Central venous catheters and heart perforation

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Central venous catheters have been in use since about 1950 and have become regarded as necessary in the care of the critically ill. They are usually inserted into the superior vena cava via a subclavian, jugular, brachial or antecubital vein. Earlier catheters were made of polyvinylchloride or polyethylene. They were inherently rigid and were made more flexible by the addition of a plasticizer, usually a phthalate ester. However, if the catheter was left in place long enough, blood would leach the plasticizer out of it, and its original rigidity would be restored.[1]

More recently, catheters made of polyurethane, Teflon or Silastic have also been developed. Some of them are relatively more flexible without the use of plasticizers. Nevertheless, most current catheters are still quite rigid,[2] and if their tips are forced against the heart or the vena cava they may perforate or otherwise damage these structures.

Although perforation of the heart and great vessels by central venous catheters[3-5] as well as breakage of the catheters and techniques to retrieve the broken pieces[6,7] have been described, the four cases we report in this issue (see page 1143) and the one reported by Karnauchow (see page 1145) were the first to be reported to the Health Protection Branch of the Department of National Health and Welfare. Three other cases involving other brands of catheters are being investigated.

Incidence of perforation

The reported incidence of perforation is relatively low.[1] Table I summarizes the data in two reviews[4,5] and includes the five cases reported in this issue of *CMAJ*. Among the 61 reported cases of perforation, death resulted in 41 (67%). Insertion of the catheter via the subclavian vein was associated with a lower death rate (50%) than insertion at other sites, especially in the arm (83%). The death rate for perforation of the right atrium, 54%, was significantly lower than that for perforation of the right ventricle, which in all cases resulted in death. The onset of symptoms of cardiac tamponade after perforation most often occurred during the first 2 days after catheterization. In general, the risk of death increased sharply when the volume of pericardial effusion was more than 300 ml. The death rates presented are for cases of cardiac tamponade with confirmed perforation, not of central venous catheterization; the death rate associated with the latter would be much lower because the incidence rate of perforation is estimated to be 0.2%.[1]

Choice of catheter

Choice of catheter depends on the intended site of vessel entry; the length of insertion must be accurately predetermined for each particular application. The lengths of the catheters range from about 10 to 50 cm. Catheters inserted via the antecubital vein are more likely to perforate the heart, as movement of the tip of a longer catheter due to arm movements is greater than that with the shorter catheters used in the jugular or subclavian approach.[1,4,5] The size of the patient must be taken into account in deciding which length of catheter to use. The tip of a 20-cm catheter inserted via the jugular vein into a large adult might be at the entrance to the right atrium, but in a smaller adult it would be deep in the right atrium or even the right ventricle.

Catheter placement

If imaging techniques such as fluoroscopy and

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ultrasonography are not available, correct placement of the catheter must be immediately confirmed by an x-ray film. For monitoring of central venous pressure and total parenteral nutrition, the catheter tip need not be advanced beyond the entrance to the right atrium. When insertion into the right atrium or right ventricle is necessary (e.g., to measure ventricular pressure), there is a greater chance of cardiac perforation due to the motion of the heart, and the position of the catheter must be periodically confirmed. In such cases it would also be desirable to select a more flexible catheter, although perforation by catheters of all current materials has been reported.

Perforation of the heart may occur at the time of insertion but may also occur any time the catheter is in place.[4,5] The new central venous catheter kits, with which the Seldinger technique is used for introducing the catheter, are preferable to the earlier kits, whose catheters were inserted through a large-bore needle. Exaggerated respiration, body or limb movements, or change in posture can drastically change the position of the catheter tip, which may result in partial or complete perforation of the heart or vessel.[8] Although the physician may want to encourage a patient to be mobile, the danger of perforation in a mobile patient with an indwelling central venous catheter cannot be overemphasized.

Table I — Characteristics of 61 cases of perforation of the heart or great vessels by central venous catheters, and death rate associated with each characteristic

Characteristic*	No. (and %) of cases	Death rate, %
Insertion site		
Arm vein	24 (41)	83
Subclavian vein	22 (37)	50
Internal jugular vein	7 (12)	57
External jugular vein	6 (10)	83
Unspecified	2	–
Perforation site		
Right atrium	20 (49)	54
Right ventricle	14 (34)	100
Superior vena cava	4 (10)	75
Mediastinum	2 (5)	75
Circumflex coronary vein	1 (2)	100
Unspecified	20	–
Time from insertion to tamponade, d		
≤ 2	37 (62)	65
3–5	10 (17)	70
6–10	9 (15)	78
> 10	4 (7)	75
Unspecified	1	–
Pericardial effusion volume, ml		
≤ 100	3 (6)	0
101–200	8 (16)	50
201–300	10 (20)	50
301–400	9 (18)	100
401–500	10 (20)	80
501–1000	9 (18)	100
2500 (pleural)	1 (2)	0
Unspecified	11	
Type of fluid in pericardium		
Clear	24 (45)	75
Lipid	6 (11)	100
Total parenteral nutrition	6 (11)	17
Blood	15 (28)	67
Radiologic dye	2 (4)	50
Unspecified	8	–
Outcome		
Died	41 (67)	–
Survived	20 (33)	–

*Cases in which the characteristic was not specified were not included in calculation of the rates.

Diagnosis of perforation and tamponade

Placement of the catheter tip in the right atrium or right ventricle is likely to result at least in some tissue damage over time owing to the inherent stiffness of the catheter and the movement of the heart during contraction. This may be manifested as irritation or pain in the throat or chest. The fact that the catheter tip may not remain in the perforation site, as demonstrated by two cases in our report, means that radiographic examination cannot rule out earlier, transient perforation.

Cardiac tamponade may be defined as an impairment of diastolic filling of the heart caused by an increase in intrapericardial pressure. The symptoms are very similar to those of pulmonary embolism, including chest pain, increased heart rate, decreased blood pressure and respiratory problems. In published case histories, pulmonary embolism has usually been suspected.[3-5] If cardiac tamponade results from trauma, such as perforation by a catheter, its onset is rapid, usually within hours. Under these conditions the complication is characterized by three clinical features: rising venous blood pressure, falling arterial pressure and a small, quiet heart.[9] Pulsus paradoxus may not be present, and an electrocardiogram may not show characteristic changes. While adults may tolerate chronic pericardial effusions of up to 1500 ml reasonably well, an acute effusion of 100 to 350 ml can prove fatal, as it raises the intrapericardial pressure and prevents filling of the heart. In infants and children, effusion volumes of 8 to 50 ml can be fatal.

The diagnosis can be made at the bedside with echocardiography.[10] If echocardiography is not available, exploratory pericardiocentesis should be undertaken. If monitoring equipment is available, a recording of the pulse pressure profile will reveal the location of the catheter tip.[11]

Prevention of perforation and tamponade

Central venous catheterization must be considered a critical and potentially hazardous procedure. The position of the catheter should be confirmed as soon as possible after insertion. Patients with indwelling central venous catheters should be cautioned to limit movements of the

upper body and should not be mobile without appropriate supervision, especially during the first 2 days after catheterization. When cardiovascular deterioration occurs in any patient with an indwelling central venous catheter, pericardial tamponade should be considered. Exploratory pericardiocentesis may be required as a lifesaving measure.

The hazard of perforation of the heart and great vessels by central venous catheters can be reduced by use of better materials to increase flexibility and by improvement in tip design. A comparative evaluation of the potential for perforation by current catheters would provide information on which selection can be based. Meanwhile, the recognized potential of central venous catheters to cause cardiac perforation and resultant tamponade calls for increased vigilance.[12]

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