Surgery Research Journal
ISSN: 2768-0428

Case series

A Needle's Misdirection: Unravelling Vascular Injuries in Malpositioned Central Venous Catheters and Safe Removal Approaches

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- Received Date: 30 Jul 2024
- Accepted Date: 07 Aug 2024
- Publication Date: 08 Aug 2024

Keywords

malpositioned central venous catheter, vascular injury, sternotomy, video assisted thoracoscopic surgery, endovascular.

Abstract

Central venous catheters (CVC) are commonly inserted to obtain vascular access. Complications such as vascular injuries arising from malpositioned CVC may occur, and safe surgical removal is required to prevent further complications. We retrospectively reviewed all patients treated in the cardiothoracic surgery department at our institution in the past 10 years for intrathoracic vascular injuries in malpositioned CVC without the need for concurrent cardiac or thoracic surgical procedures. Among the 21 patients in our series, 2 patients (10%) had a single arterial injury, 16 patients (76%) had venous injuries only, and 3 patients (14%) had both arterial and venous injuries. 16 patients (76%) underwent surgery to remove the malpositioned CVC; majority of them underwent sternotomy (n=12, 57%) and 7 of them had repair of blood vessels, and 4 patients (19%) underwent video assisted thoracoscopic surgery (VATS). 2 out of the 5 patients who had their CVC directly removed followed by external compression required emergency sternotomy due to pericardial effusion. In patients with artery or mediastinal vessel injuries, a sternotomy approach was preferred, whereas VATS was chosen when subclavian vessels or brachiocephalic vein injuries were noted. Endovascular procedures are alternatives for high surgical risk patients, but these advanced procedures are currency limited due to high expertise and facilities requirements.

Introduction

Central venous catheters (CVC) are commonly inserted in a hospital to gain vascular access for a wide range of medical purposes, including delivering medications, intravenous fluids, or total parenteral nutrition, facilitating renal replacement therapy, administering chemotherapy, measuring central venous pressure, and addressing challenges in difficult peripheral venous access.

CVCs are commonly inserted in the internal jugular vein (IJV), subclavian vein, femoral vein, or the basilic vein. The location of the underlying blood vessels of interest are guided either by surface anatomy landmarks or 2D ultrasound. Ultrasound-guided insertion of CVC have been reported since 1978 [1], with the current NICE guideline recommending ultrasound guidance in elective CVC insertion [2]. Without ultrasound guidance, the tip may be at a suboptimal position in 25-40% of CVC insertion attempts [3].

Although this is a common procedure, complications can arise from CVC insertion. Immediate complications include pneumothorax (25-30%) [3], catheter malposition (7%) [1], vascular injuries, air embolism, cardiac perforation, haemothorax, mediastinal haematoma, pericardial effusion, cardiac tamponade, and cardiac arrhythmia. Delayed complications include catheter-related infection (up to 33%), venous stenosis and formation of fibrin sheath or thrombus (5-10%). Vascular injuries can be divided into arterial injury and through-and-through venous perforation.

In the event of placement of the CVC tip in vessels other than the superior vena cava, there is an increased risk of catheter wedging, erosion or perforation of vessel walls, local venous thrombosis, catheter dysfunction and cranial retrograde injection.

Patients and methods

We retrospectively reviewed all patients treated in the cardiothoracic surgery department in our institution in the past 10 years (May 2014 to June 2024) for vascular injuries in malpositioned CVC and their methods of removal. These patients were referred from 12 different hospitals to our institution.

All the patients with intrathoracic vascular injuries were included in this series. Patients with cervical vascular injuries, those requiring concomitant cardiac or thoracic procedures, and those with incomplete data collection were excluded.

Preoperative demographic characteristics,

Citation: Han SA, Khalis A, Kan CS, Salleh A, Mohamad AMN. A Needle's Misdirection: Unravelling Vascular Injuries in Malpositioned Central Venous Catheters and Safe Removal Approaches. Surg Res J. 2024;4(2):09

including indication and type of CVC insertion, operator of CVC insertion, and location of vascular injuries were analysed and recorded.

