Review Article

MONITORING LINES AND TUBES ON CHEST RADIOGRAPH IN THE CARDIAC INTENSIVE CARE UNIT

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ABSTRACT:

A variety of medical devices are used in the intensive care unit for long durations. Each one of them is a double-edged sword: intended to save life, but life-threatening if in the wrong place. Hence, it is important to periodically check that these devices are correctly placed so as to prevent complications. The portable chest radiograph is of tremendous value in this context.

OBJECTIVE: Following the completion of this exercise the individual should be able to recognize the common complications of mechanical lines and their correct positioning as well as normal and pathological appearances of portable chest x-rays in cardiac intensive care unit.

KEYWORDS: Chest radiograph; intensive care unit; catheters; lines; tubes.

INTRODUCTION:

In the intensive care setting catheters, tubes, and monitoring devices play an important role in patient care. Proper placement of these devices is crucial to their function. The portable chest x-ray is also an important tool used to quickly recognize complications of device placement. When studying an ICU chest radiograph the proper placement of devices should be evaluated first, prior to looking for cardiopulmonary disease.The chest radiograph (CXR) plays a crucial role in critically ill patients in intensive care units. It is the most common radiological investigation ordered due to its diagnostic value in cardiorespiratory disease. The American College of Radiology (ACR) recommends a CXR immediately following placement of indwelling tubes, catheters and other devices to check the position and detect procedure related complications. [(1)]Bekemeyer and colleagues found that 27% of newly placed catheters or tubes were improperly positioned and that 6% resulted in a radiographically visible complication of the intervention. [(2)] Although many such abnormalities may not be immediately life-threatening, some require rapid correction to avoid clinical deterioration in patients with marginal cardiopulmonary reserve. All catheters have the potential risks of coiling, misplacement, knotting, and fracture. It is important to understand the function of a device as well as to recognize the complications associated with its use. We will now discuss the commonly used tubes and lines.

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NASOGASTRIC TUBE:

Chest radiography for nasogastric tube (NGT) position is commonplace in many hospitals. The aim is to positively confirm that the exit hole(s) of the NGT is/are within the gastrointestinal tract (usually the stomach). If the longer nasoenteric tube is used, the objective is to place the tip of the tube past the pylorus into the jejunum.

Nasogastric tubes (NGT) are inserted through nares and into the stomach for either feeding the patient or for aspiration of gastric contents, and for these purposes the tip should lie within the stomach. The NG tube has multiple side holes. There are terminal lead balls to facilitate identification of the tip. Pushing air into the NG tube while auscultating with a stethoscope over the stomach is the usual method by which correct positioning in the stomach is confirmed. Generally a chest x-ray is not necessary following the placement of a nasogastric tube. A chest x-ray may be obtained following the insertion of small-bore feeding tubes to rule out placement within the lung, which may have serious consequences. Also, If the side holes are positioned within the esophagus there is increased risk of aspiration (Figure 1). For this reason, the tip of the NG tube should be positioned at least 10-cm caudal to location of the gastroesophageal junction.

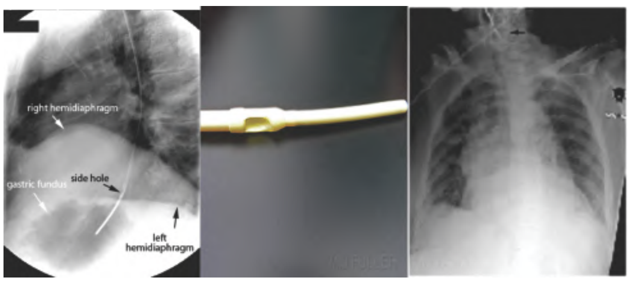

Figure 1: A.B. The tip of the NGT is within the fundus of the stomach. This tube has a sidehole only (no end hole). The sidehole is seen to be above the left hemidiaphragm. This is an unacceptable position. Frontal (C) The NGT is coiled up in the pharynx. This position can easily be missed if the patient's neck is not included on the image.

NGT will be visualized below the diaphragm. Radiographers will commonly place the cassette in the portrait position rather than the landscape position to ensure that the subdiaphragmatic anatomy is included.

