described above would largely eliminate this variation, since the intensity of the Doppler signal used for locating the vessel may be adjusted by the operator. This makes it possible for the vessel to be more easily located for cannulation, and thus reduces the need for cutdowns. In this series, although the vessel was penetrated by the Angiocath stylet on the first attempt, as indicated by the presence of arterial blood in its distal end, advancing the cannula into the lumen was at times unsuccessful, although it was achieved on subsequent attempts. Knowledge and recall of the distance between the center of the lumen of the stylet and the proximal edge of the plastic cannula is critical for successful cannulation after location of the artery. Since the purpose of accurate location of the radial artery was to cannulate the vessel, the criterion of success in the study was the latter and not the former. Cannulas with a shorter distance between the center of the lumen of the stylet and the cannular sheath would facilitate a higher success rate on the first attempt with this technique.

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Assessment of a Saline Injection Test for Location of a Right Atrial Catheter

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In 1966, Michenfelder *et al.*[1] introduced the use of a right atrial catheter for the removal of venous air emboli. Subsequently, Maroon *et al.*[2] introduced the use of the precordial Doppler probe to facilitate the diagnosis of air emboli. It is essential that the precordial Doppler probe be properly placed over the right heart and that the catheter be located in or just above the right atrium. Recently, Tinker *et al.*[3] suggested that one method of ensuring proper placement of the catheter tip and the precordial Doppler probe was forcefully to inject 5 ml of saline solution through the catheter. The resulting turbulence produced alteration in Doppler sounds that was regarded as signifying both that the probe was properly positioned over the right heart and that the catheter tip was located in or near the right atrium.

We have recently encountered a situation in which a right atrial catheter had accidentally and unknowingly been partially withdrawn from the right atrium to the axillary vein preoperatively. When saline solution was injected through the catheter, turbulence was detected by the Doppler probe, and the operation proceeded under the mistaken impression that the catheter tip was located in the right atrium. As a result of this case, we examined the relationship between catheter tip position and the disruption of Doppler sounds produced by injection of saline solution through the catheter.

Methods and Materials

Three adult patients undergoing neurosurgical anesthesia in the sitting position each had a venous catheter (Bard I-Cath®, 55 cm length) placed in the right atrium via the median antecubital vein the night before operation, with radiographic verification of its position. In all patients the full length of the catheter was inserted. One day postoperatively the precordial Doppler sounds were monitored while the catheter was withdrawn in 5-cm increments. A 5-ml volume of saline solution was injected forcefully every 5 cm until alterations in Doppler sounds were no longer detected. The Doppler sounds were tape-recorded and later processed to give an analog recording of Doppler sound amplitude and changes produced by injection of saline solution. The catheter, after complete withdrawal, was placed on the surface of the arm

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and chest to obtain an approximate location of the catheter tip during withdrawal. Injection of saline solution was also done in a fourth patient after a right subclavian catheter had inadvertently been directed into her right internal jugular vein.

Results

In the three patients with right atrial catheters, each injection of saline solution produced marked alterations in Doppler sounds even when 30 cm of catheter had been removed. The postoperative recording of Doppler sound for one of the patients is shown in figure 1. Injections as the catheter was removed further failed to alter the Doppler sounds. In these patients, placement of the catheter on the body indicated that Doppler sounds were altered by injection of saline solution even when the catheter tip was in the axilla or proximal part of the upper arm (fig. 2). As the catheter tip was withdrawn further from the right atrium, a noticeably greater time lag between injection of saline solution and disruption of Doppler sounds became apparent. In the patient with the catheter in the right internal jugular vein, injection of saline solution also produced a marked alteration in Doppler sounds, despite the catheter tip's being directed away from the heart.

Discussion

In the report by Tinker *et al.*,[3] the catheter was initially placed using the catheter tip as an exploring EKG electrode and using the appearance of a diphasic P wave to indicate that the tip was in the right atrium. At this institution, we routinely place the catheter the night preoperatively, and at that time check its position roentgenographically. We have used the saline flush at the beginning of the operation the next day both to guide placement of the precordial Doppler probe and check that the catheter tip has not migrated.

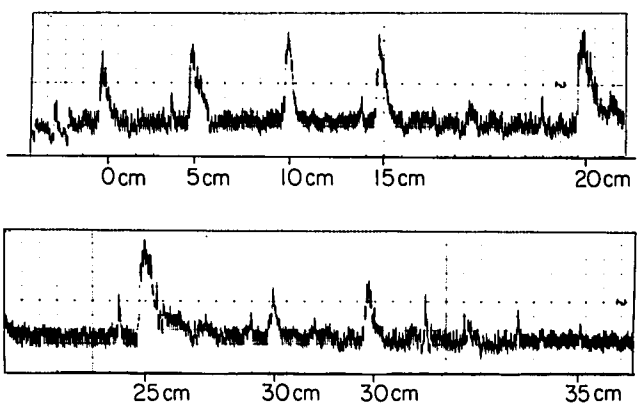

Fig. 1. Continuous recording of Doppler sound amplitude during catheter withdrawal and injection of saline solution. Amplitude increased during catheter withdrawal and injection of saline solution, as indicated by greater upward deflection. Note that the injection increased Doppler sound amplitude at each 5-cm increment until 35 cm of catheter were withdrawn.

