sources of variation remain inadequately understood and controlled.[19–21] Nonetheless, determination of mean blood pressure using noninvasive techniques appears clinically feasible and useful.

The authors gratefully acknowledge the assistance of B. William Brown, Professor of Biostatistics, and J. Halpern, Programmer, Department of Biostatistics.

## References

1. Van Bergen FH, Weatherhead DS, Treloar AE, et al: Comparison of indirect and direct methods of measuring arterial blood pressure. Circulation 10:481–490, 1954
2. Geddes LA: The Direct and Indirect Measurement of Blood Pressure. Chicago, Year Book Medical Publishers, 1970
3. Whitcher C: Blood pressure measurement, Techniques in Clinical Physiology. Edited by Belville JW, Weaver CS. London, Macmillan, 1969, pp 85–124
4. Korotkoff NS: On the subject of methods of determining blood pressure. Bull Imperial Medical Academy, St. Petersburg 11:365, 1905
5. Marey EJ: Pression et vitesse du sang, Physiologique Experimental. Volume 2. Paris, G. Masson, 1876
6. Roy CS, Adami JG: The heart beat and pulse-wave. Practitioner 45:20, 1890
7. Howell WH, Brush CE: A critical note upon clinical methods of measuring blood pressure. Boston Med Surgi J, 145:146–151, 1901
8. Erlanger J: A new instrument for determining the minimum and maximum blood pressure in man. John Hopkins Hosp Rep 12:53, 1904
9. Erlanger J: Studies in blood pressure estimation by indirect methods. Am J Physiol 55:84–158, 1921
10. Brooks C, Luckhardt A: The chief physical mechanisms concerned in clinical methods of measuring blood pressure. Am J Physiol 40:49–74, 1916
11. Pachon V, Fabre R: Sur le critere de la pression minima dans la methode oscillometrique. C Rendus Soc Biol 84:871, 1921
12. Gley P, Gomez DM: La détermination des pressions moyenne et minima par la mèthode oscillometrique. Presse Med 39:284, 1931
13. Posey JA, Geddes LA: The meaning of the point of maximum oscillations in cuff pressure in the indirect measurement of blood pressure. Part I. Cardiovasc Res Cen Bul 8:15–25, 1969
14. Geddes LA, Moore AG, Garner H, et al: The indirect measurement of mean blood pressure in the horse. Southwest Veterinarian 23:289–294, 1970
15. Yelderman M, Ream AD: A microprocessor based automated noninvasive blood pressure device for the anesthetized patient. Proceedings of the San Diego Biomedical Symposium 17:57–64. New York, Academic Press, 1978
16. Robinson DJ, Ream AK, Corbin SD, et al: Quality control of a computer based physiologic monitoring system. Proceedings of the San Diego Biomedical Symposium 16:233–242. New York, Academic Press, 1977
17. Armitage P: Statistical Methods in Medical Research. New York, John Wiley and Sons, 1971, p 43
18. Berliner K, Fujiy H, Lee DH, et al: The accuracy of blood pressure determinations, a comparison of direct and indirect measurements. Cardiologia 37:118–128, 1960
19. Geddes LA: The importance of cuff width in measurement of blood pressure indirectly. Cardiovasc Res Cen Bul 14: 69–79, 1976
20. King GE: The errors in clinical measurement of blood pressure in obesity. Clin Sci 32:223–237, 1967
21. Irvine RO: The influence of arm and cuff size on the measurement of blood pressure. NZ Med J 67:279–283 1968

Anesthesiology
50:256–258, 1979

# A Modified Doppler Flow Detector Probe—An Aid to Percutaneous Radial Arterial Cannulation in Infants and Small Children

H. M. Chinyanga, M.Sc., M.D., F.R.C.P.(C),* and J. M. Smith, Ph.D., P.Eng.†

Cannulation of the radial artery has become routine for monitoring blood pressure and obtaining blood samples during major surgical procedures and intensive care.[1] The artery to be cannulated is located by palpation or, when this is difficult, is exposed by a cutdown and the catheter introduced under direct vision. The chances of successful percutaneous cannulation decrease with decreasing age and/or size of the patient.

This paper describes a technique we developed that has increased the success rate of percutaneous cannulation of the radial artery in infants and small children, and thus reduced the need for arterial cutdowns.

## Materials and Methods

The use of Doppler ultrasound for blood flow detection is well established.[2] The technique described here utilizes a commercially available instrument‡ used in conjunction with a modified probe. The crystal dimensions of the standard probe are such

* Staff Anaesthesiologist.
† Director, Department of Medical Engineering.
Received from the Departments of Anaesthesiology and Medical Engineering, The Hospital for Sick Children, 555 University Avenue, Toronto, Ontario Canada M5G 1X8. Accepted for publication July 22, 1978.
Address reprint requests to Dr. Chinyanga.

‡ Ultrasonic Doppler flow detector, Model 811, Parks Electronics Laboratory, Beaverton, Oregon.

that the transmitted beam is much wider than the diameter of the artery, which provides a necessary condition for flow detection without the need for precise placement of the probe.

A simple modification to the conventional probe narrows the transmitted beam to a width approximating the vessel diameter, thus permitting accurate vessel location. It consists of a small prism, constructed of plexiglas, a material with relatively low attenuation to ultrasound at 10 MHz, attached with an epoxy glue to the surface of the conventional probe. The apex of the prism is truncated to provide a flat surface, 1.3 mm wide. In use, this surface in placed on the skin, which has been coated with a thin film of ultrasonic gel. Since ultrasound at 10 MHz is poorly transmitted in air, all energy entering the tissue will be coupled through the contact surface. The angle of beam divergence is inversely related to the width of this contact surface.