In some cases the NGT can become coiled up in the pharynx. If you don't include the pharynx, the result can be puzzling- where did the NGT go?A *penetrated* exposure is often required to visualize the tip of the NGT below the diaphragm, particularly when using non-digital equipment.

Inadvertent insertion into the trachea and bronchus (Figure 2) can cause pneumonia, pulmonary contusion, pulmonary laceration or pnemothorax. Pharyngeal and esophageal perforations can occur but are rare. [3]

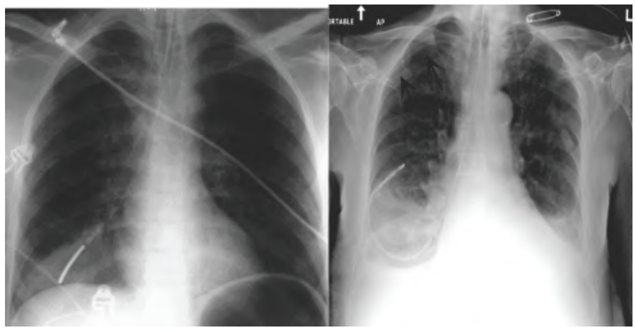

Figure 2: A. Nasogastric Tubes has travelled through tracheasto tight lower bronchus. Infusion of fluid and feed would have serious consequences. B. Nasogastric tube passed down the right main bronchus causing a large pneumothorax.

ENDOTRACHEAL TUBE

The endotracheal (ET) tube is used for ventilation of both the lungs and for prevention of aspiration. It has a terminal hole and a cuff. Successful intubation and satisfactory position of an ET tube in the neutral position of the neck is with the tip 5-7 cm above the carina. The location can vary approximately 2 cm in the caudal or cephalad directions with neck flexion and extension, respectively. [4] When the carina is not visible, the tip of the ET tube should be approximately at the level of the medial ends of the clavicle. It should lie midway between the larynx and carina so that injury to either structure or complications like inadvertent extubation or selective main-stem bronchus intubation is avoided. Selective intubation can cause collapse of the contralateral lung (Figure 3), hyperinflation of the ipsilateral lung, or pneumothorax. An immediate chest x-ray after intubation is warranted because these complications are not uncommon and because the tube is quite commonly malpositioned.[5] Main stem intubation can be clinically occult in about 60% of patients and only revealed on the chest x-ray. [6] One other thing that must also be checked for is an aspirated tooth.The rate of serious malposition of endotracheal tubes has been reported to be between 12-15%. Given that frequency, daily chest x-rays in intubated patients are recommended. Lateral radiographs are useful when an upper airway injury is suspected. Widening of the soft tissues between the trachea and cervical spine is often present when there is a space-occupying lesion such as a hematoma.Unfortunately, injury to the vocal cords, such as cord paralysis, is not evident until the patient is extubated. Catastrophic injury to the trachea, such as tracheal rupture, should be suspected in patients with pneumothorax, pneumomediastinum, subcutaneous emphysema in the neck or precipitous respiratory failure following intubation. Tracheal rupture usually occurs posteriorly through the membranous portion of the distal trachea or through the proximal main bronchi.

Figure 3 (A, B): Frontal chest radiographs show an endotracheal tube in the right main bronchus (arrowhead in A), causing hyperinflation of the ipsilateral lung and partial collapse of the left lung (curved arrow in A). After withdrawal of the tube into the trachea (arrow in B), the left lung has inflated. C: Tracheal rupture following improper intubation.

Inadvertent esophageal intubation (Figure 4) is a dreadful complication. Failure to diagnose esophageal intubation is immediately fatal if the patient has no spontaneous respiration. Methods used to diagnose esophageal intubation are hence methods which produce confirmation of tube placement within seconds of the intubation, which is mostly diagnosed clinically; it can be detected radiologicallyby the presence of an over-distended stomach in chest x-ray. Tracheal stenosis can occur following long-term tube placement.

Figure 4: Frontal radiograph of a neonate shows inadvertent placement of an endotracheal tube in the esophagus (arrow) with distension of the esophagus and stomach (arrowheads) with air.

