Zeszyty Naukowe
Państwowy Instytut Medyczny MSWiA

CLINICAL PRACTICE

ZN PIM MSWiA; 1/2026 | e-ISSN 2956-8005
DOI 10.53266/ZNPIM-00049-2023-02

Review article

Aspects of Radiological Evaluation in Central Venous Catheter (CVC) Management

Dominika Kozłowska [1], Urszula Kopydłowska [2], Katarzyna Sklinda [1], Konstanty Szułdrzyński [2], Bartosz Mruk [1], Jerzy Walecki [1]

[1] Klinika Radiologii, Radioterapii i Medycyny Nuklearnej, Państwowy Instytut Medyczny MSWiA w Warszawie, Polska;
[2] Klinika Anestezjologii i Intensywnej Terapii, Państwowy Instytut Medyczny MSWiA w Warszawie, Polska.

Abstract

Introduction and objective Radiologists frequently encounter requests from healthcare professionals to evaluate the placement of central venous catheters (CVCs) and to identify potential complications that may arise during their insertion. The confirmation of the CVC tip's precise location is typically performed through the acquisition of a bedside chest radiograph following directly catheter placement, prior to the commencement of any medical interventions involving the catheter. Radiological control of the position of the central catheter begins at the stage of performing the procedure. Ultrasound examination is not only used to locate the vessel, but also allows for the assessment of its anatomy, patency and adjacent structures. CVCs are commonly inserted in critically ill patients to facilitate the monitoring of hemodynamic parameters and to administer of parenteral nutrition or medications.These catheters are typically introduced into either the internal jugular or subclavian vein.

What's already known about this topic? The placement of a central venous catheter is a routine procedure in hospital settings. Such a collaborative approach between radiologist and healthcare professionals is pivotal in optimizing patient's care and treatment outcomes. The first-line modality to ensure accurate location and identifying potential complications is an X-ray imaging.

Abstract Central line insertion is a procedure involving the cannulation of a wide-diameter vein. This procedure is performed in hospitalized patients requiring long-term intravenous administration of drugs, potent medications - including catecholamines, high osmolarity substances and vascular irritants, such as parenteral nutrition solutions or chemotherapeutics. Central venous access allows monitoring of hemodynamic parameters and can be used as an introducer for the endocavitary electrode, enabling electrical stimulation of the myocardium. Inserting a central line may be associated with many complications, such as: pneumothorax, bleeding, too shallow, too deep or incorrect location of the catheter. Radiological assessment of the location of the catheter positioned in superior vena cava before it is used for drug delivery is the basis for safe use of central vascular access.

Streszczenie

Wprowadzenie i cel Lekarze radiolodzy często spotykają się z prośbami lekarzy klinicystów o ocenę położenia wkłuć centralnych i identyfikację potencjalnych powikłań, które mogą wystąpić podczas ich zakładania. Położenie wkłucia najczęściej jest oceniane bezpośrednio po jego założeniu w badaniu RTG przyłóżkowym klatki piersiowej. Kontrola radiologiczna położenia cewnika centralnego zaczyna się już na etapie wykonywania procedury. Badanie ultrasonograficzne nie służy jedynie lokalizacji naczynia, ale pozwala również na ocenę jego anatomii, drożności i sąsiadujących struktur. Wkłucia centralne są zakładane głównie u pacjentów ciężko chorych w celu ułatwienia monitorowania parametrów hemodynamicznych oraz podawania leków lub żywienia pozajelitowego. Cewniki te zazwyczaj wprowadza się do żyły szyjnej wewnętrznej lub podobojczykowej.

Skrócony opis stanu wiedzy Zakładanie wkłucia centralnego jest rutynową procedurą w warunkach szpitalnych. Współpraca lekarzy radiologów i lekarzy klinicystów jest kluczowa dla bezpieczeństwa pacjenta i pomyślnego przebiegu leczenia. Badaniem pierwszego rzutu umożliwiającym określenie położenia i ewentualnych powikłań związanych z wprowadzeniem cewnika centralnego jest badanie rentgenowskie.

