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Mystery Turn of the Central Venous Catheter!

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ABSTRACT: Anaesthesiologist and intensive care physicians are the best skilled people for placement of central venous catheter. Complications related to Central venous catheter placement have decreased by substantial number due to use of ultrasound guidance to place or insert the same. Sometimes central venous catheter tip can be placed in an undesired vessel which is totally unintended called as central venous catheter malposition. This undesired position is not the complication of central venous catheter insertion but not paying attention to same on post procedure X-ray chest can lead to significant mortality and morbidity. After encountering one such incidence and it's amazing look on chest x-ray(Fig 1 and Fig 2), I decided to dig into literature and found some interesting explanations that why and how it happened? After reviewing number of articles, it was found that central venous catheter malposition is associated with anatomical variance which can be congenital or acquired, use of left side of venous system for central venous catheter insertion, bevel orientation while inserting needle to locate central vein and physique of the patient. The purpose of this review is to address reasons for this malposition and ways to identify, correct and avoid the same. Even though X-ray chest is the standard imaging modality to detect complications of central venous catheter insertion, any unusual signs and symptoms of central venous catheter malposition should prompt operator to use additional diagnostic tools even if X-ray chest is normal or inconclusive to rule out malposition.

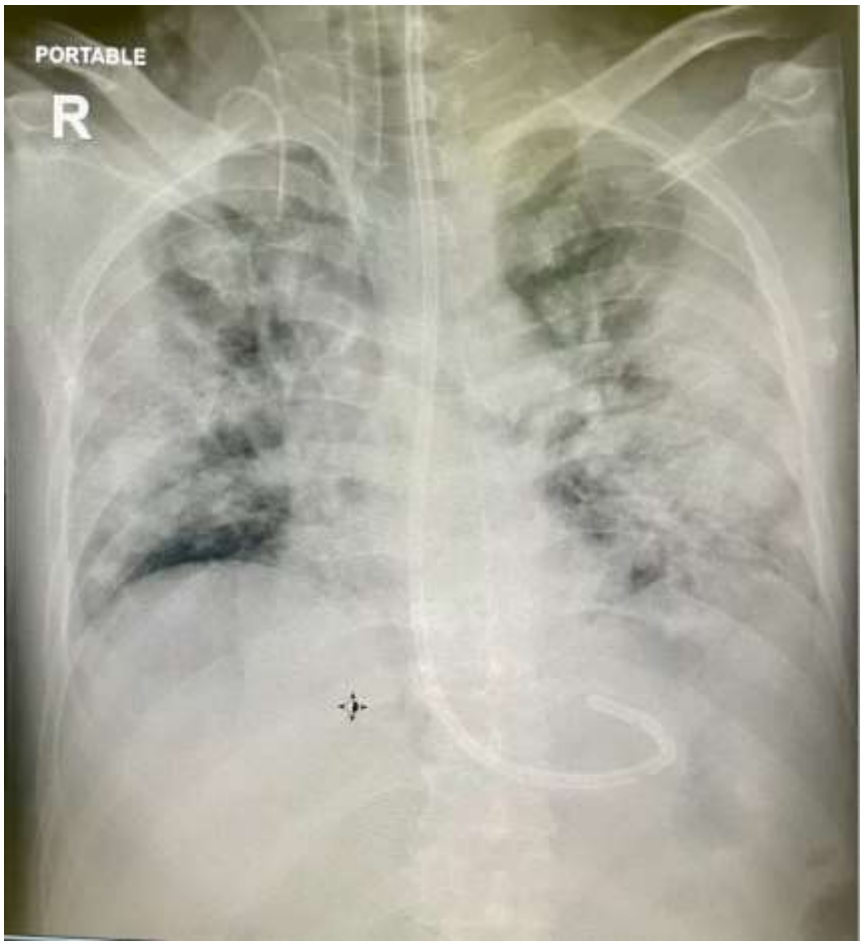

Fig 1: Showing malposition of right internal jugular venous cannulation

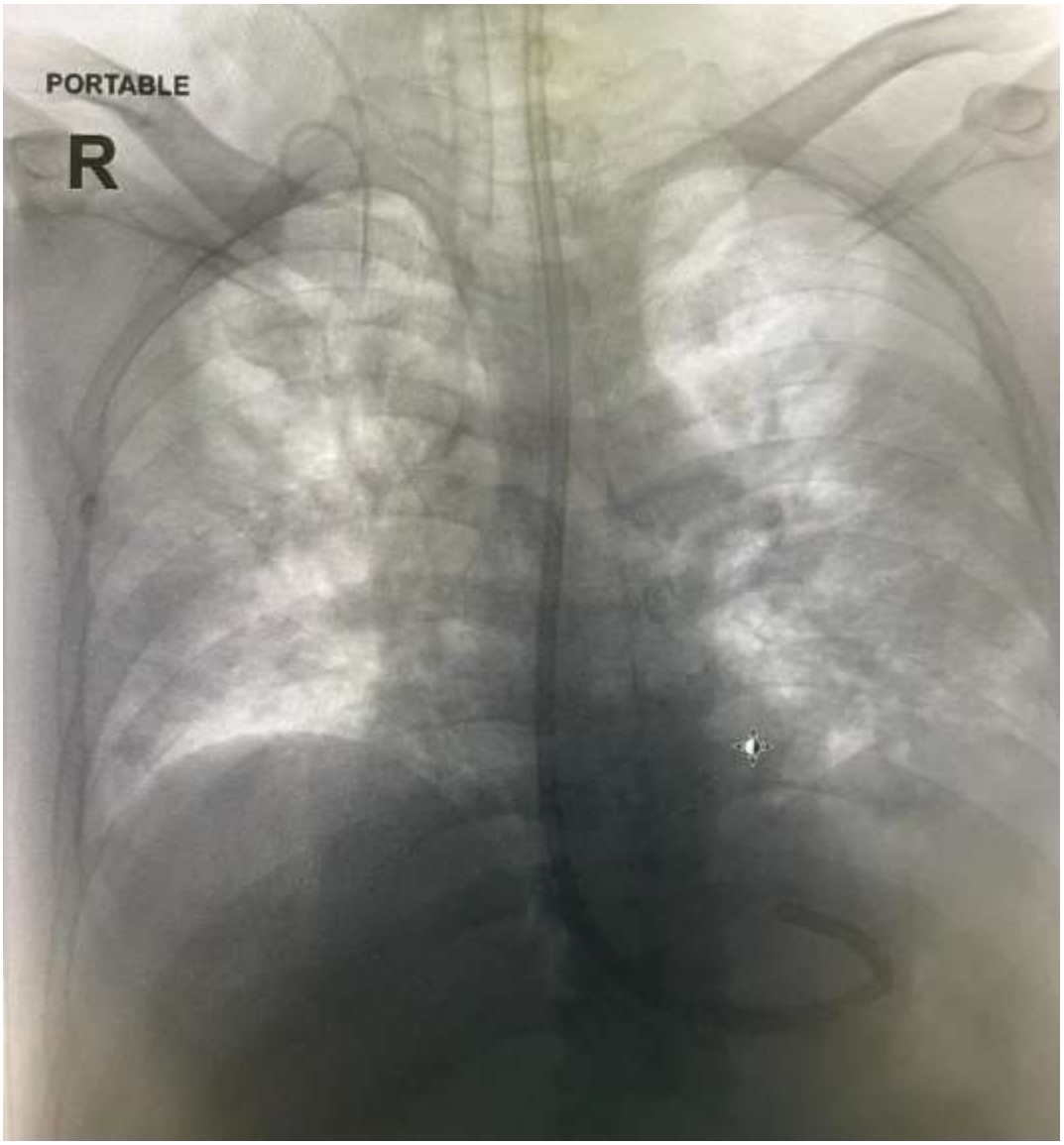

Fig 2: Negative film of figure 1 Showing malposition of right internal jugular venous cannulation for better visualization

Best course of action after diagnosing central venous catheter malposition is to remove and relocate the catheter. If one knows what is the mechanism behind occurrence of such phenomena it can help to correctly identify and prevent central venus catheter malposition thereby decreasing harm to the patient. It is said that eyes can see and ears can hear what mind knows. Most of us may think that it must be very rare occurrence but Malatinský *et al* in 1976 presented a series of 378 radiographically controlled CVC placements and reported pure loop formations (coiling) i.e. malposition in 2.9% of the cases.[1] That means it is not as rare as one might think.