TRACHEOSTOMY TUBE

For patients on ventilators in intensive care unit (ICU), elective tracheostomies are indicated if it is anticipated that their stay on the ventilator would be more than 7 days.[17] A rare complication occurs when a tracheostomy tube is fractured.[18]. Ideally tip of the tracheostomy tube should be half way between the stoma and the carina, at the level of the D3 vertebra. Unlike the ET tube, its position is maintained with neck flexion and extension. The width of the tube (diameter) should be 2/3 rd of the tracheal width, and the cuff should not distend the tracheal wall. It should lie parallel to the trachea. Other possible complications are surgical emphysema, pneumomediastinum, pneumothorax (Figure 5), hemorrhage, false tract, and tracheal stenosis. Hematoma causes widening of the superior mediastinum.

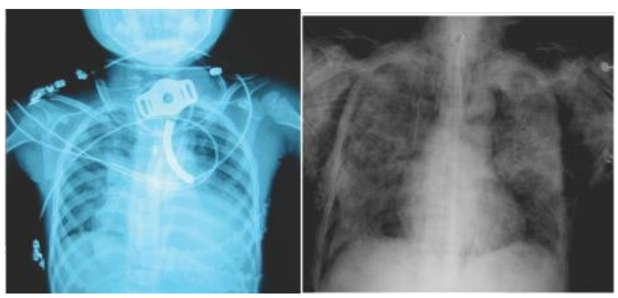

Figure 5:A. fractured outer tracheostomy tube dislodged into the left tracheobronchial tree with associated atelectasis and pleural effusion of the left lower zones. B. Frontal chest radiograph shows complications of tracheostomy: pneumothorax, pneumomediastinum, and surgical emphysema.

CHEST DRAINAGE TUBE

The pleural tube, more commonly known as the intercostal drainage tube (ICD), is inserted through the 4 th intercostal space in the anterior or mid-axillary line. It is then directed posteroinferiorly in cases of effusion and anterosuperiorly in cases of pneumothorax. The ICD tube has a terminal hole as well as side holes; the side holes can be identified on a CXR by the interruption in the radiopaque outline of the tube. No side holes should lie outside the chest/pleura and the tube should not float above the effusion like a 'lotus in the pond.' Chest tube malposition occurs in about 10% of placements, rendering the tube malfunctioning or nonfunctioning (Figure 6). [1] Occasionally the tube tip may lie in an interlobar fissure or even within the lung parenchyma (Figure 7). Both frontal and lateral CXRs are necessary to ensure proper positioning of the chest tube. Mediastinal drains are usually present following sternotomy and, except for their position, resemble pleural tubes in all respects.

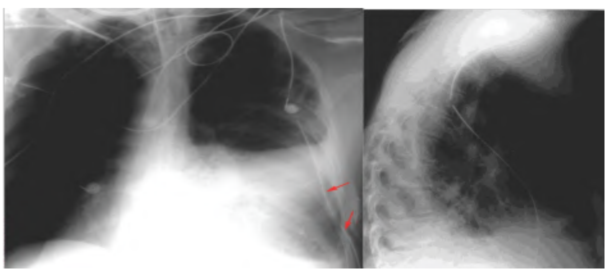

Figure 6: A. This chest tube failed to remove the pleural effusion due to anterior placement.
Btube in good position for treatment of a pneumothorax but not for an effusion.

Complications of thoracostomy tube placement frequently involve injury to adjacent structures. This is often difficult to detect with a chest x-ray alone and may require a CT scan in patients with suspected injury. CT is also useful when the location of the tube is important and unclear on plain radiographs.

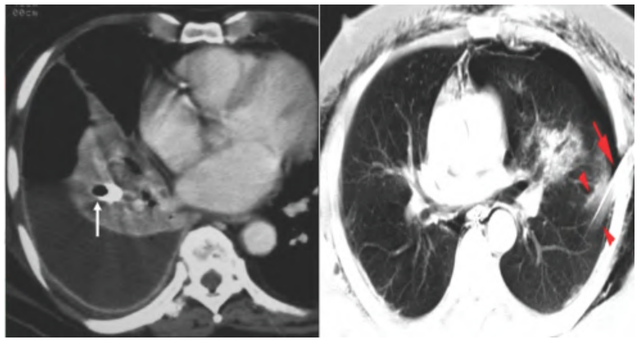

Figure 7: A. Contrast-enhanced axial CT image of the same patient as figure 6 demonstrates the tip of the intercostal drainage tube (arrow) within the lung. B.CT demonstrating chest tube (arrow) penetrating lung parenchyma with surrounding intraparenchymal hematoma (arrow heads), Pnemothorax(yellow arrow. S/C emphysema(green arrow head)