These patients underwent either surgery, such as sternotomy or video assisted thoracoscopic surgery (VATS) to remove the malpositioned CVC, or had their malpositioned CVC removed directly followed by external compression. Patients who underwent sternotomy had a midline skin incision, median sternotomy, removal of the malpositioned CVC, and some required blood vessel repair. Patients who underwent VATS had a thoracoscopic port incision at the sixth intercostal space on the mid-axillary line. Further incisions or working ports varied depending on whether the malpositioned CVC, injured blood vessel or mediastinal structures could be visualised adequately prior to removal of the malpositioned CVC. In both sternotomy and VATS patients, a chest tube was inserted into the mediastinum and pleural cavity respectively after CVC removal.

On the other hand, patients who did not undergo surgery had their malpositioned CVC directly removed followed by external compression performed in the operating theatre (OT) with the OT team on standby in the event of emergency surgery.

All the patients were monitored closely in the cardiothoracic intensive care unit (CICU) following removal of the malpositioned CVC.

Results

In the past decade, 21 patients underwent removal of malpositioned CVC in our department (Figure 1). These patients were referred from another tertiary care hospital. Computed tomography (CT) scan was used to confirm the diagnosis and to identify the course of the malpositioned CVC. There were 12 male and 9 female patients with the age range of 21 to 89 years.

The indications for CVC insertion were haemodialysis (n=18, 85%), intravenous fluid administration (n=2, 10%) and chemotherapy (n=1, 5%) (Table 1). These CVC insertions were performed mostly by doctors in the nephrology department (n=15, 71%), followed by doctors in the radiology department (n=3, 14%), anaesthesiology department (n=2, 10%), and medical department (n=1, 5%).

Majority of the malpositioned CVC had an intended left IJV insertion (n=15, 71%), followed by an incidence of 4 (19%) intended right IJV insertion, one left subclavian vein insertion, and one right subclavian vein insertion. 3 patients (14%) had both venous and arterial injuries, whereas 16 patients (76%) had only venous involvement, and 2 patients (10%) had a single injury at the artery.

The most common vascular injury was a through-and-through venous injury, with the CVC entering the left IJV and exiting the left brachiocephalic vein (n=13, 62%), with 5 patients requiring left brachiocephalic vein repair.

The majority of the patients (n=16, 76%) underwent surgery to remove the malpositioned CVC - 12 patients underwent sternotomy and 4 patients had VATS procedure (Table 2). One VATS patient experienced an iatrogenic trocar injury to the left ventricle, necessitating a conversion to thoracotomy. More than half of the patients in the sternotomy group had their injured vessel repaired during the surgery, whereby 4 of them had a venous repair and another 3 of them had an arterial repair. None of the patients with VATS required blood vessel repair.

5 patients (24%) had a non-surgical approach in removal of the malpositioned CVC. These patients had their malpositioned CVC directly removed followed by external compression in the OT with surgical equipment and team available, and were closely monitored in the CICU after CVC removal for any complications. One patient developed stroke post removal,

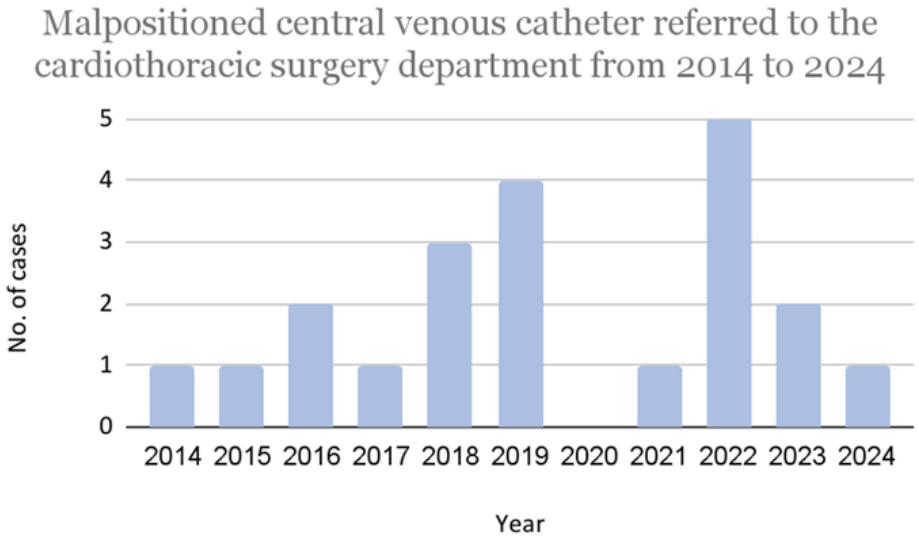


Figure 1. *Number of cases of malpositioned central venous catheter referred to the cardiothoracic surgery department from 2014-2024*