What is mean by CVC malposition?

In critical care patients access to central venous circulation is achieved through insertion of cannulation device via seldinger technique (wire guidance). [2] In these patients it is very important to have access to central venous circulation to administer potentially irritant drugs, parental nutrition, blood products and life support foods or medications. Central venous catheter can also be used for measurement of central venous pressure, cardiac output, central venous oxygen saturation, for transvenous spacing and haemodialysis. Central venous catheter placement requires knowledge of anatomy, training, skills and experience. It is not without risk even if performed by skilled physicians.

Even though central venous catheter malposition at locations other than superior vena cava have been described rarely but literature shows that its incidence is as high as 7%[3]. Most common complications of central venous catheter placement includes infection 5 to 26%, haematoma 2 to 26%, pneumothorax 0 to 30%, haemothorax, chylothorax, extravasation of medication/infusate, haemorrhage in mediastinum, haemorrhage in pericardial sac leading to cardiac tamponade and inadvertent arterial placement. If CVC (central venous catheter) in wrong position is not recognise or diagnosed promptly it can lead to serious complications like

delivery of medication in cranial circulation, in which infusate is delivered to head instead of central circulation. Other morbidities include perforation of vessel, thrombosis, catheter dysfunction and catheter wedging.

Aim of this review is to address the factors/reasons for malposition of central venous catheter and by reviewing those, to suggest ways to identify prevent and correct those errors.

What are the reasons behind CVC malposition?

Even though multiple reasons for position of central venous catheter have been mentioned in literature, exact mechanism is not known and it appears to be multifactorial. Causes of CVC malposition are described as follows.

A) Orientation of bevel while inserting Central line is one of the important reason for CVC malposition. Some studies have shown that if orientation of bevel and guidewire tip is proper we get proper placement of CVC[4], for example while using internal jugular vein route if bevel is medially oriented one gets proper catheter placement. With same thought in mind one of the small randomised control study has demonstrated that while using subclavian route, caudally oriented bevel will avoid malposition. (Fig 3)

