The carina as a radiological landmark for central venous catheter tip position

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Background. Many publications, including the instructions accompanying central venous catheters, state that it is negligent to site the catheter tip in the right atrium. If the catheter tip is above the carina on a post-procedure radiograph then it is generally accepted that the catheter lies outside the right atrium. It is also recommended that the catheter tip should lie in the long axis of the superior vena cava without acute abutment to the vein wall. We performed a retrospective audit of the position of central venous catheter tips on routine post-procedure chest radiographs in intensive care unit patients, to see if these potentially conflicting requirements had been met.

Methods. We identified 213 central venous catheters suitable for analysis, within a study population of 200 consecutive cases. We measured the distance of the central venous catheter tip above or below the carina and the angle of the central venous catheter tip to the vertical (a surrogate marker for the angle of abutment of the tip to the approximately vertical superior vena cava wall).

Results. For right-sided catheters there was a high (74/163) number placed with their tips below the carina, but a very low number (4/163) with their tips at a steep (>40°) angle to the vertical. For left-sided catheters very few (7/50) were placed with their tips below the carina, but for those 43 sited above the carina most could be considered to be in suboptimal positions. This was because they were either too high and had not even crossed the midline (9), or had an acute angle (>40°) between the tip and the vertical (27).

Conclusions. We suggest that for left-sided catheters placement of the tip below the carina is more likely to result in a satisfactory placement.

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There is ongoing controversy as to whether central venous catheter (CVC) tips should always lie above the pericardial reflection.¹ For CVC tips lying below the pericardial reflection there is a small but potentially fatal risk of pericardial tamponade if the CVC tip erodes through the vessel wall. The frequency of this risk has not been quantified. Other problems of catheter placement in the right atrium (RA) include arrhythmias, placement in the coronary sinus, and tricuspid valve damage.

Vessel wall erosion can also occur when the CVC tip lies above the pericardial reflection, usually causing hydrothorax or hydromediastinum from extravasated fluid, but this is less likely to have a fatal outcome. Perforation of the superior vena cava (SVC) is probably more likely with left-sided than with right-sided CVCs.²⁻⁴ This is influenced by the steep angle the left innominate vein makes with the SVC. Here the catheter will abut the wall of the SVC unless the tip is advanced around the curve into the lower SVC or RA. It has been shown in the laboratory that an angle of the CVC tip to vessel wall of greater than 40° is more likely to lead to vessel wall perforation.⁵ Vessel wall erosion is also influenced by the type of fluid infused, the likely mechanism being chemical trauma, suggesting that lesser angles may also be damaging.

There is appreciable morbidity from CVC tips lying too proximal, either in the left or the right innominate vein. Mechanical or chemical irritation of the vessel wall leads to pain on injection of drugs, thrombosis and subsequent infection,⁶⁻⁷ which is more likely in the upper SVC or innominate veins, especially on the left side.⁸ Extravasation injury may result from CVCs lying so proximal that one or more of the catheter openings lies outside the vessel lumen.
The upper limit of the pericardial reflection cannot be seen on a plain chest radiograph (CXR), however it is generally accepted that it is below the carina. This has been assessed in preserved cadavers,9 fresh cadavers,10 in anaesthetized children undergoing cardiac surgery11 and in adults using computerized tomograms.12 The optimum tip position is more complicated than merely ensuring placement above the carina and is also likely to be different for left- and right-sided CVCs. It may be particularly difficult for left-sided CVCs to satisfy all the criteria for optimum placement. This leaves the clinician with a dilemma: do they risk the potentially fatal but rare complication from placement in the RA or the much commoner complications from higher placement that may still have appreciable morbidity and occasional mortality. For optimum placement of left-sided CVCs do we need to ignore the recommendation to site the tip above the carina? With this in mind we decided to audit our current practice for CVC placement.

Methods
Two hundred consecutive admissions to the adult general intensive care unit (ICU) at The General Infirmary at Leeds between December 2003 and April 2004 were identified retrospectively. Post-insertion chest X-rays (CXRs) corresponding to these admissions were retrieved from the Picture Archiving & Communication System (PACS—Agfa-Gevaert Ltd, Brentford, UK). As this audit was performed retrospectively, clinicians inserting CVCs did not know that an audit would take place. We identified post-insertion CXRs by examining the radiology database for each admission chronologically and selecting the first or second CXR with a CVC in situ. Second CXRs were chosen where available, as this should have allowed clinicians to correct CVCs deemed to be in an unsatisfactory position. These CXRs were assessed for the following measurements:

- Vertical distance of the CVC tip above or below the carina.
- The angle of the distal 1 cm of the tip to the vertical. Assuming the SVC lies approximately vertical, this angle approximates the angle of the CVC tip to the wall of the SVC. The vertical against which the angles were measured was a line connecting the vertebral spinous processes.
- CVC type, site of insertion and any evidence of misplacement were recorded.