Table 1.*Patient demographic and type of central venous catheter injury*

	Overall (n=21)	**VATS (n=4)**	**Sternotomy (n=12)**	**Non-surgical (n=5)**
Age (years)	21 - 89 (55.8)	25 - 71 (49.8)	21 - 72 (53.8)	53 - 89 (65.3)
Gender				
Male	12 (57%)	2 (50%)	7 (58%)	3 (60%)
Female	9 (43%)	2 (50%)	5 (42%)	2 (40%)
Indication of CVC insertion				
Haemodialysis	18 (86%)	4 (100%)	9 (75%)	5 (100%)
Intravenous fluid administration	2 (10%)	0 (0%)	2 (17%)	0 (0%)
Chemotherapy	1 (5%)	0 (0%)	1 (8%)	0 (0%)
Type of CVC insertion				
Left IJV	16 (76%)	4 (100%)	7 (58%)	5 (100%)
Right IJV	3 (14%)	0 (0%)	3 (25%)	0 (0%)
Left SCV	1 (5%)	0 (0%)	1 (8%)	0 (0%)
Right SCV	1 (5%)	0 (0%)	1 (8%)	0 (0%)
Type of vascular injury				
Venous injury only	16 (76%)	4 (100%)	8 (67%)	4 (80%)
Arterial injury only	2 (10%)	0 (0%)	1 (8%)	1 (20%)
Venous and arterial injury	3 (14%)	0 (0%)	3 (25%)	0 (0%)
VATS: video assisted thoracoscopic surgery; CVC: central venous catheter; IJV: internal jugular vein; SCV: subclavian vein				

Table 2. *Intraoperative and postoperative data*

	Overall (n=21)	**VATS (n=4)**	**Sternotomy (n=12)**	**Non-surgical (n=5)**
Repair of blood vessel				
Venous repair only	5 (24%)	0 (0%)	4 (33%)	1 (20%)
Arterial repair only	2 (10%)	0 (0%)	2 (17%)	0 (0%)
Venous and arterial repair	1 (5%)	0 (0%)	1 (8%)	0 (0%)
No repair	13 (62%)	4 (100%)	5 (42%)	4 (80%)
Duration of procedure (mins)	5 - 253 (101.5)	17 - 245 (90.8)	20 - 253 (131.8)	5 - 20 (8)
Conversion of procedure				
Conversion to thoracotomy	1 (5%)	1 (25%)	0 (0%)	0 (0%)
Conversion to sternotomy	2 (10%)	0 (0%)	0 (0%)	2 (40%)
No conversion	18 (86%)	3 (75%)	12 (100%)	3 (60%)
Morbidity				
Bleeding / cardiac tamponade	2 (10%)	0 (0%)	0 (0%)	2 (40%)
Surgical site infection	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Neurological events	1 (5%)	0 (0%)	0 (0%)	1 (20%)
Mortality	2 (10%)	0 (0%)	1 (8%)	1 (20%)
Length of stay in hospital (days)	1 - 14 (3.6)	1 - 2 (2.5)	1 - 7 (3.4)	2 - 14 (5)
VATS: video assisted thoracoscopic surgery				

and another 2 patients required emergency sternotomy for haemostasis. These 2 patients became hypotensive and had a drop in haemoglobin level in the CICU, and an urgent echocardiogram showed pericardial effusion. Both these patients had a through-and-through venous perforation, with the CVC entering the left IJV and exiting the left brachiocephalic vein.