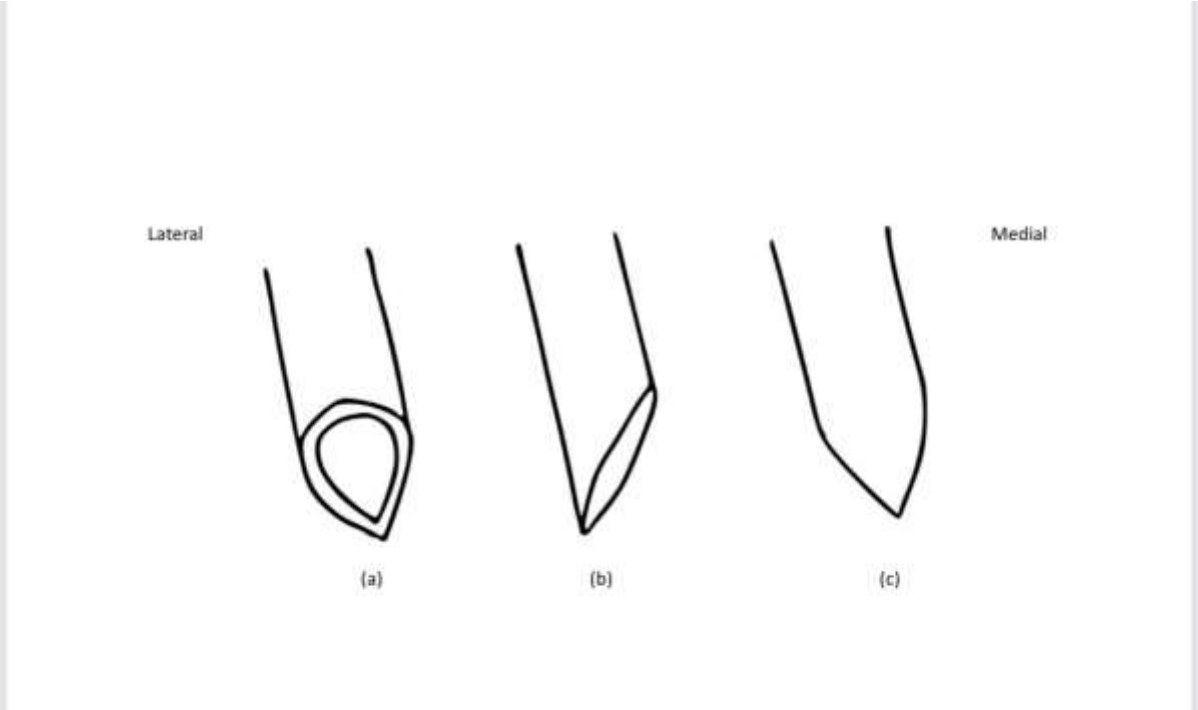

Fig 3 bevel orientation for particular CVC route with attention to medial and lateral orientation (a) bevel direction which leads to most of malpoistion (b) for Internal jugular vein(c) for subclavian route

B) Direction of J-type guidewire tip is also important as orientation of bevel. J-wire tip downward can increase successful placement rates of right subclavian venous catheterization[4]. Resistance to guidewire removal is because of locking of same at the tip of catheter and removing it with force leads to coiling or malposition.[5]

C) Body structure and movements: when patient assumes sit up or upright position mediastinal structures lengthen and abdomen contain decent leading to cephalad moment of catheter tip. This cephalad moment is more pronounced in obese[6], female with large breast and subclavian route. The same phenomena has also been proved under radiographic imaging. The mean movement of tip has been found to be move by 9 mm during expiration.[7] Redundant fatty tissue where external part of catheter has been sutured in obese patient is also contributing factor for movement of the catheter.

C) Veinous anatomical variation (Fig 4 and Fig 5)

Anatomical variation can misguide catheter tip to low resistance route leading to CVC malposition. Venus anatomical variations can be congenital or acquired. Sometimes congenital abnormalities of venous circulation are accidentally diagnosed after misplacement of central venous catheter[8]. Common congenital variations are persistent left sided superior vena cava which is present in 0.3% of healthy population, persistent left-sided superior vena cava which is present in 4.3% of patient with congenital heart disease [9],[10], dominant supreme intercostal vein draining into hemiazygos vein, dextrocardia, inferior vena cava variation, partial anomalous pulmonary venous drainage, azygous vein abnormalities (in origin course, tributaries, anastomosis and termination).[11]Retrograde venous flow secondary to IJV valve incompetence in patients with chronic obstructive pulmonary disease, primary pulmonary hypertension and prior cannulations and catheterizations of the IJV, [12],[13]High intrathoracic and intra-abdominal pressures can lead to retrograde venous flow and can make guide wire or catheter to follow unexpected route.