Streszczenie Założenie centralnego cewnika żylnego jest procedurą polegającą na kaniulacji naczynia żylnego o szerokim świetle. Procedurę tę wykonuje się u pacjentów hospitalizowanych, wymagających długotrwałego podawania leków drogą dożylną, substancji o bardzo silnym działaniu - w tym amin katecholowych, preparatów o wysokiej osmolarności oraz drażniących naczynia krwionośne, takich jak preparaty do żywienia pozajelitowego czy chemioterapeutyki. Cewnik centralny pozwala na monitorowanie parametrów hemodynamicznych oraz może służyć jako śluza dla elektrody endokawitarnej, umożliwiając prowadzenie stymulacji elektrycznej mięśnia sercowego. Założenie wkłucia centralnego może wiązać się z wieloma powikłaniami takimi jak: odma opłucnowa, krwawienie, zbyt płytka, zbyt głęboka lub niewłaściwa lokalizacja cewnika. W związku z tym ocena radiologiczna położenia cewnika zlokalizowanego w żyle głównej górnej zanim zostanie on wykorzystany do podaży leków jest warunkiem bezpiecznego użytkowania centralnego dostępu naczyniowego.

Keywords *catheter, x-ray, pneumothorax, CVC*
Słowa kluczowe *odma opłucnowa, badanie RTG, wkłucie centralne, cewnik*

Correspondence:
Dominika Kozłowska
dr.dkozlowska@gmail.com

Introduction

Radiologists frequently encounter requests from healthcare professionals to evaluate the placement of central venous catheters (CVCs) and to identify potential complications that may arise during their insertion.

Central venous access allows monitoring of hemodynamic parameters and can be used as an introducer for the endocavitary electrode, enabling electrical stimulation of the myocardium. When accessed through the internal jugular and subclavian veins, the tip of the catheter should be placed in the superior vena cava, right above the entry to the right atrium. Such placement of the catheter tip allows for high concentrations of inotropic drugs despite impaired peripheral perfusion and as a vascular sheath allows for placing the electrode tip precisely within the chambers of the heart. The vessel of choice is the right internal jugular vein - due to anatomical conditions, the cannula's path from the puncture site towards the right atrium runs almost in a straight line. Any looping or bending of the catheter tip causes damage to the endothelium, resulting in an increased risk of thrombosis and consequently - pulmonary embolism. Endothelial damage may occur through mechanical trauma (laceration, abrasion formation) or chemical injury - administration of high osmolarity medication in the peripheral direction at high infusion rates may cause phlebitis [3]. Radiological assessment of the location of the catheter positioned in superior vena cava before it is used for drug delivery is the basis for safe use of central vascular access.

However, obtaining high-quality X-ray images in such patients can pose technical challenges due to a number of factors such as the patient's supine bedside positioning or limited cooperation.

CVC Tip Location

The preferred location of the tip of a CVC is the lower portion of the superior vena cava (SVC) [Figure 1] or the superior cavoatrial junction [1]. In cases of short-term usage, such as fluid delivery or hemodynamic monitoring, positioning within the superior vena cava (SVC) is generally considered suitable. For long-term insertion, the optimal position is typically at the cavoatrial junction [2].

Radiological control of the position of the central catheter begins at the stage of performing the procedure. Ultrasound examination is not only used to locate the vessel, but also allows for the assessment of its anatomy, patency and adjacent structures. The Duplex Doppler imaging technique enables simultaneous assessment of the vessel anatomy and visualization of the characteristics of blood flow in its lumen. Monophasic flow towards the heart is characteristic of venous vessels. The choice of vessel should be made after bilateral examination of the jugular and subclavian vein system, this is especially important in patients after multiple cannulations and oncological treatment. Common findings that may contribute to cannulation failure are anatomical variants of the vein course and the presence of a thrombus in the vessel lumen. Ultrasound-guided cannulation of the vessel can be performed using the in-plane or out-of-plane technique. In in the in-plane technique, the needle is positioned in the plane of the ultrasound beam, in the out-of-plane technique - perpendicular to the plane of the beam. The choice of the transducer depends on the depth at which the vessel is located- in the case of cannulation of the internal jugular veins and subclavian veins, a linear transducer is usually used. The basis for safe venipuncture is continuous and precise control of the position of the needle tip. After obtaining free blood flow, a guide is inserted into the vessel, then