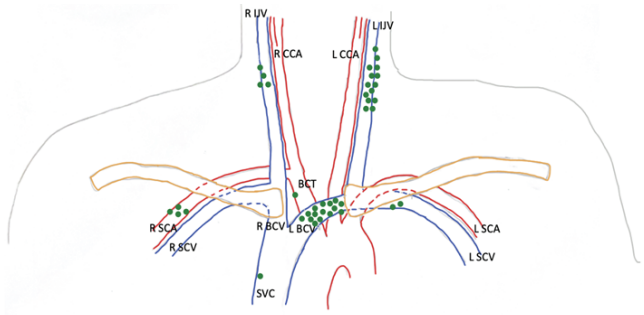
The average length of stay in our institution for all the patients after removal of malpositioned CVC was 3.6 days. Most patients were discharged back to their referring hospital for further management of their initial clinical problems.

There were 2 mortality in this series - one patient was from the sternotomy group, and another patient had a direct removal with external compression which required emergency sternotomy. Both patients died of severe pneumonia.

***Table 3**. Vascular injuries and the method of CVC removal*

Type of CVC	Vessel injured (1)	Vessel injured (2)	Method of CVC removal	No of patients	Remarks
L IJV	L IJV	L BCV	Sternotomy	6	3 patients required L BCV repair
			Left VATS	2	
			Left VATS converted to thoracotomy	1	1 patient had iatrogenic LV puncture from trocar
			Non-surgical removal	2	
			Non-surgical removal requiring sternotomy	2	2 patients had cardiac tamponade, requiring sternotomy and repair of L BCV
	L IJV	SVC	Left VATS	1	
	L SCV	L BCV	Sternotomy	1	
R IJV	R IJV	R SCA	Sternotomy	3	2 patients required repair of R SCA
	Brachiocephalic trunk		Non-surgical removal	1	
L SCV	L SCV	L BCV	Sternotomy	1	1 patient required repair of L BCV
R SCV	R SCA		Sternotomy	1	1 patient required repair of R SCA

CVC: Central venous catheter; L: Left; R: Right; IJV: internal jugular vein; BCV: brachiocephalic vein; SVC: superior vena cava; SCV: subclavian vein; SCA: subclavian artery; LV: left ventricle



Abbreviation: R: right; L: left; IJV: internal jugular vein; CCA: common carotid artery; SCA: subclavian artery; BCT: brachiocephalic trunk; SCV: subclavian vein; BCV: brachiocephalic vein; SVC: superior vena cava

***Figure 2**. Diagrammatic illustration of all vascular injuries location in the past 10 years (2014-2024) in our institution.*

Discussion

CVC insertion is commonly performed by medical practitioners for multiple indications. Nonetheless, complications can arise, particularly when performed by less experienced operators or in patients with factors such as elevated body mass index, prior catheterizations, and previous surgeries or radiotherapy in the anatomic region of interest [4]. The incorporation of ultrasound guidance during CVC insertion can reduce the complications [2,3].

Vascular injury constitutes a notable mechanical complication, with arterial puncture emerging as the most prevalent form of vascular injury, which may lead to further complications such as haemorrhage, pseudoaneurysm, arteriovenous fistula, stroke, and even death [5]. Injury to the vein is another vascular injury that may occur during CVC insertion, with the most common injury being through-and-through injury to the intrathoracic vein [6], which includes the superior vena cava, left brachiocephalic vein, and subclavian vein. These vascular injuries are mostly due to unsafe manipulation of the dilators, kinking of the guidewire, rigid dilator, sheath or catheter which may result in vessel perforation [7].

In the event of malpositioned CVC, it is pertinent to know the entire course of the CVC to determine the location and number of blood vessel(s) injured, as well as the location of the malpositioned CVC tip, which may lead to further complications such as local toxicity, blood vessel or cardiac perforation and venous thrombosis [4]. Appropriate imaging studies are of paramount importance before any attempt to remove the malpositioned CVC. This approach coincides with the American Society of Anaesthesiology guidelines [6] for leaving the malpositioned CVC in situ and consulting a general surgeon, vascular surgeon, or an interventional radiologist for an appropriate plan to remove the malpositioned CVC.