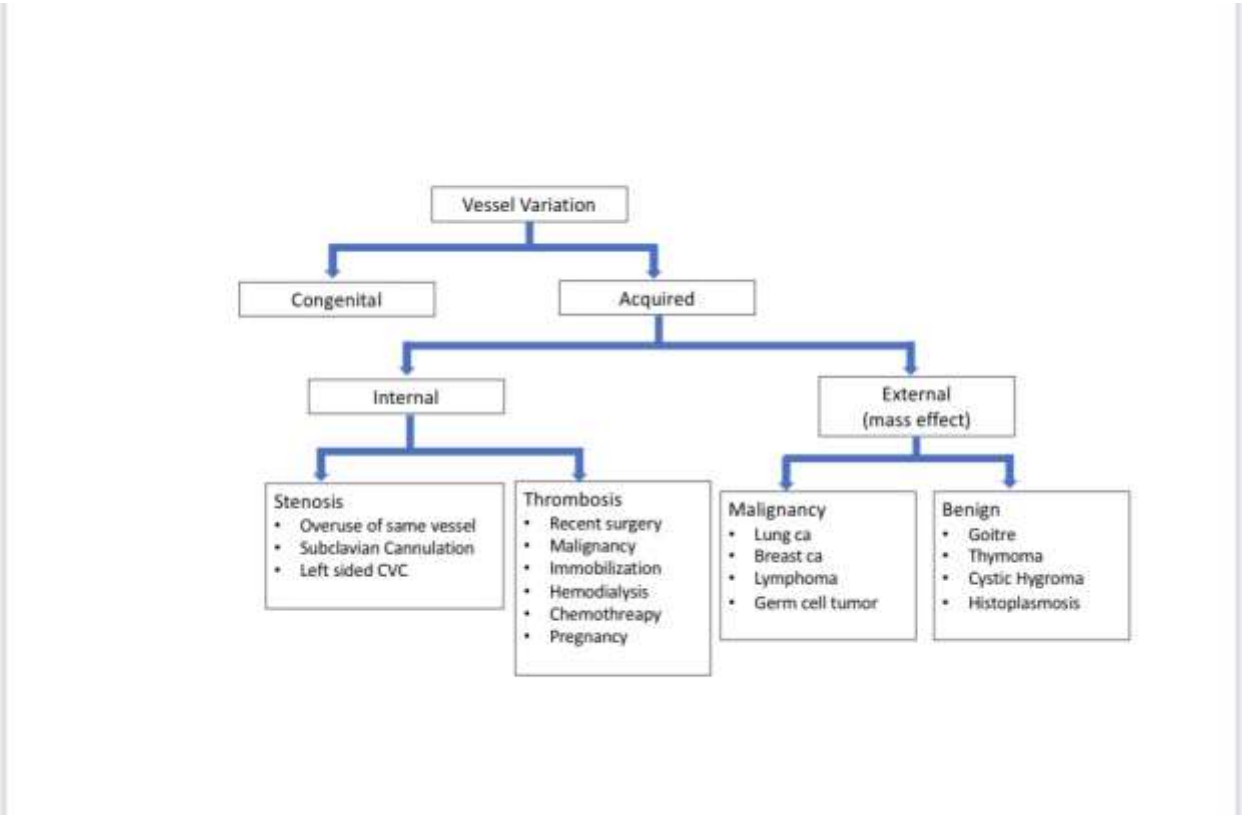

Fig 4: Classification of causes of venous anatomical variation.

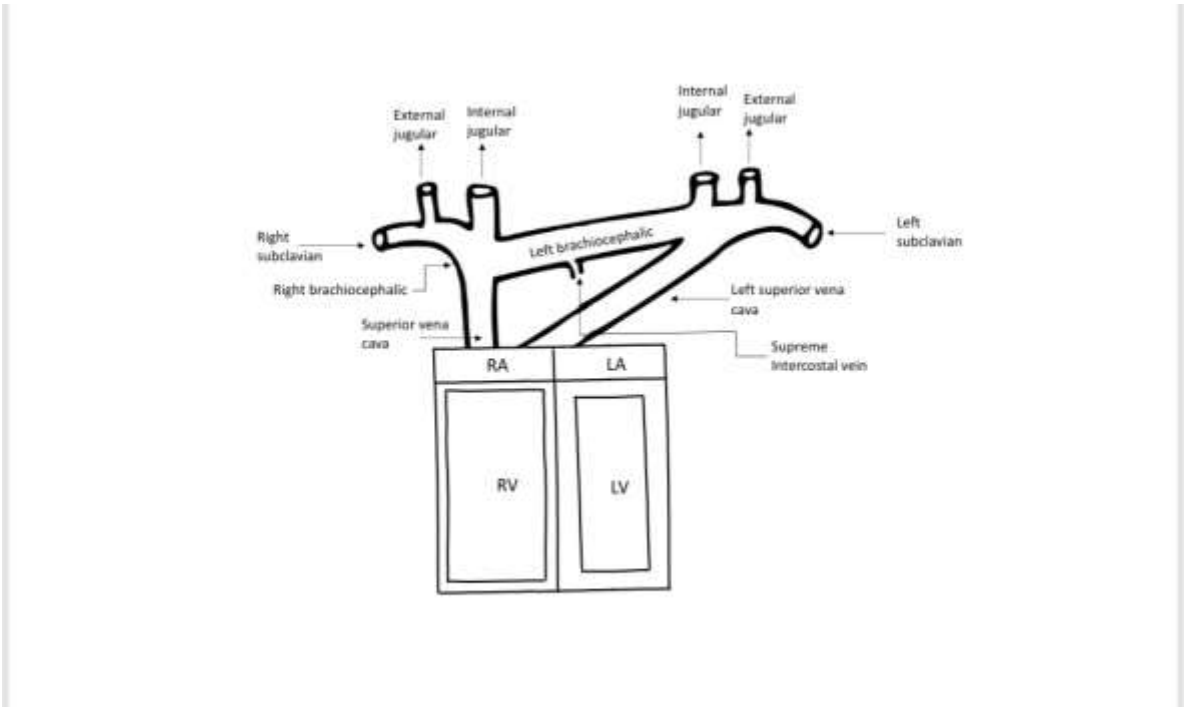

Fig 5. Common congenital variation is a persistent left sided venous circulation and mostly malposition are on left due to long and oblique course of vessels on that side.