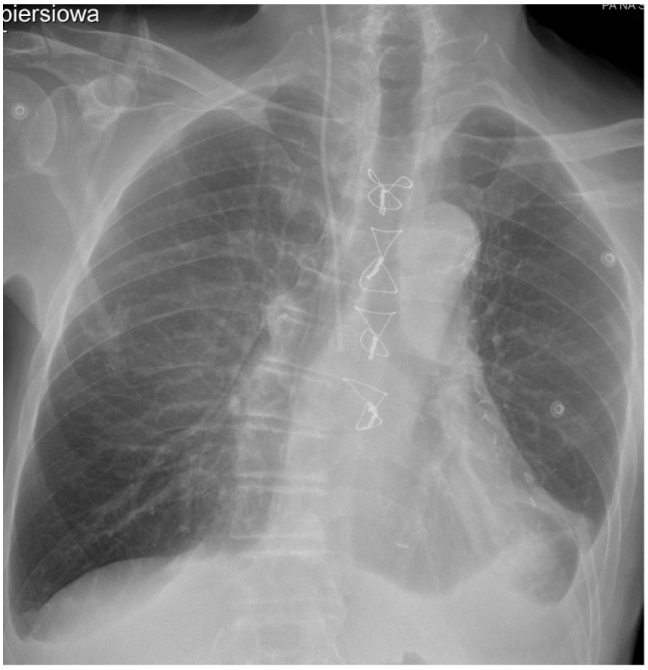

Figure 1 *The X-ray present correct insertion of CVC through the right internal jugular vein to VCS.*

a dilator. A tunnel is created through which the catheter is smoothly inserted central. Easy insertion ability, flow of blood through all cannula taps, and the absence of blood pulsation are not reliable signs of correct positioning of the catheter in the vein. Imaging the position of the catheter along its entire course in the vessel is not available using ultrasound, so it must ultimately be confirmed by X-ray or, in case of doubt, computed tomography.

Complications

Post-CVC insertion X-ray serves as a valuable tool for detecting prevalent complications, notably iatrogenic pneumothorax [Figure 2].

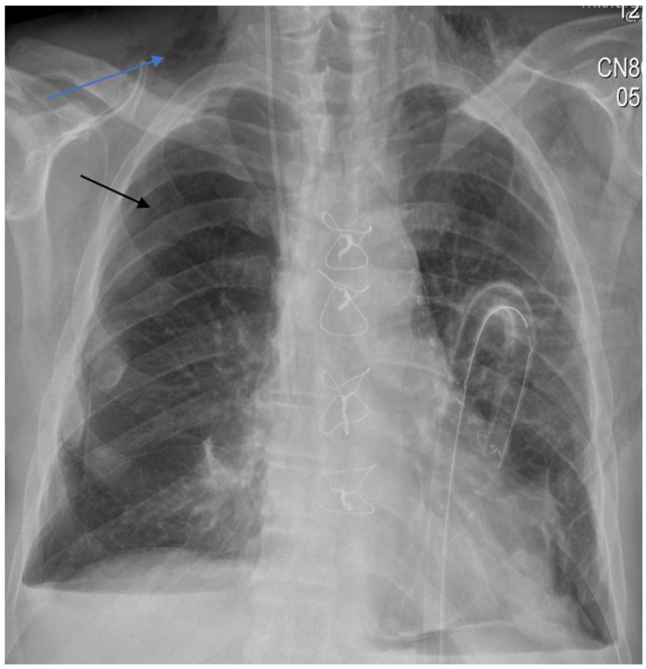

Figure 2 *The X-ray of the right-sided pneumothorax as the complication of insertion of CVC. (black arrow); Right-sided subcutaneous emphysema (blue arrow) as another complication of insertion of CVC.*

Subcutaneous emphysema is often associated with pneumothorax and studies indicate a higher incidence of pneumothorax following subclavian vein puncture [2]. However, X-rays, particularly when taken in the supine position, might not always reveal small pneumothoraces. Generally, conservative management suffices for such cases, without significantly impacting the patient's treatment trajectory.

In situations of clinical uncertainty, a chest CT scan is the modality capable of identifying pneumothoraces invisible on X-ray. Furthermore, X-ray can play a crucial role in identifying improper catheter placement, thereby mitigating the risk of delayed complications like pericardial tamponade or vessel wall erosion. The tip of the CVC may be positioned too shallow (e.g., in the jugular, subclavian, or brachiocephalic vein) or too deep, such as in the right atrium [Figures 3, 4, 5]. Adoption of ultrasound-guided insertion as a standard of care has contributed to a reduced risk of complications.

