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Peroperative intravasal electrographic control of catheter tip position in access ports placed by venous cut-down technique

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INTRODUCTION

Optimal tip positioning of percutaneously inserted central venous catheters (CVC), at the junction between superior vena cava (SVC) and right atrium (RA), is known to be essential in order to avoid damage to the vein wall (tip too high in the SVC)[1] or to the heart valve (tip too deep in the RA)[2,3] and also to keep the access functional.[4] Clinical judgement alone, based on anatomical criteria, provides 40–70% optimal positioning.[5–7] Chest X-ray performed after the procedure is currently used as control document[8] to track down malpositions and also to exclude complications such as pneumo- or hydrothorax, but does not allow intra-operative repositioning of eventually misplaced catheter tips.

Alternative techniques were developed for peroperative checking. Hellerstein described the intravasal electrocardiography (IEG) technique in 1949, where the catheter itself, filled with a conductive saline solution, acts as one of the electrodes of the conventional external electrocardiogram set-up, tracing changes in the P-wave pattern in relation to the anatomical position of the catheter tip.[9] This allows a peroperative accurate tip positioning in more than 90% of cases.[5,7] A refinement was brought for catheters placed by the Seldinger technique, where the metallic guide-wire acts as an electrode[10,11] providing higher quality images than the saline column.[5] Doppler sonography has been proposed as well: a 2 MHz probe placed at the right sternal border detects turbulences associated with the injection of liquid through the catheter.[12]

Accurate tip positioning is even more crucial for long-term intravenous catheters connected to access ports, as they might remain *in situ* for years. For these catheters, peroperative fluoroscopic control of tip position has been propagated as the golden standard[13,14] and is currently used in our department.[15] Misplaced catheter tips can be correctly re-inserted under direct visual control, with a maximum chance of success.[16] However, anatomical landmarks can be obscured by local conditions such as mediastinal shift, pleural effusion, or abnormal chest geometry[17] and the cumulative radiation dose to the medical and paramedical staff constitutes a non-neglectable disadvantage of this technique.

Since the intracardiac electrography technique appears both reliable and safe for percutaneous catheters, it seems logical to examine the feasibility of this technique for long-term accesses inserted through surgical cut-down of smaller peripheral chest veins, with its specific positioning problems.

AIM OF THE STUDY

Prospective evaluation of the IEG monitoring technique for optimal tip positioning of catheters placed by venous cut-down and connected to a totally implantable access port.

The questions addressed in the study are (1) is a peroperative IEG control for catheter tip positioning feasible for accesses placed by venous cut-down? (2) which are the electrographic patterns that fit our fluoroscopic landmarks best? (3) is this technique as accurate as fluoroscopy? (4) is this technique safe?

PATIENTS, MATERIAL AND METHODS

Patients

Over a 4-month period, 135 consecutive adult patients needing the insertion of a long-term subcutaneous access

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device for intravenous chemotherapy entered the study after informed consent. All procedures were performed by venous cut-down under local anaesthesia. All patients underwent control of catheter tip position by means of IEG, fluoroscopy and chest X-ray.

Principles of IEG-guided catheter placement

During the intravasal progression of a conducting guide-wire (electrode) connected to any classical ECG monitoring device, typical changes in the IEG pattern can be seen, essentially concerning the P-wave which is related to atrial depolarization.

When this electrode comes closer to the atrium, the amplitude of the P-wave rises, due to the superpositon of the intracardiac atrial electrogram generated by atrial myocytes on the surface P-wave.[18] The amplitude of this wave might be greater than the surface QRS complex and will remain high as long as the tip remains in the atrium, recording the intracardiac signal. It will decrease and disappear when the tip leaves the atrium, either into the superior or the inferior vena cava. Motion of the tip of this electrode allows us to detect exactly the position of the cavo-atrial junction.

Ports and catheters

Standard size Celsite® access ports (Ref. ST201 – B. Braun Medical) were provided with an attachable radio-opaque silicone catheter showing distance marks at each centimetre level (outer diameter 2.8 mm; inner diameter 1.1 mm), sterile J-tip stainless steel conducting guide-wire (0.96 mm, 60 cm length) and connection cable, together with a specially designed reusable switch-box.

Technique of catheter placement using venous cut-down and IEG monitoring

Venous cut-down of the external jugular or cephalic vein is performed in the operating room, with fluoroscopic control of catheter tip position, according to the technique previously described[15] under local anaesthesia and slightly modified to fit simultaneous use of IEG monitoring.