D) Seldinger technique[14]: The catheter is inserted over the guidewire and placed in the central vein. Encountering Resistance and use of excessive force while inserting the CVC predisposes to malpositioning [15]. Common sites of resistance are the junction of first rib and clavicle for the subclavian vein and the junction of venous tributaries for the IJV and brachiocephalic vein.[16]
Direction of J-type guidewire tip during insertion and its locking with catheter tip during removal, both may cause looping of CVC. There can be resistance to guidewire or catheter insertion due to bottleneck between clavicle and first rib. If insertion is not smooth and force is applied for insertion of guidewire/CVC, it may lead to placement of same in undesired vessel, coiling or knotting [15].

This obstacle can be mitigated by putting sandbag between scapula along axis of spine which opens up space between clavicle and first rib.

Extra length of insertion of guidewire and catheter[17] can lead to CVC malposition. Peres formula which is height in centimetre divided by ten gives the approximate length of insertion of catheter

Granziera Et al States that acquired variation in Venous circulation is way more common than congenital. Acquired variation can be external or internal[18]. Stenosis or thrombosis are the main reasons for internal vessel distortion. Vessel stenosis is because of over use of same vessels, subclavian cannulation, use of left side of neck for CVC [19]. Causes of thrombosis are well-known like recent surgery, malignancy, immobilisation, haemodialysis, chemotherapy and pregnancy.

External vessel distortion is because of compression due to mass on the vessel. This mass effect may be due to malignancy like lung cancer, breast cancer, lymphoma, Germ cell tumour or benign mass like substernal goitre, thymoma, cystic hygroma and histoplasmosis. Malignancy causes more than 85% of external vessel distortion.

Schummer Et al in their prospective study of 1794 central venous catheterisation by skilled operators found that 6.7% incidence of malposition and this incidence is most common when left side of neck was used to either cannulate left internal jugular vein or left subclavian vein. Increased incidence of malposition on left side attributes to long left brachiocephalic vessels, more oblique course to heart and presence of many small tributaries in that region. After this discussion one can define central venous catheter malposition as CVC tip placement in the vein other than superior vena cava or right atrium, impingement on the lateral wall of superior vena cava; arterial calculation. Incidence of central venous catheter malposition in various places in decreasing order is as follows - Left internal jugular vein 12%, right subclavian 9.3%, left subclavian 7.3%, right internal jugular vein 4.3%. (Fig 6)

