Misplacement and Loop Formation of Central Venous Catheters

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Exact placement is an essential prerequisite for long-term use of a central venous catheter. Reported data show an extremely wide range of catheter misplacements: from less than 1% to more than 60%. Some approaches appear to be less advantageous than others, but the highest rates of misplacement occur in the cubital, external jugular and saphenous veins.

A series is presented of 378 radiographically controlled central venous catheters analysed for aberrant placement and loop formation. The total occurrence of faulty positioning and coiling reached 5.3%, while the respective incidences were 30% for the external jugular vein, 5.7% for the internal jugular vein, 5.5% for the infraclavicular technique of subclavian venepuncture, 5.3% for the innominate vein and 1.4% for the supraclavicular approach of subclavian venepuncture. The total frequency for pure loop formation was 2.9%.

The authors discuss numerous reported data on catheter malpositioning, according to the specific techniques used, and compare them with their own results. The relatively low incidence in the present series is possibly due to the high proportion of cases where the supraclavicular subclavian approach was used, the omission of the saphenous/femoral and cubital techniques, and to pre-determining the length of the inserted catheter segments.

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The correct location of a central venous catheter (CVC) should always be ensured to avoid serious complications such as thrombosis, thrombophlebitis and perforations of the myocardium (Brandt et al. 1970). The risk of thrombosis is already increased because of elevated osmolality and viscosity and the changed pH of infused solutions (Vere et al. 1960). Loop formation and kinking of intravenous catheters further increase the risk of thrombosis by elevating the intravascular flow resistance and by altering the venous flow pattern (Sabuncu et al. 1969). If the position of the catheter is not corrected, a large proportion of patients develop marked thrombotic changes.

Valid central venous pressure (CVP) measurements require that the catheter tip be placed in the innominate veins, the superior vena cava or the right atrium (Wilson et al. 1962, Sykes 1963, Hardaway 1968). Although right atrial catheterization is associated with known possible complications (Adar & Mozes 1971), right atrial pressure provides the best guide to the CVP.

The simplest way of checking the intrathoracic location of the catheter tip is by observing oscillations of 2–4 cm H$_2$O in the manometer column, synchronous with respiratory movements. Low fluctuations reaching 0.5 to 1.0 cm H$_2$O may indicate that the catheter lumen is lying against the venous wall or a valve. In such a case, the free fall of pressure in inspiration is not balanced by an equal rise of pressure in expiration. Rapid and high fluctuations of 8–10 cm H$_2$O usually indicate that the catheter has been advanced into the right ventricle (Kinyon et al. 1966).
Nevertheless, this method often fails to exclude misplacement and loop formation. Kellner & Smart (1972) using antecubital, external jugular (EJV) and subclavian (SV) veins often observed spuriously high CVP readings which decreased 2–6 cm on replacement of the catheter tip; only in 3.6% of cases was the respiratory swing absent, while X-ray findings showed that 24.6% of the catheter tips were not localised in central veins. Shang & Rosen (1973), catheterizing by the basilic vein route, found reliable CVP measurements in only 47.2% and 22.3% of cases when using Intracath-catheters and Drum-cartridge-catheters, respectively.

Thus, the clinical criteria of correct placement cannot be relied upon (Langston 1971, Johnston & Clark 1972, Kellner & Smart 1972). In spite of the use of ECG control (Bull 1969) or fluoroscopy during the threading of the catheter, chest X-ray has remained the only reliable routine method for verifying the whole course of the inserted catheteral segment, as well as the location of the catheter tip.

At the Clinic of Anaesthesiology and Resuscitation, Bratislava, 378 consecutive central venous catheterizations were performed between February 5th, 1972 and March 15th, 1975. We present a retrospective analysis of catheter misplacements and loop formation based on roentgenographic investigation.

MATERIALS AND METHODS

In 351 patients, CVC (which was indicated for CVP measurements, i.v. fluid therapy or parenteral nutrition) was carried out on 378 occasions, transcutaneously on each side, using the route of the following entry vessels: EJV, 20 occasions; IJV, 87 occasions (Jernigan et al. 1970); SV on 142 occasions by supraclavicular technique (Yoffa 1965) and on 91 occasions by infraclavicular technique (Aubaniac 1952); while the innominate vein (Burr & Gasser 1971) was used 38 times on the right only. Unsuccessful punctures or catheterizations were excluded from the whole series.