The patient lies on an operating table allowing fluoroscopy. Three ECG adhesive patches are placed on the skin, behind both shoulders and at the apex of the heart and connected to the ECG monitor. The right shoulder patch is connected through the switch-box to the monitoring device (see drawing). The catheter is cut at the 50 cm length mark and the ports are filled with a heparin solution (100 IU/ml in NaCl 0.9%).

The metallic guide-wire is pushed into the catheter with just its soft J-end emerging from the proximal tip. At the opposite extremity, forceps are placed on the protruding part of the guide-wire as a landmark. The J-end of the metallic guide is pulled back inside the catheter for about 10 cm, leaving a soft proximal catheter end.

The soft catheter portion is gently advanced into the bloodstream for 20 cm. The guide-wire is inserted back into the catheter as far as necessary to bring the marking forceps back into contact with the external extremity of the catheter. The J-tip emerges then into the bloodstream and the wire is attached to the sterile cable, connected through the switch-box to the ECG monitor. The catheter–guide-wire complex is advanced in the vein or pulled back until typical IEG P-wave patterns are seen on the cardiac monitor. The different intravasal catheter lengths at which these P-wave patterns can be seen are recorded.

Peroperative fluoroscopy is performed in order to check the final position of the catheter tip which should be at the junction between SVC and right atrium. This 'ideal' radioscopic position is retained and the intravasal catheter length needed to reach this point is recorded.

The guide-wire is removed, the catheter flushed, trimmed and connected to the subcutaneous port. After control of easy blood withdrawal and injection of heparinized saline and closure of the wound, a standing chest X-ray is performed.

Measurements and scoring system (Figure 1)

For each patient, the length of the intravasal segment of the catheter was noted, at four predetermined P-wave patterns on the IEG, namely

(1) at the rising P-wave level (Fig. 1.2)
(2) at the beginning (Fig. 1.3) and at the end (Fig. 1.4) of the maximal P-amplitude zone
(3) where a negative P-wave (Fig. 1.5) could be found, followed by the positive P-wave.

The catheter length needed to reach a point in the SVC situated 2 cm under the radiological projection of the right main bronchus under fluoroscopy was recorded. If this structure was not clearly visible, the J-point marking the beginning of the curve of the right atrium was retained.

A standing chest X-ray was performed in the radiology department as independent control. These X-ray images were provided with a centimetre scale allowing us to measure the distance between the ideal and the actual tip location. If the position was optimal, the value given for this distance was 0. Too short catheters remaining in the SVC, were given a negative value (-1, -2 … cm) whilst for catheter tips beneath the reference point, the excess length was recorded as a positive value ($+1$, $+2$ … cm).

Statistical analysis

The lengths of the catheter needed to reach the four different points with typical P-wave shapes on the IEG