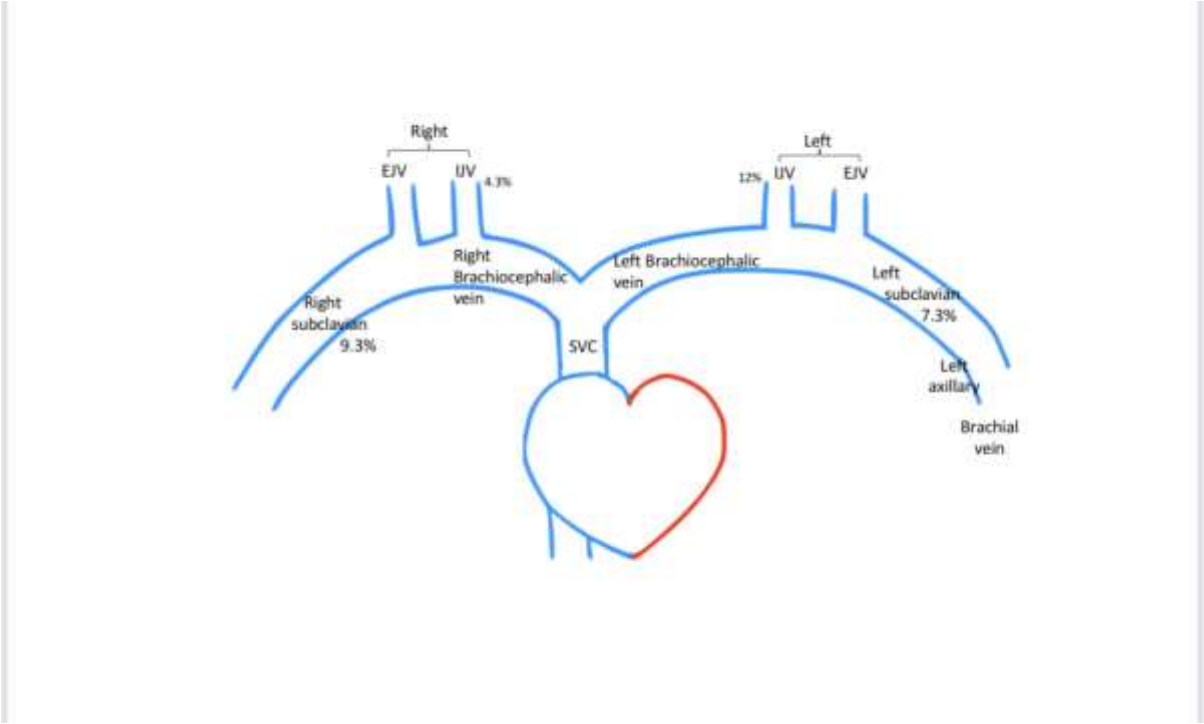

Fig 6: Incidence of central venous catheter malposition in various places in decreasing order - Left internal jugular vein 12%, right subclavian 9.3%, left subclavian 7.3%, right internal jugular vein 4.3%. IJV: Internal jugular vein. EJV: External jugular vein

If it is very well known that using neck for CVC insertion is the only factor for malposition why don't we use femoral approach which is less difficult technically and doesn't have complications like pneumothorax or haemothorax . Answer to this dilemma is CLABSI(Central line associated blood stream infections). A randomised study found that higher rate of infectious complications when femoral approach is used (19.8% versus 4.5% $p < 0.001$)[20]. A meta-analysis of 113652 catheter days found that there is no difference in CLABSI between femoral, subclavian and internal jugular vein site of cannulation [21]. Timsit et Al published same results as meta-analysis showing that 1/1000 versus 1.1/1000 catheter days infection in internal jugular vein vs femoral vein cannulation.

What are the measures to prevent central venous catheter malposition?

A) Selecting the vessel

From preceding discussion it is obvious that incidence of central venous cannulation malposition is greater when left thoracic venous system is selected then right one[22]. First preference should be given to right side unless there is any contraindication. When anatomical abnormalities are suspected because of scar tissue, history of recurrent cannulation, long-term haemodialysis catheter

placement, thoracic tumours, the affected side or vessel should be avoided. Even though nowadays use of ultra sound is a very common practice for central venous cannulation it doesn't necessarily prevent malposition.

B) Choosing a technique

Various authors have mentioned pearls of wisdom for various approaches for central venous catheter insertion. Tripathi M et al suggested keeping J tip of guide wire pointed caudally during insertion in subclavian approach[23]. Additionally position of head is important while using subclavian approach. For example while using subclavian approach if head is laterally flexed towards ipsilateral side of central venous insertion, it will narrow entry point for internal jugular vein and prevents entering of same in internal jugular vein [24]. Similarly if head is rotated away it will stretch and narrow internal jugular vein, which will prevent entry of catheter in it and will help in successful placement of catheter in desired vessel. Finger in fossa technique means manual compression of ipsilateral internal jugular vein to avoid unintended placement of central venous catheter tip in it [25]. Lastly selecting appropriate length of catheter is very important while selecting left or right approach. Inappropriate length increases the incidence of catheter misplacement, displacement and migration increases.

Confirming placement

It is routine practice to order chest x-ray after central venous catheter placement for confirmation of position and to diagnose any subclinical complication. Chest x-ray takes some time to be done and again some extra time to review the same in busy intensive care unit schedule. If one incorporates some clinical test to verify the placement, it can help in real-time detection of position. First in this list will be flush test. In this test catheter is flushed with 5 to 10 ML of saline with force and palpate for thrill with palmer aspect of hand [26]or auscultate for bruit. If flush test is used for internal jugular vein cannulation operator should feel thrill or audible bruit in internal jugular vein region indicating correct placement [27]. If bruit or thrill is present in internal jugular vein region when subclavian approach has been used it indicates catheter tip has gone upward and there could be coiling in internal jugular vein region.