All measurements were made using the software available on the hospital PACS system. Images were numbered then anonymized before analysis.

We also commented on the overall suitability of CVC position. We suggested arbitrarily that catheter tips at 5 cm or greater above or below the carina were likely to be too high or low respectively.

Although we did not look back at medical records to get details of placement techniques, we can state that with the exception of a small number of pre-existing long term i.v. devices such as Hickman lines all procedures were performed in the ICU or operating theatre without the use of ECG-guided positioning or X-ray screening.

Results
We identified and examined the radiological records of 200 consecutive ICU admissions. We found 148 patients who had CVCs visible on CXR—many with multiple CVCs during their in-patient stay. We identified 243 CVCs. We excluded 30 of these as unsuitable for measurement (Fig. 1). We were not able to record the length of the CVCs (the two usual multilumen CVC lengths available in our institution were 16 and 20 cm), nor did we know the depth to which they were inserted.

Table 1 shows the site of insertion of the 213 CVCs audited. It is clear that in the population audited the

<table>
<thead>
<tr>
<th>Internal jugular</th>
<th>Subclavian</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>Right</td>
<td>148 (69%)</td>
<td>15 (7%)</td>
</tr>
<tr>
<td>Left</td>
<td>40 (19%)</td>
<td>10 (4%)</td>
</tr>
<tr>
<td>Total</td>
<td>188 (88%)</td>
<td>25 (12%)</td>
</tr>
</tbody>
</table>

Fig 1 Details of CVCs audited. CVC, central venous catheter; PAFC, pulmonary artery floating catheter; IJ, internal jugular; innom, innominate vein; sub, subclavian vein.
The internal jugular vein was favoured over the subclavian and that the majority were inserted from the right-hand side.

The vertical distance of the catheter tip from the carina was measured. Table 2 shows the proportion of CVCs located below the carina according to site of insertion.

Figure 2 shows the distribution of the distance of CVC tips from the carina. Right-sided CVCs, whether placed via the internal jugular or subclavian routes, were more likely to lie with their tips below the carina than left-sided CVCs. CVCs placed via the left internal jugular vein were least likely to have their tips lying below the carina. Table 3 shows the number of CVCs >50 mm above and below the carina according to site of insertion.

We also audited the angle the CVC tips made with the vertical. Right-sided CVCs were found to rarely have a significant angle between the tip and the SVC—only 4 of the 163 right-sided CVCs had tips with angles greater than 5° to the vertical (range 12°–90°). Further data relate to left-sided CVCs only.

The left-sided CVCs were investigated further to examine the relationship between tip position and angle to the SVC (Fig. 3 and Table 4). A high proportion, 27/43 (63%), of the CVCs above the carina had an angle to the vertical above 40°. None of the CVCs below the carina had an angle to the vertical above 40° (in fact they were all less than 20° to the vertical). The number of CVCs that would satisfy both criteria for adequate position, that is, above the carina and an angle to the SVC of less than 40°, was small [16 of 43 (37%)] and the majority of these (9) were high up in the innominate vein and had not even crossed the midline.

These figures show that the majority of right-sided catheter tips could be considered to be in a satisfactory position but a smaller number were either too high in the SVC or too low in the RA. The majority of left-sided catheter tips could be considered unsatisfactory because of the risk of abutment at and acute angle to the wall of the SVC or placement in the innominate vein.

A typical example of poor catheter tip position is shown in Figure 4 where the tip of a left-sided catheter is abutting the right side of the SVC at an acute angle with the risk of impending catheter perforation.

**Discussion**

This study demonstrates that a high proportion (38% overall) of CVCs were sited with their tips below the carina. The proportion was higher with right-sided CVCs (45%). We suspect these findings are typical of practice elsewhere. CVCs of standard length of 16 or 20 cm are used within the setting of the ICU and operating theatre. There is undoubtedly reluctance from many clinicians to leave portions of the CVC outside the patient for reasons of sterility...
and security, therefore, most CVCs are inserted to their full length. Even the shorter 16 cm CVC, if fully inserted from the right side, often results in the tip lying below the carina.\textsuperscript{13} Either shorter CVCs should be used or clinicians should be more ready to withdraw them to a safer position after post-insertion chest radiographs.

