position

• Positioning errors:
  • Coiled tube
  • Proximal/“marginal” placement
    • Aspiration risk

Tube terminating proximal to the GE junction
Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk

Tube tip below GE junction; side hole within distal esophagus
Enteric Tubes – Abnormal Position

• Positioning errors:
  • Coiled tube
  • Proximal/“marginal” placement
    • Aspiration risk
  • Kinked tube

Tube kinked within proximal stomach
Enteric Tubes – Abnormal Position

- Positioning errors:
  - Coiled tube
  - Proximal/“marginal” placement
    - Aspiration risk
  - Kinked tube
  - Pulmonary placement

Tube inserted through right bronchus into RLL
Tube inserted through left bronchus and deflected into right bronchus
Enteric Tubes – Abnormal Position

Positioning errors:
- Coiled tube
- Proximal/“marginal” placement
  - Aspiration risk
- Kinked tube
- Pulmonary placement

Tube inserted through right bronchus into RLL

Follow up chest X ray with right sided pneumothorax
Enteric Tubes – Abnormal Position

• Positioning errors:
  • Coiled tube
  • Proximal/“marginal” placement
    • Aspiration risk
  • Kinked tube
  • Pulmonary placement

Tube inserted through right bronchus into RLL

Tube inserted through left bronchus and deflected into right bronchus
Enteric Tubes – Abnormal Position

• Positioning errors:
  • Coiled tube
  • Proximal/“marginal” placement
    • Aspiration risk
  • Kinked tube
  • Pulmonary placement
  • Intracranial placement*

*Extremely rare (case reports); usually post-trauma

Tube inserted through right bronchus into RLL
Tube inserted through left bronchus and deflected into right bronchus
Enteric Tubes – Complications

- Complications:
  - Pulmonary contusion/laceration

Tube coiled within esophagus; second loop entering right bronchus with right airspace opacity
Enteric Tubes – Complications

• Complications:
  • Pulmonary contusion/laceration
  • Pneumothorax

Tube entering left bronchus with left basilar pneumothorax (deep sulcus-green arrow)
Enteric Tubes – Complications

• Complications:
  • Pulmonary contusion/laceration
  • Pneumothorax
  • Aspiration of feedings
    • Pneumonia
    • Abscess
    • Empyema

Tube entering right bronchus; RLL infiltrate after initiation of feeds
Enteric Tubes – Complications

• Complications:
  • Pulmonary contusion/laceration
  • Pneumothorax
  • Aspiration of feedings
    • Pneumonia
    • Abscess
    • Empyema
  • Diaphragmatic perforation
  • Esophageal perforation
    • Widened mediastinum, pneumomediastinum
  • Gastric perforation
    • Pneumoperitoneum

Tube entering right bronchus; RLL infiltrate after initiation of feeds
Enteric Tubes—Indications for Studies

- Radiographic evaluation indicated:
  - After enteric tube insertion (appropriateness score = 9)
  - Patient with enteric tube in place – clinical indications only (9)

- Radiographic evaluation NOT indicated:
  - Daily, routine follow-up (1)

- Imaging technique pearls:
  - Images should attempt to include pharynx → stomach
    - Maximize visualization of tube course
  - Higher penetration may allow better stripe/tip visualization

Legend: 1-3: usually not appropriate; 4-6: may be appropriate; 7-9: usually appropriate
Cardiac Devices – Normal Position

• Pacemakers
  • Pulse generator and lead wire with electrodes
  • Single lead: lead tip in RV apex (rarely RA)
  • Two lead: leads tips in RA and RV
  • Three lead (biventricular pacing/CRT): leads tips in RA, RV, and coronary sinus/cardiac vein
    • RV lead: stimulates septum
    • Coronary sinus: stimulates lateral LV wall
      • Postero-superior to RV lead
    • No leads in left heart (elevated pressures)
  • All leads should have gentle curves
Cardiac Devices – Normal Position

Single lead pacemaker with tip in RV (arrow)

Dual lead pacemaker with tip in RA (straight) and RV (curved)
Cardiac Devices – Normal Position

Triple lead pacemaker with leads in RA, RV, and coronary sinus
Cardiac Devices – Normal Position

• AICDs
  • Pulse generator and lead wires with electrodes
  • Leads distinguished from pacemakers by generally thicker wires and thick, radiopaque coils distally
    • Coil necessary for higher energy discharge (i.e. defibrillation)
    • Thicker wires → greater insulation
      • Less reliable indicator
  • Generally have two coils (single or separate wires)
    • Primary coil - RV
    • Additional coil – SVC or brachiocephalic vein
Cardiac Devices – Normal Position

