Central venous catheterization and fatal cardiac tamponade

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Cardiac tamponade is a poorly recognized complication of central venous catheterization associated with a high mortality. We present a case of fatal cardiac tamponade after intrapericardial infusion of total parenteral nutrition in a patient who had two central venous catheters. We suggest that catheter tip position should always be confirmed before use of a catheter. Tamponade should be suspected in a patient who deteriorates when a central venous catheter is used and resuscitation via the catheter should be avoided.

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Complications from central venous catheters are numerous. Cardiac tamponade is a rare but well documented complication that is often fatal. Clinicians fail to consider the diagnosis in patients with typical acute signs and symptoms.¹⁻⁵ The time from insertion of the central venous catheter to onset of the clinical features varies from minutes...
the cannula (‘Leader Cath’, Vygon Ltd) was inserted into the left internal jugular vein using the Seldinger technique to act as a dedicated feeding catheter. The position of this line was confirmed by aspiration of blood, which occurred freely and spontaneously perforation of the sigmoid colon was made. On the first day after surgery, parenteral nutrition was considered necessary. A triple lumen central venous catheter was inserted into the right internal jugular vein using the Seldinger technique. Blood was freely aspirated from the vein before and after insertion of the catheter and correct positioning of the catheter tip in the superior vena cava was confirmed by chest radiography. A diagnosis of ulcerative colitis, toxic megacolon, and spontaneous perforation of the sigmoid colon was made. The patient underwent an emergency subtotal colectomy and ileostomy. On the first day after surgery, parenteral nutrition was re-started via the central venous catheter using an infusion pump. A chest radiograph showed no displacement of the catheter tip.

On the second day after operation, a 16G single lumen cannula (‘Leader Cath’, Vygon Ltd) was inserted into the left internal jugular vein using the Seldinger technique to act as a dedicated feeding catheter. The position of this line was checked by aspiration of blood, which occurred freely and the pressure trace from a transducer, which was obtained to confirm venous placement. A chest radiograph was ordered, but not taken immediately. The parenteral nutrition was transferred to this cannula and commenced at 90 ml h⁻¹.

Within 60 min of the change of infusion sites, the patient complained of abdominal, low back and leg pains, and passed bloodstained fluid per rectum. Cardiovascular measurements did not change during this hour. Over the subsequent 30 min, the ECG changed from sinus rhythm at 110 beats min⁻¹ to a narrow complex tachycardia of 180–190 beats min⁻¹, and was accompanied by a decrease in systolic arterial pressure from 140 to 90 mm Hg. The central venous pressure measured from the cannula on the right was 9 mm Hg just before the onset of tachycardia, and was unchanged from the previous hour. There were no respiratory symptoms at the onset of tachycardia. The ventilatory frequency was 17 breaths min⁻¹ and pulse oximeter saturation 96% while breathing on 2 litre min⁻¹ oxygen from a standard mask.

A provisional diagnosis of intra-abdominal haemorrhage was made and rapid i.v. fluids were given whilst medical and surgical opinions were obtained. Urgent chest radiography and echocardiography were arranged. Within 15 min of the onset of tachycardia, the patient became unresponsive with no palpable pulses. Cardiopulmonary resuscitation was commenced but pulseless electrical activity rapidly became asystole and despite prolonged efforts, the patient died. The position of the tip of the left-sided catheter was never documented on a radiograph.

At post-mortem, examination the pericardium contained approximately 200 ml of whitish fluid. Analysis of this fluid showed lipids identical to those in the parenteral nutrition. In comparing the lipid concentrations in the infusion fluid and pericardial fluid, it was concluded that 65 ml of TPN solution had been misplaced. No erosion or perforation of a cardiac chamber or great vessel could be found. All catheters had been removed from the patient before transfer to the mortuary, according to the current standard procedure, so the post-mortem position of the left internal jugular cannula tip could not be confirmed. Gross pulmonary oedema and bilateral pleural effusions were noted, probably caused by acute left ventricular failure and cardiopulmonary resuscitation. The cause of death was attributed to cardiac tamponade from parenteral nutrition infusion.