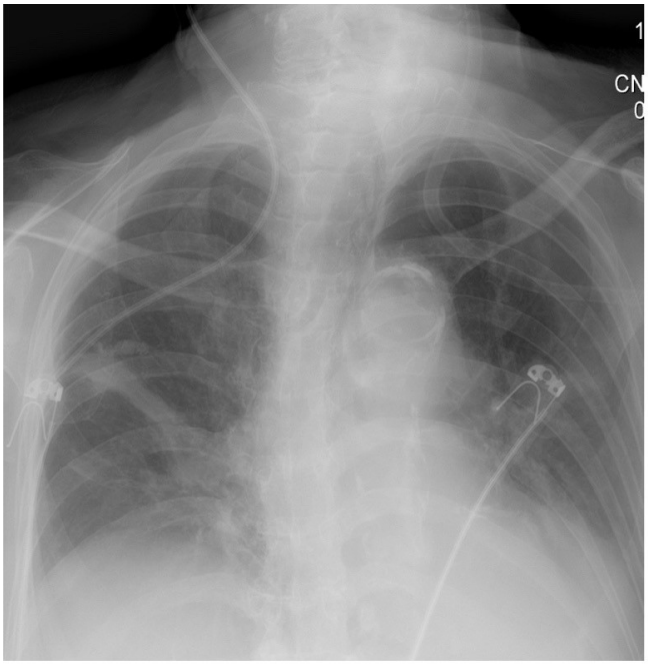

Figure 3 *The X-ray of the chest shows the misplaced catheter – the tip entered the right subclavian vein.*

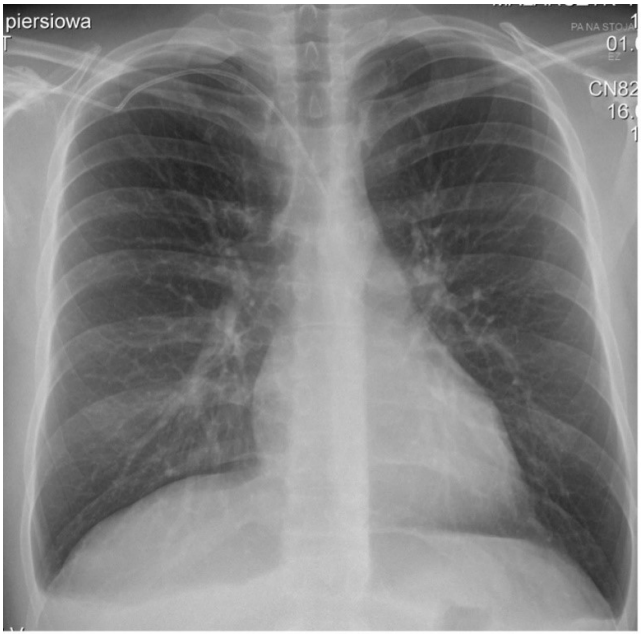

Figure 4 *The X-ray of the misplaced catheter – arterial injection.*

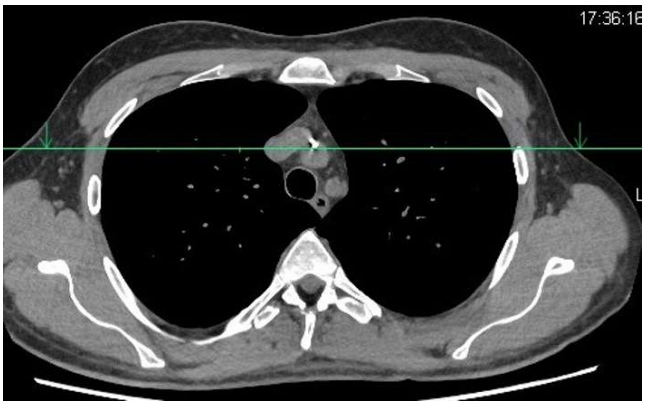

Figure 5 *The same misplaced catheter as above seen as a "white dot" in axial CT image without contrast enhancement – the tip in brachiocephalic trunk.*

Conclusion

In conclusion, the placement of a central venous catheter is a routine procedure in hospital settings. Ensuring accurate positioning and identifying potential complications is of paramount importance for patient's safety [1]. X-ray imaging is the first-line modality of visualizing the location of the CVC and assessing potential issues.

Thorough and accurate interpretation of the radiological study requires comprehensive information about the patient's clinical status and the intended purpose of the examination from the referring clinician. Such a collaborative approach is pivotal in optimizing patient's care and treatment outcomes.

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