CENTRAL VENOUS LINE

The intravascular volume status of critically ill patients is crucial to their management. Central venous lines (catheters) are used for a variety of purposes, e.g., hemodynamic pressure monitoring; hemodialysis; and administration of medications, nutrition, and fluids. [7] They provide long-term venous access. Central venous lines are inserted through major veins such as the subclavian, internal jugular, or femoral veins into the superior vena cava. The tip of the line should be distal to the last venous valve, which is located at the junction of the internal jugular and the subclavian veins. On the CXR, the position of the valve corresponds to the inner aspect of the first rib (Figure 8). Many central venous lines have two or three lumens, each with a different orifice. If the tip of the line is positioned in the superior vena cava, all orifices will be distal to the last valve. On the CXR, the first anterior intercostal space corresponds to the approximate site of the junction of the brachiocephalic veins to form the superior vena cava(Figure8). On the CXR, the cavoatrial junction corresponds to the lower border of bronchus intermedius(Figure 8). [8] If the line tip reaches the right atrium, it can cause dysrhythmia or result in injection of undiluted toxic medications into the heart.

In about 30% of cases the initial radiographs show a malpositioned central venous line. [9] Complications vary with the type of line and the site of insertion. [10] Pneumothorax occurs in up to 6% of procedures and is more common with the subclavian approach (Figure9). [5] If initial placement fails, a CXR before attempting the procedure on the other side helps avoid bilateral pneumothoraces.

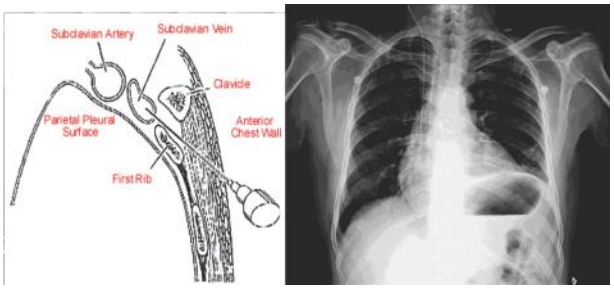

Figure 8: A. This sagittal view of the chest shows the proximity of the parietal pleural and the subclavian vein.B.Central venous catheter tip (small arrow) at junction of right subclavian vein and superior vena cava.

Figure 9: Frontal chest radiograph shows a right-sided pneumothorax following insertion of a central venous catheter.

If the central venous line tip abuts the venous wall there is a risk of vessel perforation, with resultant infusion of fluid into the mediastinum or pleural or pericardial space. On the CXR, this complication will appear as mediastinal widening (Figure 10), enlargement of the cardiac silhouette, or a new pleural effusion (Figure 11)

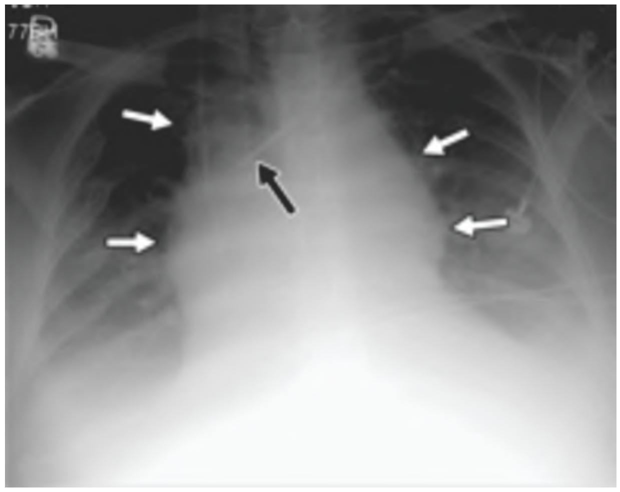

Figure 10: Frontal chest x-ray following placement of a central venous catheter shows right paratracheal soft tissue with a bulging contour (arrows), due to mediastinal hematoma.