**Discussion**

Cardiac tamponade caused by central venous catheters is well documented with more than 100 cases being reported since 1958.¹⁷¹¹ The incidence is not clear from anecdotal and reference-based publications, for two reasons. Reported series have an extremely variable incidence from 0.0001 to 1.4% of all catheter insertions, with no distinction in the literature between feeding and non-feeding catheters. Under reporting of the condition is very likely.²⁸⁻¹²⁻¹⁴ This rare complication is associated with a very high mortality. Nasim and colleagues³ noted that before 1980 there was a 77% death rate in cases reported in the English literature. From 1980 to 1989 this was 47%.³ Other reports give mortality rate of between 65 and 100%.¹⁴⁻⁶ The current mortality rate is still probably great. Cardiac tamponade can present within minutes of insertion of a central venous catheter to several months later.⁶

The variation in reported incidence and time to presentation is partly related to the many risk factors associated with this complication. Direct trauma at insertion predisposes to vascular or endocardial damage and perforation. The site of insertion and position of the catheter tip are important factors. Cardiac tamponade is more frequent when catheters are inserted via peripheral rather than central
veins. This risk could be partly related to the movement of the catheter tip with changes in arm, neck and head position.\textsuperscript{1,7,10} Abduction or elevation of the arm of a patient with an antecubital vein catheter advances the catheter tip by up to 7 cm. In adults, the tip of a catheter inserted via the subclavian or internal jugular vein can move by up to 2 cm.\textsuperscript{1} Movement is least with catheters inserted via a subclavian vein. Poor skin fixation also predisposes to tip movement.\textsuperscript{7} Improved skin fixation may be aided by short 10 or 15 cm long catheters that can be positioned optimally and securely.

The angle that the catheter tip forms with the wall of a vein or cardiac chamber is thought to be an important factor responsible in vessel trauma. When the tip lies at a more perpendicular angle to the wall there is an increased chance of direct trauma and erosion.\textsuperscript{6,8} This is particularly relevant when considering catheters inserted via the subclavian veins or left internal jugular vein, as their more tortuous anatomical course increases the chance of direct contact with the constantly moving vessel walls.\textsuperscript{15}

Catheter material and design may be an important factor, although cardiac tamponade has been reported with catheters made of flexible material.\textsuperscript{1,3,9} Flexible ‘Pig-tail’ tipped catheters have been shown to significantly reduce the chances of rupture.\textsuperscript{13,16}

Early recognition and treatment of cardiac tamponade is essential if mortality is to be avoided. Symptoms and signs are usually sudden and include nausea, dyspnoea, retrosternal chest pain, cyanosis, venous engorgement, pulsus paradoxus, and confusion.\textsuperscript{5} The most common findings noted by Nasim and colleagues\textsuperscript{9} from case reports were hypotension (88%), raised central venous pressure (70%) and a disturbance in cardiac rhythm (67%), mainly tachycardia. However in 29% of these cases death occurred suddenly after ‘vague premonitory signs’,\textsuperscript{3} as in the present report. Diagnosis of cardiac tamponade is more difficult in sedated ventilated patients, so awareness of catheter-related complications is even more vital.

Investigations may not always assist diagnosis. Signs such as low voltage QRS complexes or electrical alternans may not always be present on an ECG.\textsuperscript{5,8} Chest radiographs may not show any abnormalities until considerable fluid has accumulated in the pericardial sac. Transthoracic or transoesophageal echocardiographic investigations are diagnostic.\textsuperscript{3,5,7} These techniques are unfortunately not widely available and delaying treatment to obtain these investigations may be fatal. Injection of radio-opaque contrast has also been described for diagnosis of pericardial placement of a catheter tip\textsuperscript{1,14} but is not without risk.\textsuperscript{17}

Misdiagnosis in cases of cardiac tamponade can lead to a worsening of the clinical condition. Tachycardia and hypotension related to the low cardiac output state may be considered to be caused by hypovolaemia. Giving fluid via the catheter will worsen the condition of the patient. Once the diagnosis has been made, prompt treatment is required. Administration of fluid through the catheter should be stopped, followed by attempted aspiration. If this is unsuccessful then it is appropriate to withdraw the catheter. Failure to improve will require a pericardiocentesis, followed by a thoracotomy if this does not work.\textsuperscript{5,6,18} Tragically, diagnosis may only be at post-mortem examination. The pericardial fluid is usually not bloody but of similar composition to that which had been infused. Common sites of perforation are the right atrium and right ventricle (80%) followed by the superior vena cava.\textsuperscript{5,11} Perforation has also been reported in the left atrium (patent foramen ovale) and the left pericardiophrenic vein.\textsuperscript{10,11} However, there are fatal cases where no evidence of erosion and perforation could be found.\textsuperscript{11}

Endocardial injury is thought to be caused by either movement of the catheter tip (e.g. arm movements), by movements of the cardiac chambers and lower superior vena cava (cardiac cycle) or by direct trauma. Injury causes thrombus formation and eventually adherence of the catheter to the endocardium. Erosion occurs which may lead to perforation. Infusion of fluids may then be directly into the pericardial space.\textsuperscript{1,19}

Hyperosmolar solutions such as parenteral nutrition increase the risk of erosion and perforation of a vein wall or the endocardium.\textsuperscript{5,7,9} Because of this risk, we believe that the distal port of any multi-lumen catheter should not be used for the infusion of hyperosmolar fluid.