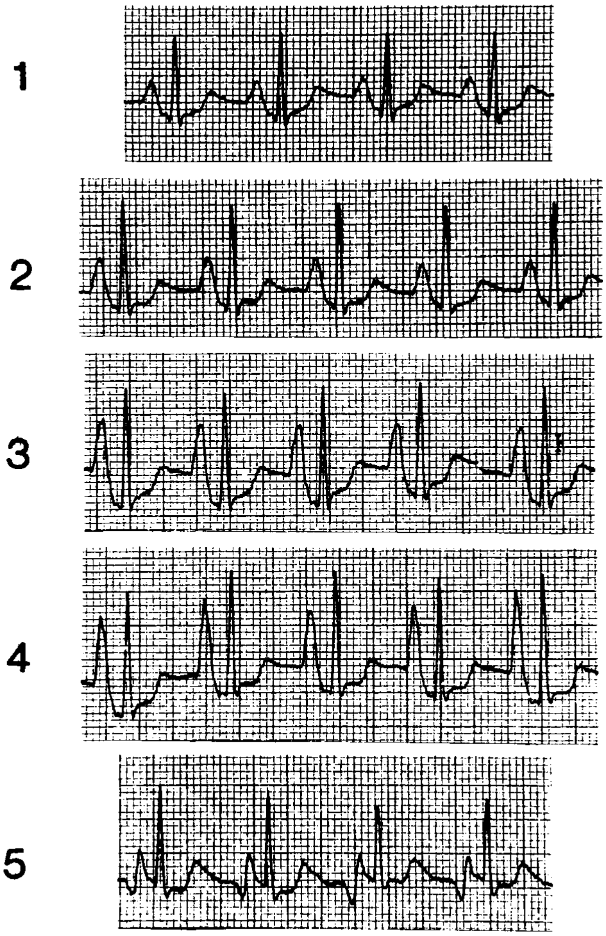

Figure 1 Intravasal electrogram recordings of different P-wave patterns with the different positions of the catheter tip. (1) Tip of catheter in the SVC, 4 cm above the junction with the RA. There is a normal P-wave morphology. (2) Tip of catheter in the SVC, 2 cm above the junction with the RA. There is an increase in the amplitude of the P-wave. (3) Tip of catheter at the junction of the SVC with the RA. Beginning of the area with the maximal P-wave amplitudes. The 'intra-atrial' electrogram is superimposed on the 'surface' P-wave. (4) Tip of catheter 2 cm deep in the RA. The P-wave amplitude is still maximal. (5) Tip of the catheter 10 cm deep in the RA at the junction with the IVC. There is a biphasic P-wave with an initial negative deflection.

were compared, by means of a paired Wilcoxon signed rank test, to the length needed during fluoroscopy to reach the predetermined anatomical position, and the median as well as the interquartile ranges of the length differences were given.

RESULTS

Feasibility

The technique was easy to learn. The length of the procedure was only increased by a few minutes, by double checking the tip position.

Nine patients could not be evaluated (Table 1). This was due to either poor IEG monitoring (no clear P-wave could be seen in two cases of atrial fibrillation and in one patient with a cardiac pacemaker), access through the inferior vena cava system (two cases), technical problems during the procedure (related to the monitoring device in three cases or to a difficult insertion into a very thin vein in one case).

We evaluated a total of 126 patients. Correct positioning of the catheter tip in the SVC could be obtained in 116 cases with the sole IEG method (92%).

No P-wave change was seen in 10 cases (8%), always due to malposition of the catheter in another vein and correction under direct fluoroscopy was necessary.

Correlation between typical IEG P-wave patterns and anatomical landmarks on fluoroscopy

Comparison between the catheter length needed to obtain the four predefined P-wave patterns and the catheter length needed to reach the fluoroscopic landmarks showed that the earliest point where the maximal P-wave was recorded fitted best with the correct position on fluoroscopy (Table 2).

The point where the P-wave started to increase and the end of the area with the maximal P-wave amplitude were respectively too proximal and too deep into the heart according to fluoroscopy. Although the median distance to the negative P-wave point fitted well wiht the values on fluoroscopy, this point was not detected

Table 1 Catheter positioning with IEG: feasibility of the technique

Total number of cases	135			
Non-evaluable	9	Contra-indication for IEG	Atrial fibrillation	2
			Cardiac pacemaker	1
			Saphenous access	2
		Technical problems during procedure		4
Evaluable	126	Clear P-wave change		116
		No P-wave change		10

Table 2 Ideal IEG P-wave shapes expressed as median distance and inter-quartile range between actual tip position at four different IEG checkpoints and ideal position on fluoroscopy, expressed in cm

	Median distance	Q25–Q75	*P* value
At rising P-level	−3	(−5, −2)	0.0001
Negative P-wave	0.5	(−1, 3)	0.6446
Begin max. P-area	0	(−1, 1)	0.2526
End max. P-area	1.25	(0, 3)	0.0001

Table 3 Accuracy of positioning technique expressed as the difference in cm between tip position on arrival to the 'maximal P-wave area' based on IEG and the ideal tip position on chest X-ray, using as reference the right main bronchus or the junction between superior vena cava and right atrium

	Median distance	Q25–Q75	Extreme values
Right main bronchus	0	(−1, 1)	(−5, +2)
Junction SVC-RA	0	(−1.5, 1)	(−5, +4)

in 23% of the cases. Furthermore, this pattern appeared both before and after the proximal P-wave area.

Correct position of catheter tip on chest X-ray

Eighty-eight percent of the standing chest X-ray controls showed a correct position of the catheter tip within a range of 2 cm from the optimal point of reference on the chest X-ray i.e. 2 cm caudal to the lower border of the right main bronchus (Table 3). This validates our radioscopic technique for catheter tip placement. Twelve percent of the catheters were 3–5 cm too short, according to the radiography: in fact, fluoroscopy is performed in the supine position, with a relative compression of thoracic structures by the diaphragm, whilst standing chest X-rays tend to show an elongated mediastinum and SVC, with an ensuing relative shortening of the catheter.