We used 5 cm long puncture needles for inserting 30 cm nylon catheters (outer ø 2 mm, inner ø 1.5 mm; made by Vygon, France). Table 1 shows the lengths of inserted catheter segments from the skin to the catheter tip which, with a few exceptions, were not exceeded.

<table>
<thead>
<tr>
<th>Entry vein</th>
<th>Right</th>
<th>Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>External jugular vein</td>
<td>17 cm</td>
<td>22 cm</td>
</tr>
<tr>
<td>Internal jugular vein</td>
<td>17 cm</td>
<td>22 cm</td>
</tr>
<tr>
<td>Subclavian vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-infraclavicular technique</td>
<td>16 cm</td>
<td>21 cm</td>
</tr>
<tr>
<td>Subclavian vein</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-supraclavicular technique</td>
<td>15 cm</td>
<td>20 cm</td>
</tr>
<tr>
<td>Innominate vein</td>
<td></td>
<td>11 cm</td>
</tr>
</tbody>
</table>

Immediately after insertion, the correct placement of the catheter was routinely checked by means of blood aspiration, and by observing the free flow of fluid from a drip and the respiratory swing of the manometer meniscus. All catheters were inserted into the superior vena cava, and whether or not the catheter was thought to lie in an acceptable position, a roentgenogram was taken by a portable system at the bedside, after injecting 1–2 ml of 60% or 76% radiopaque medium (Verografin® SPOFA) into the lumen (since both types of catheter lacked radiopacity). When the catheter tip was located within the thoracic cavity and devoid of positional anomaly, it was left as correctly placed. On occasions where correction was required, the chest X-ray was repeated after repositioning. On 14 occasions (3.7%) no chest X-ray was taken.

RESULTS

The correct placement of CVC was verified on 364 out of 378 occasions (96.3%) in 351 patients. Misplacement and/or loop formation of catheters was seen on a total of 20 occasions, i.e. 5.3%. A survey of cases is given in Table 2 and the percentage of mal-positioning with various techniques is shown in Table 3.

The highest rate of incorrect placement was observed with the approach to EJV (30%). In 6 out of 20 attempts the catheter tip tended to stick in small cervical plexus veins.
Table 2
Survey of misplacements and loop formation.

<table>
<thead>
<tr>
<th>Patient</th>
<th>No. of occasions</th>
<th>Entry vein</th>
<th>Misplacement into incorrect vessel</th>
<th>Loop formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1–6</td>
<td>6</td>
<td>Ext. jug. veins</td>
<td>Cervical plexus veins</td>
<td>—</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>Int. jug. vein/L/</td>
<td>—</td>
<td>Simple loop in the entry vein</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>Int. jug. vein/L/</td>
<td>Ipsilateral subcl. and innominate vv. Thoracic duct</td>
<td>Double loop</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>Int. jug. vein/L/</td>
<td>—</td>
<td>Simple loop in the ipsilat. innominate v. with the tip in thoracic duct</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Int. jug. vein/R/</td>
<td>—</td>
<td>Simple loop in the ipsilat. jugulocr. subclavian venous junction</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>Int. jug. vein/R/</td>
<td>—</td>
<td>Simple loop in the superior vena cava with the tip directed upwards</td>
</tr>
<tr>
<td>12–13</td>
<td>2</td>
<td>Subclavian infraclavicular technique /R/</td>
<td>Ipsilateral internal jugular vein</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>1</td>
<td>Subclavian infraclavicular technique /R/</td>
<td>Contralateral innominate vein</td>
<td>Simple loop in the superior vena cava with the tip in the contralateral innominate vein</td>
</tr>
<tr>
<td>15–16</td>
<td>2</td>
<td>Subclavian infraclavicular technique /R/</td>
<td>Contralateral innominate vein</td>
<td>—</td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>Subclavian supraclavicular technique /L/</td>
<td>Ipsilateral internal jugular vein</td>
<td>Loop in the internal jugular vein with the tip directed back into innominate vein</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
<td>Subclavian supraclavicular technique /R/</td>
<td>Ipsilateral internal jugular vein</td>
<td>Loop in the internal jugular vein with the tip directed downwards</td>
</tr>
<tr>
<td>19–20</td>
<td>2</td>
<td>Innominate vein /R/</td>
<td>—</td>
<td>Simple loop in the superior vena cava</td>
</tr>
</tbody>
</table>

The incidence of aberrant placements was nearly equal with the use of IJV, the infraclavicular subclavian technique and the right innominate vein (5.7%, 5.5% and 5.3%, respectively).