The modified probe was evaluated as an aid to arterial cannulation in 23 anesthetized infants and small children weighing 4.3–20.0 kg (mean weight 11.9 ± 4.41 kg) who underwent major operations. Their ages ranged from 2 months to 4 years.

After induction of anesthesia, the modified Allen's test[3] as described by Furman[4] for children during general anesthesia was performed. The hand was dorsiflexed to an angle of approximately 50–60 degrees over a small role of gauze sponges, and the skin over the wrist was cleansed with iodine and alcohol and dried. A thin film of Doppler ultrasonic jelly was applied over the radial surface of the wrist. The probe was slowly moved from the lateral to the medial size until the characteristic Doppler sound due to arterial blood flow was heard. The prism was then carefully displaced from side to side over this point until the point of maximum intensity of the sound was located. The probe assembly was then securely strapped on the hand (fig. 1). An incision was made in the skin about 0.5 cm distal to the center of the contact surface of the prism. A 22-gauge Angiocath® was then carefully introduced and slowly advanced through the skin incision at a 15–20-degree angle. Usually, as the tip of the Angiocath passed under the prism, the intensity of the Doppler sounds was markedly reduced or became inaudible as the cannula partially or completely masked the artery. Blood usually appeared at the tip of the introducer during the change in the intensity of the Doppler sound. In a few cases the lumen of the vessel was penetrated before the Doppler sound changed. Once blood appeared in the stylet and was rising steadily in its hub, the catheter was advanced into the lumen of the vessel, and the stylet was withdrawn.

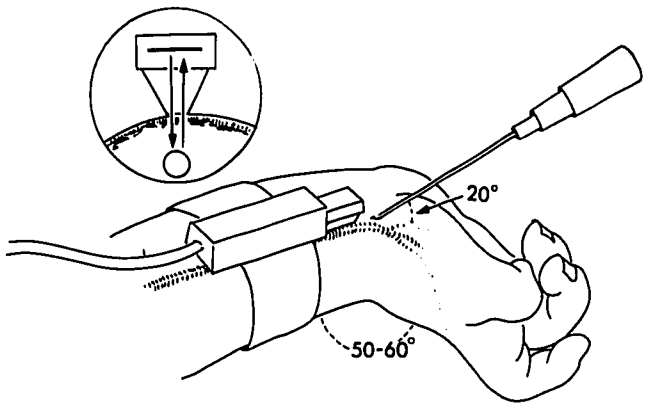


FIG. 1. The modified Doppler ultrasound assembly attached to the wrist. The prism is coupled to the skin directly over the radial artery. The Angiocath is inserted through the skin towards the center of the prism.

For the purpose of this series, a maximum of three attempts at penetrating the artery and successfully cannulating it was allowed. When after advancing the catheter unit to a depth of about 5 mm the artery was not punctured, or was punctured but not successfully cannulated, the whole unit was withdrawn to skin surface, redirected, and advanced again.

TABLE 1. Cannulation of the Radial Artery in Infants and Small Children with the Aid of the Doppler Ultrasound Device

| | |
|---|---|
| Number of patients | 23 |
| Age | 2 months–4 years (mean 2.20 ± 1.36) |
| Weight | 4.3–20 kg (mean 11.9 ± 4.41) |
| Total successes | 20 (86.9 per cent) |
| Success on 1 attempt | 12 (52.1 per cent) |
| Success on one and two attempts | 19 (82.6 per cent) |

## RESULTS

Of the 23 patients, 20 had successful radial arterial cannulations, for a success rate of 86.9 per cent. In 12 cases (52.1 per cent) cannulations were successful on the first attempt; in 19 (82.6 per cent), after a maximum of two attempts (table 1).

## DISCUSSION

Percutaneous cannulation of the radial artery in infants and small children is difficult. As a result, in this age group, cannulation is often performed by cutdown. This significantly increases the chances of complications.[5]

Chances for accurate location of the radial artery in the small child by palpation vary widely, according to the individuals doing the locating. The technique

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.

The authors thank Dr. D. Steward for his critical review of the manuscript and Mr. E. Zouch for skillful technical assistance.

## References

1. Brown AE, Sweeney DB, Lumley J: Percutaneous radial artery cannulation. Anesthesia 24:532–536, 1969
2. Harper AM, Lorimer AR, Thomas DL: Methods of measuring blood flow, Scientific Foundations of Anaesthesia. Edited by Scurr C, Feldman S. London, William Heinemann Medical Books, 1974, pp 56–57
3. Allen EV: Thromboangitis obliterans: A method of diagnosis of chronic occlusive arterial lesions distal to the wrist with illustrative cases. Am J Med Sci 178:237–244, 1929
4. Furman EF, Hairabet JK, Roman DG: The use of indwelling radial artery needles in paediatric anaesthesia. Br J Anaesth 44:531–532, 1972
5. Miyasaka K, Edmonds JF, Conn AW: Complications of radial artery lines in the pediatric patient. Can Anaesth Soc J 23:9–14, 1976

Anesthesiology
50:258–260, 1979

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

Peter S. Colley, M. D.,* Edward G. Pavlin, M.D.,* Jay Groepper, M.D.†

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

* Assistant Professor, Department of Anesthesiology.
† Resident, Department of Anesthesiology.

Received from the Department of Anesthesiology and the Anesthesia Research Center, University of Washington School of Medicine, Seattle, Washington 98195. Accepted for publication July 23, 1978.

Address reprint requests to Dr. Colley: Department of Anesthesiology RN-10, University of Washington School of Medicine, Seattle, Washington 98195.