After an iatrogenic intrathoracic vessel puncture of the malpositioned CVC, there are 3 different approaches that can be taken: (1) direct removal of the CVC with external compression, (2) open surgical exploration and direct repair, or an (3) endovascular approach.

Removal of the CVC followed by external compression is not recommended because it can lead to further complications, such as stroke, pseudoaneurysm [8], and death [9]. These complications were observed in a retrospective review by Shah et al [8] and a case series by Guilbert et al [9]. Guilbert et al also showed a 5.6% stroke risk, and reported pseudoaneurysm and arteriovenous fistula as late as 2 weeks after direct removal with external compression. The remaining patients in both studies who underwent surgical removal [8,9] or an endovascular approach [9] did not have any post-removal complications.

Sternotomy, VATS, and thoracotomy are surgical techniques for intrathoracic vascular injuries in malpositioned CVC. A sternotomy approach provides a good exposure of mediastinal vessels, the heart, and the ascending aorta [10,11]. It also permits quick relief from cardiac tamponade [10,12] and blood vessels repair [13]. Mini sternotomy should be considered as it results

in less postoperative pain, reduced analgesic usage, and has a quicker recovery period without compromising visualisation of the mediastinal structures and blood vessels. Siordia et al [13] reported a case of a successful left brachiocephalic vein repair via a mini sternotomy approach.

There are also multiple case reports [14-16] of successful VATS approach in managing subclavian vessels and right brachiocephalic vein injury in malpositioned CVC. VATS provides a good intrathoracic visualisation of subclavian vessels in the thoracic inlet, as well as a magnified view of pleural cavity to aid in evacuation of haemothorax post vascular injury. Multiple haemostatic techniques can be utilised during VATS such as direct pressure, vascular repair, and application of haemostatic agents. VATS had been favoured over open thoracotomy due to its more rapid intrathoracic access, shorter recovery period and minimal postoperative pain and shoulder dysfunction [15] . In addition, patients who are critically ill may not be able to tolerate open thoracotomy.

Lately, endovascular procedures such as balloon tamponade, coil embolization, stent placement and arterial closure device have been increasingly used to manage vascular injuries [9,17, 18]. It is the treatment of choice for patients who are at high risk of surgery.

A retrospective review of 9 patients with inadvertent arterial catheterization by Nicholson et al [18] had shown successful management with endovascular approach - 2 patients underwent balloon tamponade, 3 patients required stent-graft placement, and 4 patients had an arterial closure device inserted. One patient who underwent balloon tamponade required open surgery as the haemostasis was unsuccessful and a stent-graft could not be inserted. Another patient who had a stent-graft insertion experienced partial visual loss as the stent-graft had occluded the vertebral artery. There were no mortality related to these endovascular procedures. A systematic review by Dixon et al [17] reported a success rate of 94.6% and 100% in endovascular management and open surgical approach respectively, to remove the malpositioned CVC. These figures are significantly better than the 5.6% success rate from removal of CVC with external compression. Two complications arose from the endovascular management [17] – failure to control haemorrhage and embolic stroke.

Conclusion

CVC insertion is not a risk-free procedure, and malpositioned of the CVC and vascular injury among its complications. The commonly seen vascular injuries are arterial puncture and through-and-through venous injury, which can cause haemorrhage, haemothorax, pseudoaneurysm, arteriovenous fistula, stroke, and death [5]. Retrospective reviews have revealed that removal with external compression is associated with complications such as stroke, pseudoaneurysm, arteriovenous fistula and death [1,9]. Hence, it is not the best option for managing a malpositioned CVC. Sternotomy [10-14] allows good exposure to the mediastinal structures and repair of blood vessels; VATS procedure provides a good visualisation, access, and haemostasis to the subclavian vessels and right brachiocephalic vein injuries [14-16]. Endovascular techniques [9,17, 18] are less invasive techniques for managing malpositioned CVC, and are the ideal approach for patients who are critically ill and cannot tolerate general anaesthesia. Unfortunately, these advanced procedures are currently limited and can vary based on healthcare infrastructure, resources and specialised training.

Declarations

Funding: The authors did not receive support from any organisation for the submitted work.

Conflict of interest: All authors have no conflicts of interest to declare.

Ethical approval: Not required.

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