Parenteral nutrition solutions may be infused using high-pressure pumps at rates usually exceeding 100 ml h\textsuperscript{-1}. Tamponade can occur with less than 200 ml of any fluid rapidly infused into the pericardial sac. The present report illustrates the dangers of rapid infusion and the risk of giving isosmolar solutions rapidly into the distal port of a catheter. Such practice is common in the operating theatre, in intensive care units, and during resuscitation.\textsuperscript{20} Typical checks used in the operating theatre to ascertain the position of a central venous catheter include the easy aspiration and injection of blood and the pressure waveforms measured from the catheter.\textsuperscript{18} The present report shows how these may not be reliable signs when used alone.\textsuperscript{2} The ECG technique for checking intravascular placement of central venous catheters may be useful when chest radiography cannot be done immediately after catheter insertion (e.g. during surgery), but this will not indicate catheter tip position.\textsuperscript{3,21}

In locations other than the operating theatre, chest radiographs are used routinely to check catheter tip position and diagnose other complications of catheter insertion. A radiograph does not confirm i.v. placement, nor exclude extravascular or intra-arterial placement of a catheter,\textsuperscript{17} yet it is considered to be an essential step in the prevention of complications.\textsuperscript{22–24} We question whether use of a central venous catheter for drug and fluid administration without evidence of tip position is a safe and medico-legally defensible practice during elective surgery. We do not believe that it is acceptable to dismiss chest radiography as impracticable and inconvenient in the operating theatre. Transoesophageal echocardiography allows definitive
identification of tip position in the operating theatre, but is rarely available except in cardiac operating theatres. We suggest that pre-operative fluoroscopically guided catheter placement may be the minimal standard for patients undergoing all elective and semi-urgent surgery. Such a change in practice would have significant cost and training implications.

The standard chest radiograph is a guide to tip position only. The ‘Greenall Criterion’ states that the tip should lie no more than 2 cm below a line joining the lower surfaces of the clavicular heads on a postero-anterior chest radiograph. Many authors have quoted this criterion in their publications. However, in some patients only semi-erect chest radiographs can be obtained, which are subject to geometric or image distortion. As a result the catheter tip can appear to be in a different position. Rutherford and colleagues described this effect and introduced the ‘Right Main Bronchus Criterion’. The effects of geometric distortion are markedly reduced, by assuring that the tip lies proximal to the angle formed between the right main bronchus and the trachea. As this anatomical landmark represents the upper limit of the pericardial reflection over the lower superior vena cava, there is almost no risk of catheter induced cardiac tamponade. Absence of all risk, however, cannot realistically be achieved as the position of a catheter tip does change with arm, head, neck, and vessel movements. The optimal position for central venous catheter is a complex subject. Catheters placed in the lower superior vena cava or right atrium undoubtedly pose the highest risk of catheter induced cardiac tamponade. Another concern is the risk of extravasation of infused fluid via the proximal port of multiple lumen catheters if they are not placed far enough into the great veins. To avert this problem only catheters with a proximal lumen opening within 5 cm from the catheter tip should be used and a particular insertion approach should be used. For catheters inserted via the internal jugular vein, the ‘high’ approach should be used to ensure that more of the catheter is present in the vein. Catheters inserted via the subclavian veins should be inserted as laterally as practically possible. Portable ultrasound probes, some of which incorporate an introducer needle guide, can be used successfully for this goal. We believe that the optimal position for all catheters is above the pericardial reflection, in the upper superior vena cava or brachiocephalic veins. Catheters in the subclavian vein (especially left) and left internal jugular vein have caused concern because of the more perpendicular angle with which the tip may lie compared with the vessel wall. In this situation, flexible or ‘Pig-tail’ tipped catheters may be of enormous benefit.

The correct length of catheter to be inserted is also a contentious issue. Studies using right atrial electrocardiography or formulae based on patient weight can reduce the risk of tip malposition. Chalkiadis and Goucke recently concluded that no particular depth of insertion could be recommended, and stated that the ‘depth of insertion should be determined in a similar fashion to the placement of an epidural catheter where the skin-to-space distance is measured. Provision within catheter insertion kits of a venepuncture needle with graduations every one centimetre would facilitate this technique’.

This report illustrates the need to maintain a high level of awareness about catheter-tip position, even when preventive practices suggest it is sited correctly. Cardiac tamponade must be considered in any patient with an indwelling central venous catheter who shows evidence of clinical deterioration, however vague the symptoms and signs. Resuscitation using the catheter should be avoided until cardiac tamponade has been excluded.

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