Among 87 catheterizations via IJV, five incorrect placements were seen, as follows: a simple loop in the punctured IJV on the left; a double loop located in the ipsilateral (left) SV and innominate vein (Fig. 1a, b); an even more exceptional picture with IJV cannulation on the left when a simple loop was formed in the ipsilateral innominate vein as a result of wedging the catheter tip in the upper part of the thoracic duct (MÁJEK et al. 1975); using the right IJV, two simple loops
Table 3
Percentages of misplacements and formation of loops with techniques used.

<table>
<thead>
<tr>
<th>No. of occasions</th>
<th>Technique used</th>
<th>No. of occasions of misplacement and looping</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>External jugular vein</td>
<td>6</td>
</tr>
<tr>
<td>87</td>
<td>Internal jugular vein</td>
<td>5</td>
</tr>
<tr>
<td>91</td>
<td>Subclavian vein (infraclavicular)</td>
<td>5</td>
</tr>
<tr>
<td>142</td>
<td>Subclavian vein (supraclavicular)</td>
<td>2</td>
</tr>
<tr>
<td>38</td>
<td>Right brachiocephalic vein</td>
<td>2</td>
</tr>
<tr>
<td>Total 378</td>
<td></td>
<td>20</td>
</tr>
</tbody>
</table>

Total 378

Fig. 1. Chest roentgenogram in a 31-year-old man with multiple fractures, post-traumatic renal failure and fat embolism. (See patient 8 in Table 2.)

a) Central venous catheter inserted via the left internal jugular vein and forming a double loop in the left subclavian and innominate veins, with the tip directed centripetally.
were observed—a loop in the jugulo-subclavian venous junction with the tip directed into the punctured vein (Fig. 2), and a simple loop formed in the superior vena cava with the tip curving back and up.

On catheterizing by the infraclavicular subclavian approach, all five observed misplacements occurred on cannulating the right vein: The catheter slipped twice in the ipsilateral IJV; on one occasion it entered the superior vena cava and, after forming a simple loop, the tip reached the contralateral innominate vein; and on two occasions the catheter was simply misdirected into the contralateral innominate vein.

The lowest incidence of faulty placements (1.4%) was recorded in the group of 142 supraclavicular approaches to the SV. The left IJV was threaded once and a simple loop was formed in this vein with the tip directed centripetally into the ipsilateral innominate vein. When approaching from the right, the catheter passed once into the ipsilateral IJV, forming a loop with the tip directed centrally downwards.

When the right innominate vein was used
as the entry vessel, loop formation occurred twice in the superior vena cava with the tip curving back and up.

DISCUSSION

A misplaced catheter can be positioned too high or too low, it can be inserted into a smaller affluent vein, or ipsilateral or contralateral retrograde insertion (with or without coiling) can be made into other communicating veins. Loop formation is not very unusual, as occasionally the catheter tip becomes caught in the ostium of one of the tributary venous branches, which causes loop formation and coiling during further threading of the catheter.

The percentage of catheter misplacements varies widely from less than 1% to more than 60%. While McConnell & Fox (1972), catheterizing via the IJV, found no X-ray evidence of faulty positioning on 70 occasions, and Freeman (1968), and Haapaniemi & Slátis (1974), using supraclavicular techniques, recorded rates of misplacements of only 0.7% and 1.7%, respectively, other authors have observed a much higher frequency with various techniques. Langston (1971) reported 29%, Gilday & Downs (1969) 33%, Reichelt (1966) 36%, Deitel & McIntyre (1971) 50%, and Shang & Rosen (1973) as high as 60.4% incidence of unsatisfactory catheter placements.