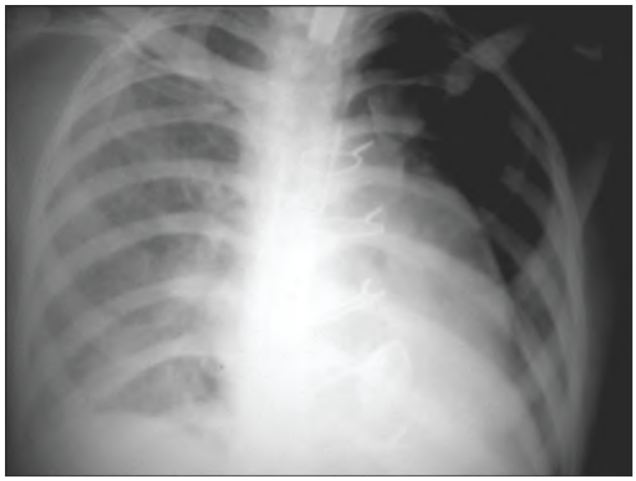

Figure 11: Chest X-ray taken after CVP line insertion showing homogeneous haze over right hemithorax (which was a fresh finding compared to earlier normal radiographs). This was due to vessel perforation by the catheter and resultant accumulation of fluid in the pleural space.

Other complications are abnormal course, cardiac perforation, and arrhythmias. Abnormal course of a central venous line or malpositioning occurs when it enters a tributary such as the azygos vein, subclavianvein, internal mammary vein, or an anomalous vein such as a persistent left-sided superior vena cava; the line may even enter the carotid vessels (Figure12). [11

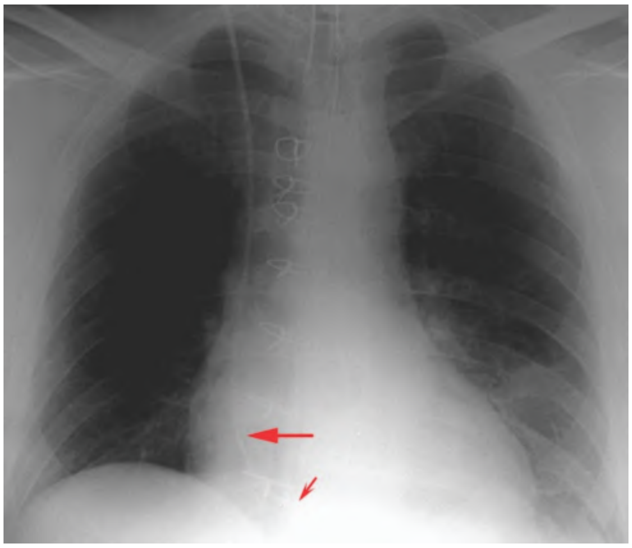

Figure 12: A. Placement of CVP line beyond SVP. Intracardiac placement of a central venous catheter (arrow). The tip (small arrow) is within the right ventricle.

PULMONARY ARTERY CATHETER (SWAN-GANZ)

Swan-Ganz catheters (pulmonary capillary wedge pressure monitors) are used to measure pulmonary wedge pressures. These catheters allow the intensivist to have an accurate measurement of the patient's volume status and can help differentiate between cardiac and non-cardiac pulmonary edema. Pulmonary capillary wedge pressure catheters (PCWP) are introduced percutaneously into the venous system. They are advanced through the right heart and into the pulmonary artery. A balloon at the end of the catheter is then inflated causing the tip of the catheter to be wedged into a branch of the pulmonary artery. Once the tip is wedged, the balloon should be deflated. Once a reading is obtained, the tip is pulled back to the main pulmonary artery. The catheter tip should ideally be positioned no more distally than the proximal interlobar pulmonary arteries. To avoid complications, the tip of the Swan-Ganz catheter must not be more than 1 cm lateral to the mediastinal margin. The rule of thumb is that the catheter should not extend beyond the pulmonary hilum on the CXR; else, it should be retracted. [12] The complication rate of pulmonary infarction is reduced when the balloon is inflated only during pressure measurement and insertion. Potential complications are pulmonary infarction (Figure 13), pulmonary artery perforation, arrhythmias, cardiac perforation, intracardiac knotting and placement in the inferior vena cava (Figure 14A,B,C).