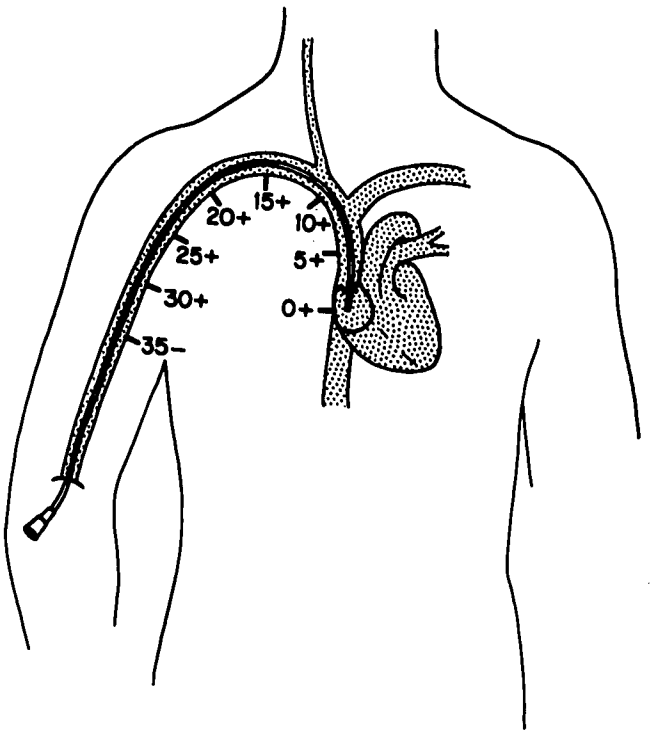

Fig. 2. Diagram showing estimated positions of catheter tip during its withdrawal in 5-cm increments. Signs indicate presence (+) or absence (–) of altered Doppler sounds produced by injection of saline solution.

We have found that the alteration of precordial Doppler sounds produced by injection of 5 ml of saline solution through a right atrial catheter does not necessarily indicate that the catheter tip is positioned so as to be effective in the diagnosis or treatment of right-heart venous air embolism. It appears that the turbulence produced by the injection travels for a considerable distance in the vascular system. The time lag between injection and a detectable change in Doppler sounds was very brief, even when the catheter was withdrawn a considerable distance, and would appear to be of limited value in detection of catheter tip malposition. Although injection of saline solution does not verify the position of the catheter, we have continued to use this test to facilitate positioning of the precordial Doppler probe. In addition, the site of insertion of right atrial catheters used for diagnosis and treatment of air emboli is carefully inspected preoperatively to ensure that the catheter has not been dislodged.

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Mishap with an Epidural Catheter

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In 1949, Curbello introduced continuous epidural anesthesia.[1] For a decade in our hospital we have practiced this technique by inserting a radiopaque Teflon catheter through a Tuohy needle. Although 202 broken central venous and cardiac catheters have been documented,[2] we can find only two reports in the medical literature of broken epidural catheters.[3,4]

Report of a Case

An 18-year-old white woman, 57.1 kg, gravida 1, para 0, was scheduled for delivery with the use of continuous epidural anesthesia. The patient was in Stage 1 labor with the cervix 6 cm dilated when epidural anesthesia was started. By use of the Tuohy needle, the epidural space was identified at L2–3 and 2 ml 0.5 per cent bupivacaine were given as a test dose. Next, a 20-gauge radiopaque Teflon catheter, 91.4 cm long, was inserted through the Tuohy needle in the following manner. First, the stylet was withdrawn about 7.5 cm from the catheter end. The catheter was advanced through the needle until slight resistance was met. The needle was then gently angled cephalad and the catheter pushed inwards without difficulty as the needle was removed. An additional 6 ml 0.5 per cent bupivacaine were added through the catheter. The patient had analgesia to pinprick to T8 bilaterally, and she was comfortable for an hour and 30 minutes.

For vaginal delivery we injected 18 ml 2 per cent chlorprocaine through the epidural catheter to achieve perineal analgesia. The patient did not obtain relief of pain. Subsequently, delivery proceeded with use of nitrous oxide, oxygen, and local infiltration of the perineum. The epidural catheter was removed with ease at the end of delivery, but was incomplete. The end was ragged and the removed catheter segment measured 83.4 cm, leaving 8 cm in the patient.

Discussion

Why this particular catheter broke is not clear. Although it was inserted with minimal difficulty, the most likely explanation for the breakage seemed to be shredding by the Tuohy needle at the time of insertion. However, good analgesia was obtained with the initial dose of 6 ml 0.5 per cent bupivacaine but no pain relief was provided by the second dose. This discrepancy suggests that the catheter was initially intact but broke during the first stage of labor.

Because the patient was very restless on arrival to the delivery room, the catheter might have been pinched between two vertebral processes. The distal end of the removed catheter segment was frayed. A different edge results when the catheter is sheared off by being pulled back and across the needle tip.

Another possible way for the catheter to break is at the time of removal. The patient's position on insertion is one of back flexion. In this case the longer section of catheter was removed with ease.

Although the catheter was radiopaque according to the package, it was impossible for our radiology department to locate the broken end in the epidural space due to the density of the surrounding vertebral processes. Unfortunately, we were not able to see or feel the end of the broken material under the lumbar skin. According to the manufacturer, the epidural catheter is inert and should not produce any foreign-body reaction. Detection of the lost catheter might be possible by xeroradiography; nevertheless, we prefer not to expose the patient to a large dose of radiation if not indicated. The scan with ultrasonography used for detection of ophthalmic foreign bodies has not been used to locate foreign bodies in the epidural space.[5–7] Although it is also not likely that the catheter in the epidural space will dissolve, attempted surgical removal could provide more complications than leaving it alone, keeping in mind that possible migration of the broken catheter cannot be excluded.[8] Follow-up examinations for neurologic complications during the last 12 months have shown no abnormality.

Plastic materials for use in man are subjected to three testing methods: systemic injection and intracutaneous and implantation tests.[9] Extracts of catheter

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