Burri & Gasser (1971) made a retrospective analysis of 11,051 central venous catheterizations (including their own experience) which showed the following percentage of malpositioning: 9.2% with basilic vein (BV), 12% with EJV, 8% with infraclavicular
technique for SV, and 25% with the use of the great saphenous vein as the site of entry. In their prospective study of 3,037 radiologically controlled catheters, and using the same techniques, 453 (14.9%) were found to be misplaced; the respective percentages were 16.7% (BV), 17.8% (EJV), 9.3% (SV) and 40.4% (other, but predominantly the saphenous vein). A 2% incidence of pure loop formation was found which agrees with the 2.9% (loops on 11 occasions) found in the present series.

With catheterizations via basilic, subclavian and jugular veins, the most frequent placement complication is deviation of the catheteral tip into the left or right IJV (Burri & Gasser 1971). Nevertheless, entering the contralateral IJV is extremely rare; the only report is that of Marshall (1973) who observed that a catheter, inserted through the right jugular vein, passed via the innominate veins into the left IJV. From these entry veins, the catheter often slips into the axillary vein or SV; also, when catheterizing through the EJV and BV, the catheter often sticks in the small cervical plexus veins.

Antecubital veins. The reported data differ significantly. With this approach, Thomas (1972) recorded 13%, Johnston & Clark (1972) 18%, Woods et al. (1974) 21% and Deitel & McIntyre (1971) 28% occurrence of malpositioning.

In comparison with CV, the BV seems to be the vein of choice. Webre & Arens (1973), who distributed patients according to the entry vein, recorded a 55% rate of aberrant positions with CV and a 35% incidence with the BV. When using CV, threading through the cephalo-subclavian junction is often difficult; some catheters fail to pass beyond the clavipectoral fascia. The majority of authors reported on misplaced catheters inserted via BV; the correct placement failed in 6% (Ladd & Schreiner 1951), 7% (Holt 1967), 8% (Fischer et al. 1966), 9% (Stoeckel 1969), 16.7% (Burri & Gasser 1971), 29.7% (with Drum-cartridge-catheters, Shang & Rosen 1973), 36% (Reichel 1966) and 60.4% (with Intracath-catheters, Shang & Rosen 1973). Nevertheless, the side from which the catheter is inserted does not alter the likelihood of malpositioning (Woods et al. 1974).

With the cubital approach, deviations are mainly into IJV bilaterally (Sellars 1970, Kellner & Smart 1972, Webre & Arens 1973, Woods et al. 1974). IJV malpositions are more frequent with the arm at 90° to the body; the highest success rate can be expected with the arm positioned at less than 45° to the body (Woods et al. 1974). Then, to avoid entering the IJV, the patient's head may be turned towards the side of insertion to make the angle between the SV and the IJV more acute (Deitel & McIntyre 1971). The catheter tip may also be advanced into the right ventricle, or may be placed too peripherally in the subclavian, cephalic or axillary vein (Woods et al. 1974); exceptionally, it may deviate from right to left SV, to pass down the lateral thoracic vein or coil in the axilla (Webre & Arens 1973), and on rare occasions, even the cervical plexus veins may be entered (Kellner & Smart 1972). Though exceptionally some catheters inserted through the CV may turn back distally into the ipsilateral axillary vein (Kellner & Smart 1972, Woods et al. 1974), the reverse has not occurred. Occasionally, the catheter tip becomes placed in the SV of the contralateral side or the azygos vein (Kellner & Smart 1972).

Incorrect placements resulting from the inadequate length of the inserted segment should be avoided by means of an estimate on the body surface. The distance from the cubital fossa to the right atrium may be measured on the skin before the catheter is inserted. An adequate length is given by the measured distance from the site of insertion to the anterior end of the right fourth chondrosternal junction along the line of the anatomical presumptive course of the veins (Woods et al. 1974). Another possibility is provided by measuring the distance from the point of insertion to one-third of the way
down from the supraspinal notch to the xiphoïd process (Brandt et al. 1970).

**External jugular vein.** The incorrectly placed catheter may deviate in the ipsilateral SV or IJV, may become coiled in the vein, or, commonly, may stick in some of the small neck veins (Burri & Gasser 1971). Burri (1970) observed 12%, Burri & Gasser (1971) 17.8% and Deitel & McIntyre (1971) a 50% rate of misplacements.