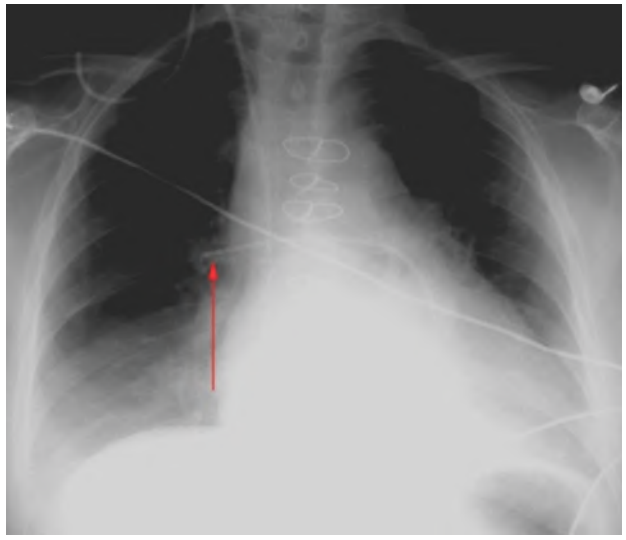

Figure 13: A. Chest x-ray showing location of Swan-Ganz catheter tip (arrow) in the right pulmonary artery(red arrow).

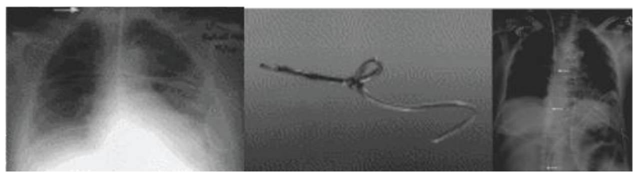

Figure 14: A.Chest X-ray showing knotted catheter in the superior vena cava B. Catheter showing the knot following successful surgical removal. C.X-ray chest shows malposition of a Swan-Ganz catheter (arrows) in the inferior vena cava.

INTRA-AORTIC BALLOON PUMP

Intraaortic balloon pumps (IABP) are used to improve coronary artery perfusion. When distended in diastole; the balloon causes increased pressure in the proximal aorta, thus improving coronary artery perfusion. Broadened applications of intra-aortic balloon pumping have resulted in increasing numbers of patients being treated by this modality.Intra-aortic balloon pump (IABP) is a long-balloon temporary circulatory assist device that works on the principle of cardiac counter-pulsation. The IABP is used to support the circulation. The balloon, approximately 25-cm long, is mounted on a catheter. The catheter tip is visible as a 3 x 4-mm rectangular metallic density while the rest of the catheter is radiolucent (Figure 15). The catheter is inserted through the femoral artery. The balloon is inflated with gas during diastole and deflates during systole, resulting in increase in coronary blood flow and reduction in left ventricular afterload (and hence, reduction in myocardial oxygen consumption). [13] The various indications are acute myocardial infarction (MI) with cardiogenic shock, post-coronary artery bypass graft (high-risk cases with low ejection fraction of <20%), acute mitral insufficiency, and cardiac transplantation. It is contraindicated in aortic regurgitation, aortic dissection, and in the presence of a prosthetic graft in the thoracic aorta (within 12 months of surgery). To avoid occlusion of the left subclavian artery and visceral and renal arteries, its tip should be slightly cephalad to the adjacent carina (2nd -3rd intercostal space). The balloon should not occlude more than 85-90% of the aortic diameter. Most complications of IABP are related to insertion of the catheter, more specifically to vessel injury. Intimal injury can occur anywhere from the femoral arteriotomy to the aortic arch. More severe injury, dissection and perforation, tend to occur at the aorto-iliac segment where some resistance is encountered. Balloon rupture with air embolization and septicemia are rare potential complications.

Figure 15: X-ray chest shows tip of this catheter is an approximately **1-cm metallic marker** approximately 2-4 cm below the level of the aortic arch.

PACEMAKERS

A pacemaker is a small device that's placed under the skin of chest or abdomen to help control abnormal heart rhythms. This device uses electrical pulses to prompt the heart to beat at a normal rate.Pacemakers are used in cases of severe sinus node dysfunction, complete heart block, and various arrhythmias. They have two main elements: a pulse generator and a lead wire with electrodes. The single-lead pacemaker is the most basic type and is positioned with its tip in the right ventricular apex (Figure 16) A. An atrioventricular two-lead sequential pacemaker has one electrode in the right atrium and the other at the right ventricular apex (Figure 16) B. Sometimes a third lead is placed in the coronary sinus to pace the left ventricle (Figure 17). It is not feasible to insert an electrode in the left side of the heart due to the high pressures in these chambers. Temporary epicardial wires are sometimes inserted during cardiac surgery; the tips of these wires resemble a corkscrew. They can be removed easily.