Second bed side test is use of ultrasound for bubble test. In bubble test 10 ML of agitated normal saline is flushed through central venous catheter and ultrasonography visualised in the right atrium verifying adequacy of central venous catheter tip placement [28-30]. Limitations of this technique include operators skill and presence of any aberrant vessels.

Lastly gold standard [31] for confirmation of CVC placement is X- ray chest. X-ray chest is done to confirm tip placement at atrio caval junction and to diagnose or to rule out any complications. Although there is no unanimous opinion about ideal position of tip on x-ray chest, it is generally acceptable to have same at junction of superior vena cava and right atrium. Another important point is that tip should not come in contact with cardiac tissue. [32]. This position helps in minimising complications during its use i.e. central venous catheter should be placed in large vessels with high blood flow without touching any vessel wall or junctions [33].

Atrial electrocardiography

ECG is routinely used as one of the standard monitoring modality . This ECG can be modified to right atrial ECG using wire cable and adaptor provided in Central venous catheter set. It helps to secure position of catheter in SVC and additionally does not increase any cost.[34]

Signs and symptoms of CVC malposition

Certain signs and symptoms describe below plus difficulty in using central venous catheter effectively can give some indication of CVC malposition. Infusion through central venous catheter which has been placed in small tributary of large central vein is associated with chest pain. if hypertonic saline is infused through left internal mammary vein it is associated with retrosternal chest pain along with radiation to back [35]. If CVC is misplaced in cephalad direction in internal jugular vein and/or near intracranial structure, patient will complain of ear gargling or water running sensation. Even use of PICC line through brachial vein for infusion of hypertonic saline leads to or shoulder pain.

Difficulty in aspiration from central venous catheter port is another warning sign of malposition. The absence of free flow on aspiration from one lumen of a central catheter should not be undervalued[36].This happens because of collapse of weak vessel wall on catheter while applying negative pressure for aspiration. However it doesn't mean that if there is free aspiration, catheter has optimal position. Another important sign of malposition is technical difficulty in inserting guide wire or catheter.

Use of imaging for malposition confirmation

X-ray chest is most important imaging tool used to diagnose catheter malposition[37]. Despite high accuracy of x-ray chest to detect position of catheter, it needs great anatomical knowledge of thoracic and mediastinal vessels. X-ray chest is two dimensional modality compare to CT which is 3-D, so x-ray chest will have some limitations compare to CT. For instance if position of catheter looks doubtful in anteroposterior x-ray chest, lateral chest x-ray should be sought to diagnose CVC malposition. If there is still uncertainty following approaches can be taken viz first contrast injection while taking chest x-ray, second CT for precise localisation[38]. Misplaced central venous catheter in internal mammary vein appears to be placed in superior vena cava in standard

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CXR when right internal vein approach is used. This happens as internal memory vein terminates into brachycephalic vein which overlies superior vena cava. In this case as compare to conventional x-ray, CT can be very useful to manage misplaced central venous catheter even though it is expensive and cannot be used routinely.

Another imaging modality which can be used during central venous catheter placement itself – real-time radiograph imaging, which doesn't use any contrast media and can help for wire and catheter placement. It has got some limitations as plain radiograph.

Fixing malposition

Most of the experts believe that malposition central Venous catheter should be attended on priority basis to reposition, remove or replace as soon as possible [33],[39] One paediatric population study author found that if it is left in place for 24 hours most of the CVC malposition spontaneously correct itself [40]. But no similar study has been conducted for adults. For catheter placed in arterial circulation help of interventional radiology or vascular speciality will be needed to remove CVC.

CONCLUSION

Congenital or acquired variation in anatomy, skills and technique of operators are important factors associated with malposition of central venous catheter. Knowledge about how malposition occurs, mechanism behind it and how to avoid, recognise and correct this condition could decrease morbidity and mortality. Signs and symptoms and imaging modalities can help to diagnose CVC malposition. In general CVC malposition should be dealt on priority basis to re-position, remove or replace.

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Conflicts of interest/ Competing interests

There are no conflicts of interest./ The author(s) declare no competing interests.

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