The high incidence (30%) of malpositioning in our EJV group is associated with the use of this approach early in the series; later this approach was completely abandoned. Auxiliary manoeuvres to overcome the hindrance caused by the valve at the EJV/SV or EJV/IJV junctions (injecting or infusing isotonic saline through the catheter being inserted, encouraging the patient to cough, lowering the shoulder caudal and pressing on the catheter tip region from the outside) were not used on every unsuccessful occasion.

**Internal jugular vein.** Although use of this entry vein appears to be advantageous, malpositions were described repeatedly (English et al. 1969, Kellner & Smart 1972, Marshall 1973). McConnell & Fox (1972) found no radiological evidence of malpositioning in a series of 70 cannulations. English et al. (1969) reported on two out of 500 occasions when the catheter was threaded back up the SV, but they did not analyse the total incidence of faulty positioning. Jernigan et al. (1970) failed to evaluate the misplacement rate experienced in their large series comprising 1,000 catheterizations. Malpositions are rarer than with other routes, particularly if the right vein is chosen (Kellner & Smart 1972). Bell et al. (1973) blame long catheters; they state that when a 20 cm catheter thus inserted permits the free aspiration of blood, it can lie only in the superior vena cava or the right atrium, but if a 30 cm catheter is used this need not be so.

The 5.7% occurrence of faulty positions in our IJV group is higher than expected. Out of five occasions, the wrong placement occurred twice on the right and three times on the left, but in each case it was caused by loop formation.


Again, the reported percentage of malpositioning varies over a wide range: 0.7% (Freeman 1968), 2.5% (Kösters & Bartels 1970), 3.8% (Goin et al. 1972), 4.1% (Christensen et al. 1967), 5% (Scholz & Loewe 1969), 9.3% (Burri & Gasser 1971), 10% (Eisterer & Kutsche-Lisberg 1968), 14.3% (Shang & Rosen 1973), 19% (Wrightzky & Vogel 1967), 24% (Deitel & McIntyre 1971) and 26% (Mogensen et al. 1971).

Our experience conforms roughly to that of some of the above authors, showing aberrant insertions into the IJV or contralateral innominate vein. Our frequency (5.5%) lies among the lower percentages.

**Subclavian supraclavicular approach.** From the standpoint of correct positioning, this technique proved to be very advantageous. The supraclavicular technique used by Haapaniemi & Slåtis (1974), although it aimed at cannulating the central venous system through the jugulo-subclavian venous junction, may be included in this group. The potential aberrant insertions are roughly similar to those with the infraclavicular technique. Nevertheless, the frequency is substantially reduced. While Yoffa (1965) and Defalque & Nord (1970) failed to distribute cases with correctly placed and malpositioned or looped catheters, Freeman (1968) recorded 0.7% and Haapaniemi & Slåtis (1974) 1.7% incidence of catheteral misplacements. Our
experience corresponds well with that of the authors mentioned with regard to the incidence (1.4%), as well as to the veins mis-threaded (IJV).

Innominate vein. The published papers are devoted exclusively to problems of technique. There are no reports dealing with the incidence of location failure, and our innominate vein group is too small to draw conclusions. Nevertheless, the Tuohy needle with the bent tip directed downwards helped us to avoid entering the contralateral innominate vein. Both misplacements arose on account of loop formation, probably as a result of wedging the catheter tip in some smaller affluent vein.

Femoral and saphenous approach. The occurrence of misplaced catheters inserted via veins draining into the inferior vena cava is consistently high. Brücke et al. (1966) and Burri & Gasser (1971) both reported a 25% incidence of misplacements. The percentage was even higher in the series of Pokieser et al. (1966) who found a 28% rate of malpositioning, including three loops in the inferior vena cava and three loops in the iliac vein. The deviating catheters entered the ascending lumbar vein, internal iliac vein and superior gluteal vein; and, retrogradely, the superficial femoral vein, left renal vein and the contralateral iliac vein. In their prospective study, Burri & Gasser (1971), using predominantly the saphenous vein in the last group, found a 40.4% rate of misplacement.

Summarizing, it may be said that the relatively low incidence of malpositioning in the present series (5.3%) was presumably due to the larger proportion of cases where the supraclavicular subclavian technique was used, the omission of cubital and saphenous (femoral) vein catheterizations, as well as the pre-determined length of the inserted catheteral segments. The Tuohy needle with its curved tip made it possible to direct the inserted catheter more easily in a centripetal direction, thus often preventing an incorrect position.

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