Figure 16: (A) Optimal position of the electrode of a single-lead pacemaker. The electrode has been placed in the right ventricular apex. (B) shows a two-lead pacemaker that has one electrode in the right

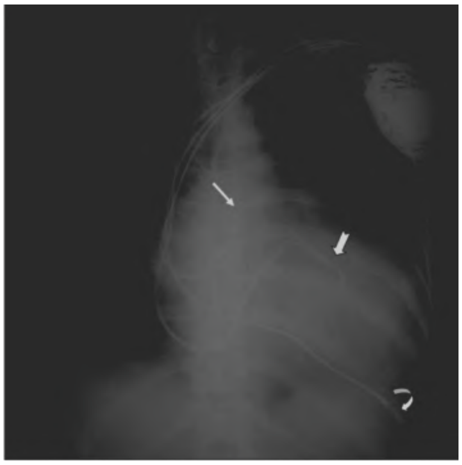

Figure 17: Optimal position of a biventricular pacemaker. Besides the electrodes in the right atrium (straight arrow) and right ventricle (curved arrow), the third electrode is placed in the coronary sinus (notched arrow)

A lateral CXR is usually required to confirm the position of the electrode in the right atrial appendage. The tip points anteriorly when correctly positioned. The tip may have a slight bend as it abuts the wall but there should no sharp bends. The potential complications are malposition, intracardiac knotting (Figure 18), fracture, perforation (Figure 19), cardiac tamponade, arrhythmias, infection, and hemorrhage. Twiddler's syndrome is a rare disorder in which twisting of the lead occurs either due to the patient's manipulation or spontaneously (Figure 20).

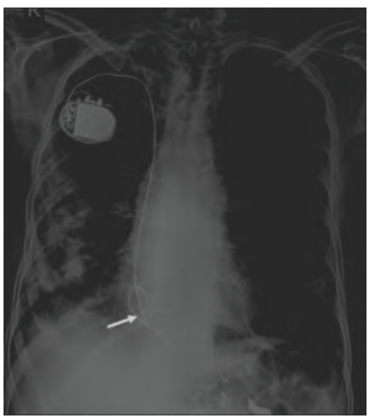

Figure 18: Chest radiograph shows coiling of the lead (arrow) of a single-lead pacemaker in the right atrium.

Figure 20: Chest radiograph shows recoil of the pacemaker lead with its tip in the superior vena cava (arrow). This is called Twiddler's syndrome.

IMPLANTABLE CARDIOVERTER DEBRILLATOR (ICD)

An implantable cardioverter-defibrillator (ICD) is a specialized device designed to directly treat a cardiac tachydysrhythmia. Newer-generation ICDs are also equipped with a demand pacing system and are a combination of an ICD and a pacemaker.It has two electrodes (one electrode in the right atrium and the other in the right ventricle). The lead is wider compared to the pacemaker lead and has a 'coiled-spring' appearance (Figure 21). The implantation procedure, much like implanting a permanent pacemaker, has become very safe. Complications are similar to those with transvenous pacemakers.

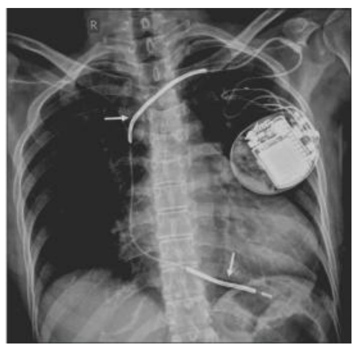

Figure 21: Chest Radiograph of a patient with implantable cardioverterdebrillator.

Dense bands (arrows) along the electrode are characteristic of this device.

CONCLUSION

The portable CXR is invaluable for monitoring the various indwelling devices used in critically ill patients. A systematic approach and knowledge of the radiographic features of the common indwelling tubes and lines is of the utmostimportance.

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