AICD with coils in SVC and RV (single wire)
Cardiac Devices—Complications

- Complications
  - Pneumothorax
  - Vascular injury
  - Myocardial perforation (RV)
    - Pericardial effusion
    - Tamponade
  - Lead fracture
  - Lead twisting (Twiddler’s syndrome)
Cardiac Devices– Complications

• Complications
  • Pneumothorax
  • Vascular injury
  • Myocardial perforation (RV)
    • Pericardial effusion
    • Tamponade
  • Lead fracture
  • Lead twisting (Twiddler’s syndrome)

Right ventricular lead fracture
## Summary

- Endotracheal tubes

<table>
<thead>
<tr>
<th>Normal Position</th>
<th>Common Positioning Errors</th>
<th>Important Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• At least 2 cm above carina</td>
<td>• Too high</td>
<td>• Spontaneous extubation</td>
</tr>
<tr>
<td>• At or below medial ends of the clavicle</td>
<td>• Mainstem bronchus intubation</td>
<td>• Aspiration</td>
</tr>
<tr>
<td>• Varies ±2 cm with neck movement</td>
<td>• Esophageal intubation</td>
<td>• Atelectasis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Pneumothorax</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Gastric/esophageal injury or perforation</td>
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</tbody>
</table>
Summary

- Tracheostomy tubes

<table>
<thead>
<tr>
<th>Normal Position</th>
<th>Common Positioning Errors</th>
<th>Important Complications</th>
</tr>
</thead>
</table>
| • Similar tip positioning as ETT  
  • At least 2/3 of “smooth” portion in trachea | • Too high/incomplete insertion | • Tracheal injury  
  • Pneumothorax  
  • Hemorrhage |
Summary

- Central venous catheters

<table>
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<th>Common Positioning Errors</th>
<th>Important Complications</th>
</tr>
</thead>
</table>
| • Tip terminating over cavo-atrial junction (inferior border of right bronchus) | • Ipsilateral IJ  
• Contralateral brachiocephalic  
• RA/RV  
* Beware of anatomic variants | • Pneumothorax  
• Vascular perforation |
Summary

- PA catheters

<table>
<thead>
<tr>
<th>Normal Position</th>
<th>Common Positioning Errors</th>
<th>Important Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tip position in proximal interlobar PA (roughly within mediastinal shadow)</td>
<td>• Too distal positioning</td>
<td>• PA infarction</td>
</tr>
<tr>
<td>*Resting position depends on function</td>
<td>• Otherwise similar to that of CVCs</td>
<td>• PA rupture/dissection</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Otherwise similar to that of CVCs</td>
</tr>
</tbody>
</table>
Summary

• Chest tubes

<table>
<thead>
<tr>
<th>Normal Position</th>
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<th>Important Complications</th>
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</thead>
<tbody>
<tr>
<td>• Air removal – directed anterior and superior</td>
<td>• Incomplete insertion</td>
<td>• Ineffective drainage</td>
</tr>
<tr>
<td>• Fluid removal – posterior and inferior</td>
<td>• Tube kinking</td>
<td>• Pulmonary laceration/contusion</td>
</tr>
<tr>
<td>• All side holes completely visualized with the pleural space</td>
<td>• Chest wall</td>
<td>• Pulmonary infarction</td>
</tr>
<tr>
<td></td>
<td>• Lung fissures</td>
<td>• Subcutaneous emphysema</td>
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<tr>
<td></td>
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<td>• Reexpansion pulmonary edema</td>
</tr>
</tbody>
</table>
### Summary

- **Enteric tubes**

<table>
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<th>Normal Position</th>
<th>Common Positioning Errors</th>
<th>Important Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Roughly vertical/midline course down esophagus</td>
<td>• Coiled tube</td>
<td>• Aspiration</td>
</tr>
<tr>
<td>• Tip and all side holes distal to GE junction</td>
<td>• Proximal/&quot;marginal&quot;</td>
<td>• Pulmonary contusion/laceration</td>
</tr>
<tr>
<td>• Distal position depends on function</td>
<td>• Kinked tube</td>
<td>• Pneumothorax</td>
</tr>
<tr>
<td></td>
<td>• Pulmonary placement</td>
<td>• Esophageal/gastric perforation</td>
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References


