A new catheter for detection and treatment of venous air embolism

Technical note

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The authors report the successful application of the No. 8 French multi-orifice flow-directed catheter designed for pulmonary angiography in the monitoring and treatment of venous air embolism during neurosurgical procedures. Delays in operating room time were reduced with this technique, which ensures rapid and precise placement of a right atrial central line and which also eliminates the need for a chest film as a method of confirming placement of the central line in the right atrium. The flow-directed guidance system permits reliable introduction of the catheter via any central venous access route, including the basilic vein, and eliminates the usual difficulties associated with placement of conventional single-orifice polyethylene catheters. No complications associated with placement of this catheter into the right atrium have occurred in 20 cannulations.

KEY WORDS • air embolism • right atrial catheter • pulmonary angiography

EARLY detection and treatment of venous air embolism is a lifesaving procedure. Air may be introduced into the venous system by any technique in which the pressure in the exposed veins is less than the atmospheric pressure. Venous air embolism probably occurs most predictably and most frequently in neurosurgery, particularly in the exploration of the posterior fossa performed with the patient in the sitting position. The high incidence in this procedure is due to the opening of a noncollapsible vein such as a diploic vein or dural sinus, which can then aspirate air.8,9,12,17,20

Gottlieb, et al.,6 and Whitby22 have reported a mortality rate of up to 93% when venous embolism is left untreated. Death may result from mechanical obstruction of the pulmonary outflow tract by a bolus of air,5,8,9,12 or from pulmonary reflex response to the slow infusion of venous air, or both.1 Early detection and treatment of the former, aspiration of air from the right atrium has dramatically reduced the incidence of impending death.10,12,16,18,21 Tinker, et al.,21 and Robertson, et al.14 described a technique for positioning a 90-cm No. 15 polyethylene catheter into the right atrium. The catheter is used as the exploring electrode of an electrocardiographic (EKG) oscilloscope, and is inserted until the positive amplitude of the biphasic P-wave is approximately equal to the negative amplitude. The purpose of this catheter is to assure the anesthesiologist that the sounds detected on the precordial Doppler device are originating from the right atrium.7,11 In the event that there is a large air embolism, aspiration through a large-bore central venous catheter can be therapeutic as well.

Changes in central venous pressure and pulmonary artery pressure have been found to provide sensitive, sustained, and reliable means of monitoring for venous air embolism in dogs.1,6

Sink, et al.,17 have reported inadequate air aspiration from a “triple lumen” Swan-Ganz catheter positioned in the right atrium when air was injected through an external jugular vein. We have also noted that the lumen area of this catheter (0.75 sq mm) is inadequate for effecting rapid aspiration of right atrial blood. We reasoned that, in lieu of placing a central venous catheter into the right atrium by an EKG technique14,21 and confirming its placement by chest film, it should be possible to place a flow-directed catheter into the right atrium, using transduced
pressures and wave-form analysis as confirmation of placement. Furthermore, it should be possible to employ a flow-directed catheter of sufficient internal bore to provide rapid therapeutic aspiration of right atrial fluid.

We report a new technique using a No. 8 French flow-directed pulmonary angiography catheter* with a lumen area of 2.3 sq mm which is constructed with eight side ports (four to each side) off the central lumen (Fig. 1). These side ports are located 24 mm proximal to the tip of the catheter and allow aspiration of blood from the right atrium in contrast to the "triple lumen" catheter.† Recent experimental data‡ further confirmed our clinical impression regarding the superior aspirating qualities of a large-bore multiorifice catheter in the treatment of venous air embolism.

*Flow-directed pulmonary angiography catheter, Model 93A-119-8F, manufactured by Edwards Laboratories, Santa Ana, California.
†Triple-lumen catheter, Model 93A-131-7F, manufactured by Edwards Laboratories, Santa Ana, California.
‡Recent experimental data

FIG. 2. Waveform tracing showing passage of catheter into the right ventricle and subsequent withdrawal into the right atrium next to the tricuspid valve.

Technique

Any central venous access route is acceptable for insertion of the catheter. We have successfully and reliably employed the basilic, right and left external jugular, internal jugular, subclavian, and femoral venous approaches, using a modified Seldinger technique.

A No. 16 cannula is introduced into the respective venous channel, and a No. .035 short-spring guide wire is introduced, flexible end first, through the cannula into the vessel. Upon removal of the cannula, a dilator and thin-walled sheath are inserted together over the guide wire into the vessel. The guide wire and dilator are removed, and the flow-directed catheter is introduced through the sheath into the vessel. The catheter is connected to a pressure transducer and oscilloscope, and inserted until a right ventricular pressure and waveform are observed (Fig. 2). The catheter is withdrawn until the right ventricular pressure and waveform are no longer observed on the oscilloscope screen, and then retracted an additional 2.5 cm to remove the catheter tip from the tricuspid orifice. A three-way stopcock is placed between the pressure line and catheter hub to permit monitoring of right atrial pressure and easy aspiration through the catheter.

In our experience, follow-up chest films confirmed this technique as a reliable method of right atrial catheter placement (Fig. 3).

Discussion

We describe the clinically useful and potentially lifesaving application of a No. 8 French flow-directed pulmonary angiography catheter. This catheter benefits both the patient and the anesthesiologist by providing a sensitive and reliable means of monitoring for venous air embolism, with or without concomitant use of a precordial Doppler recording device. We have compared the aspirating qualities of this catheter against a No. 16 polyethylene catheter and a triple-lumen Swan-Ganz catheter. The pulmonary angiography catheter aspirated blood at a rate of 107
We believe that a chest film confirming placement of this catheter can be eliminated, thereby saving time in the operating room. At our institution, relying on x-ray confirmation of catheter placement often results in delays of 30 to 45 minutes. When compared with the average time of 12 to 15 minutes required for placement of the pulmonary angiography catheter, the advantages of the pulmonary angiography catheter technique are obvious. The cost of using the pulmonary angiography catheter is about the same as the cost of obtaining a confirmatory chest film. In conclusion, we have found that our technique offers a precise and reliable method of placement of a right atrial catheter, is time-efficient, and permits therapeutic aspiration of blood from the right atrium.

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References


ml/min as compared to 172 ml/min and 12 ml/min with the No. 16 polyethylene and Swan-Ganz catheters, respectively. The reason for the difference between the pulmonary angiography and polyethylene catheters was thought to be associated with the difference in catheter length and its influence on resistance. Indeed, when the pulmonary angiography catheter (110 cm) was reduced to the same length as the polyethylene catheter (20.32 cm), its rate of blood aspiration far exceeded the latter at a rate of 285 ml/min. This finding suggests that the construction of a shorter pulmonary angiography catheter for placement in the internal jugular or subclavian veins would significantly enhance its effectiveness for aspirating blood.

Theoretically, aspiration of this multi-orifice catheter should distribute negative pressure over a greater area, thereby increasing the efficiency of the catheter for aspirating air. Multiple holes in the catheter also reduce the risk of catheter obstruction by clot formation. The balloon located at the catheter tip serves to disperse the forces of pressure at the catheter tip over a wider surface area, thus reducing the risk of arrhythmogenesis during introduction of the catheter into the cardiac chambers.

The flow-directed guidance principle makes the catheter extremely useful in achieving rapid and precise placement in the right atrium, and gives the anesthesiologist the capability of aspirating the right ventricle, right ventricular outflow tract, and the pulmonary artery as well.

Fig. 3. Chest film confirming the position of the catheter tip in the right atrium just proximal to the tricuspid valve (arrow).


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