Schematic zones for catheter tip positioning can be categorized as shown in Figure 5.\textsuperscript{1}

Zone A represents the lower SVC and upper RA. In this zone CVCs placed from the left side are likely to lie parallel to the vessel walls. However, a part of this zone lies within the RA and therefore within the pericardial reflection. This may represent a necessary compromise for left-sided
CVCs to ensure they lie parallel to the vessel wall. Right-sided CVCs in this zone, however, should be pulled back to zone B. The azygous vein junction with the SVC lies within this zone and catheters may pass into this system.

Zone B represents the area around the junction of the left and right innominate veins and the upper SVC. This is a suitable area for CVCs placed from the right side, however left-sided CVCs will enter this area at a steep angle (see Fig. 4) and are at risk of abutting the lateral wall of the SVC and should ideally be advanced into zone A.

Zone C represents the left innominate vein proximal to the SVC. CVCs in zone C are probably suitable for short-term fluid therapy and CVP monitoring, but not for inotrope infusions or long-term use. The safety of this site has been questioned. 14

Instructions accompanying the packaging of CVCs state that it is negligent to site the CVC with the tip in the RA. This is because of the potential risk of pericardial tamponade if the CVC tip erodes through the vessel wall below the pericardial reflection. The upper limit of the pericardial reflection cannot be seen on CXR, but anatomical studies have shown that it is very unlikely to extend above the level of the carina. 9

Left-sided CVCs were less likely to be placed below the carina—only 14% in this audit. This is presumably due to the greater distance of the insertion point from the SVC than for right-sided CVCs. CVCs 16 cm long may not even reach the SVC from the left side. A high proportion of left-sided lines above the carina had a steep (≥40°) angle to the vertical. These can be further divided into two groups: those lying within the left innominate vein proximal to the SVC (zone C) and those where the tip abuts the right internal wall of the SVC (zone B). The latter group has a higher chance of vessel wall perforation and associated morbidity. As the junction of the innominate vein with the SVC cannot be identified on CXR then it is difficult to differentiate between these groups.

In both these two groups (zones B and C), however, the position is unsatisfactory: either because the proximal position increases the chance of thrombosis or because there is an increased risk of vessel wall perforation. Ideally the tip of left-sided catheters should be sited well below the junction of the innominate vein with the SVC (so that the CVC tip is parallel with the SVC 2) and above the pericardial reflection. This audit shows that in practice those left-sided CVC tips that are vertical are generally sited below the carina. This renders the advice to site all CVCs above the carina inappropriate, particularly if they are inserted from the left side.

The higher incidence of vessel wall perforation seen with left-sided CVCs can be accounted for by the increased risk of mechanical and chemical trauma as the CVC tip enters the SVC from the left innominate vein. The amount of travel of the CVC within the vessel with position from supine to upright, 15 respiration and arm movement 16 has been shown to be in excess of 2–3 cm. This suggests that those CVCs, which are only just vertical on CXR, may not in fact always be so and perhaps should be advanced even further down the SVC.

These factors are less important when CVCs are placed on a short-term basis such as for monitoring and fluid therapy in the context of major surgery. However, for those CVCs likely to remain in situ for a longer period of time and those used for infusing irritant substances, such as inotropes and TPN, precise placement and the incidence of complications become more significant.

There are a number of ways to potentially improve practice. Firstly, different length catheters for right- and left-sided placement should be stocked and used. A range of 12–30 cm should be suitable for all approaches from the upper body in different size adults; there should be increased awareness of the issues discussed above, including specialties other than Anaesthesia and Intensive Care Medicine. Secondly, greater use of ECG guidance and radiological screening should be made during placement of CVCs. The limitations of ECG guidance for left-sided placements have been recently highlighted. 14 17 Thirdly, it should be accepted that left-sided catheters may require placement within the RA for positioning to be acceptable. We suggest that for left-sided catheters placement at or below the carina is more likely to result in a satisfactory tip position. Finally, it is difficult to aseptically reinsert catheters more deeply after the insertion procedures are complete, and impossible if the chosen catheter is too short. Catheters can however be withdrawn if a CXR shows it has been inserted too far and clip on retaining wings make this process easier. Hence it may be preferable to choose and insert longer catheters initially but be prepared to withdraw them after imaging.

We conclude that right-sided CVCs should generally be sited above the carina in line with current guidelines. Left-sided CVCs should be sited in the SVC with the tip at a shallow angle to the vessel wall. In reality this will mean that the tip will often require to be sited below the carina and pericardial reflection in the upper RA.

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