Complications

No peroperative adverse reactions were observed in this series although there were occasional asymptomatic extrasystoles. Only one patient complained of transient palpitations. Pneumothorax, haemothorax or nerve injury never occurred.

DISCUSSION

Intravasal electrogram monitoring appears to be a reliable control technique for cather tip positioning in the SVC system. As already stressed by other authors, patients with known arrhythmia,[19] cardiac pacemakers[20,21] or need for access through the inferior cava system,[22] are not suitable candidates for this technique. In the first two groups, ECG changes are not always clear, and for the latter, the ideal ECG reference point is not yet known.

The ideal reference point advocated by McGee *et al.*[23] for stiff percutaneous catheters inserted through the internal jugular vein, is the place in the SVC where on the intravasal electrogram, the P-wave is still normal or just starts to increase. Doing so, no single catheter was too long, but 9/25 tips were located 3–7 cm above the junction SVC-RA. Taking into account the risk of vein wall perforation and thrombosis when the catheter reaches the upper segment of the SVC with an angle of 45°[1] and the blood withdrawal difficulties due to aspiration of the vein wall onto the catheter,[16–24] other authors advocated a deeper position into the right atrium, between the sino-atrial and the auriculo-ventricular sinus.[25] Since the damage risk due to repeated contact between catheter tip and heart valve already reported in other series[3] and our own experience of impaired blood withdrawal from tips located too deeply, we rather advocate positioning the catheter tip between these two points, namely at the junction between SVC and RA.

In our pilot study, the beginning of the area where the IEG displayed the maximal P-wave amplitude fitted best with the cava-atrial junction.

A biphasic P-wave, with an initial negative deflection, has been advocated by other authors as reference point[25] corresponding to the direct recording of the simus node. However, this pattern was not reliable in our series because it could not be located properly in 23% of cases and in the remaining it could be found over a large area, both cranial and distal to the optimal location. This is probably because the sinus node[26] is located posteriorly below the junction of the SVC and the RA, and is difficult to reach with a non-stearable catheter.[27] Furthermore, far field recordings of the atrial signal in the vena cava can resemble this biphasic recording and make it therefore less specific as a reference point.[28]

Since the catheter tip is submitted to respiratory motion, body movements and heart contractions displace it up and down over a few centimetres and the ideal position should therefore be considered an average or mean position.

A clear P-wave change has never been associated with incorrect tip position neither in our series of combined IEG technique and venous cut-down, nor in others using percutaneous puncture.[21,25]

On the contrary, an absence of IEG change, providing the initial ECG was normal, combined with a smooth intravasal catheter progression always correlated with incorrect tip position, found by fluoroscopic control to be in the internal jugular, subclavian or axillary veins. IEG technique alone is unable to show where the tip really is in the absence of any P-wave change. An attempt can be made to pull the catheter out of the vein and to insert it again, after changing the patient's position on the operating table.[7,16] In refractory cases or in the case of unexplained resistance to catheter progression, a peroperative fluoroscopic control, if necessary with contrast injection, is mandatory. The use of a soft J-tip guide-wire, such as the Terumo® guide-wire, which is able to pass through difficult venous cross-roads is often efficient.[15] If still unsuccessful, another vein has to be considered for dissection.

Taking into account the importance of inserting the tip of long-term venous catheters down to the junction between SVC and RA, no catheter should be left behind without reaching this point. Excluding three cases with technical problems in this pilot study, 4.5% of the patients were considered unsuitable candidates for this technique; in 8% of the cases, positioning failed with IEG alone but we did not face any false-positive IEG changes. In 92% of the cases in our series, a clear change in the P-wave pattern was noticed and found to be reliable for tip positioning, which means that fluoroscopy as well as control chest X-ray later on might be avoided in these patients. Furthermore, there is no need to rule out any pneumothorax after the procedure, for this complication is totally excluded in the surgical cut-down technique, as shown in our experience including more than 6000 accesses. However, radiological facilities have to be available in the operating room for rescue, in patients with an arrhythmia or in case no clear modification in the P-wave pattern is seen during catheter progression.

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