Determination of Blood Pressure in Low-flow States by the Doppler Technique

CHARLES L. WALTERMATH, M.D.,* AND DONALD D. PREUSS, M.D.†

The Doppler ultrasound device provides a simple, nondestructive method for monitoring cardiovascular function when cardiac output is low. It has been used for patients in shock and for infants. The pressures obtained correlate well with those obtained by direct arterial needle.1

An instrument with a high-frequency (10 MHz) output will detect blood flow in vessels as small as the digital arteries in adults or the radial artery in the premature infant. The high-frequency instrument is also useful in continuous-flow situations (cardiopulmonary bypass) where there is little or no movement of the vessel wall. In this situation the reflective medium for the signal is thought to be the moving blood cells.

For two years we have used this instrument for monitoring blood pressures during cardiopulmonary bypass in a patient group which ranged from adults to infants weighing less than ten pounds. The doppler transducer is secured with adhesive tape over the radial artery at the wrist and a blood pressure cuff of appropriate size is placed around the upper arm. The doppler signal is best monitored audibly with earphones, but by using appropriate output circuits the signal can be reproduced on an oscilloscope or a permanent record can be made with a direct electronic writer. The cuff is inflated until the doppler signal is obliterated and then slowly deflated until blood flow is again audible: this is the systolic pressure. By listening carefully a change in the signal can be recognized as the diastolic pressure. We usually monitor only the systolic pressure because it is easiest to determine. When the patient is on cardiopulmonary bypass a rapidly changing signal

* Assistant Professor.
† Resident II.

Received from the Department of Anesthesiology, University of Oregon Medical School, Portland, Oregon 97201. Supported in part by National Heart and Lung Institute Grant No. S-R01-HL09816.

† Model 803, Parks Electronics, Beaverton, Oregon.

Fig. 1. The transition to total cardiopulmonary bypass. The flow deflections during the period of partial bypass were generated by the patient's heart. At the arrow the aorta was cross-clamped. The tracing "total bypass" is the flow pattern generated by the pump.

77
Fig. 2. The pattern of flow change during determination of blood pressure in a patient on total bypass. As the cuff is inflated the blood in the vessel under the cuff is pushed distally. When the cuff pressure exceeds the perfusion pressure no blood flow is detected. When the cuff is deflated to the perfusion pressure the pump output is again audible (visible).

which corresponds to the rotation of the pump can be heard. This pressure is easily determined by using the blood pressure cuff as described above.

Figure 1 is a record of the change in blood flow in an adult patient during transition from an intact circulation to cardiopulmonary bypass. The systolic pressure prior to bypass is 80 mm Hg and the mean pressure with the bypass is 40 mm Hg.

Figure 2 is a record of a blood pressure determination during cardiopulmonary bypass. The large flow spurts on cuff inflation occur as the blood under the cuff is rapidly expelled into the distal artery. As the cuff is slowly deflated, the blood again moves through the vessel and can be heard flowing distally. The pressure at which this occurs is recorded as the mean blood pressure.

Arterial air embolization during bypass can also be detected. The usual audible signal is a swishing sound that corresponds to changes in flow. An air bubble passing the transducer produces a high-frequency ping. Monitoring for embolization is best done over the carotid artery.

This instrument can also be used to monitor cardiac output during cardiac massage. The doppler transducer is placed over the femoral or carotid artery; when cardiac massage is effective the characteristic swishing sound can be heard. Figure 3 is a record of this technique. This is a more sensitive monitor of blood flow than is palpation of the pulse dur-

Fig. 3. Flow generated by closed-chest cardiac massage after cardiac arrest in an adult female patient. This tracing was taken over the carotid artery.
ing closed-chest cardiac massage. Also, the relatively low pressures produced can be accurately determined if the doppler transducer is placed over a distal artery and a blood pressure cuff is used as described above.

When using the doppler it must be remembered that the signal heard or recorded is a manifestation of flow, not pressure. The pressure measurement is derived by using a blood pressure cuff to interrupt the flow that is heard or recorded. Effects to quantitate pressure and volume flow using instrument output alone have not been rewarding.

Reference

Electric Shock Hazard Associated with Pressure Transducers

PETER GRAYSTONE, M.I.E.E.E., AND MOLLY E. TOWELL, F.R.C.S. (C)*

In a series of experiments measuring the effects of asphyxia on fetal goats in utero, two of the values routinely recorded were arterial and venous pressures. Cannulae were attached to two Statham pressure transducers which were connected to a Beckman Type R Dynograph by means of the regular shielded cables supplied with the transducers. In the course of one of the experiments in which fetal ECG and fetal heart rate were being monitored, an arterial cannula was connected to one of the Statham gauges; at the time of connecting the venous cannula gross irregularities appeared in the previously-stable heart rate. This was found to be due to ventricular fibrillation, which eventually resulted in the death of the fetus. An arterial blood sample obtained immediately before cardiac arrhythmia was observed showed pH 7.4, P\textsubscript{CO}\textsubscript{2} 28 mm Hg, base excess -6.3 mEq/l and O\textsubscript{2} saturation 66 per cent; these values are all within the normal range for fetal goats. Subsequently, it was found that the shielding wire had broken loose in the plug connecting the venous pressure transducer cable to the Beckman Dynograph. Analysis of the experimental record

* Medical Research Council (Canada) Scholar.
Received from the Department of Obstetrics and Gynaecology, University of British Columbia, Vancouver, B. C. Supported by Medical Research Council Grant MA 2500.

led to the conclusion that fetal death was due to electric shock.

Recent articles 1-2 about electric shock hazards in hospitals have stressed the danger of leakage of current in intravenous recording techniques. A current flow between arterial and venous cannulae as low as 20 microamperes may be sufficient to cause ventricular fibrillation. Measurements of arterial–venous resistance of other fetal goats were made using the cannulation technique used in the fatal experiment. The A-V resistance was found to be approximately 400,000 ohms. From Ohms Law, by simple calculation, the A-V voltage difference required to give a current of 20 microamperes is 8 volts.

The arterial–venous pressure recording system used with the fetal goat is shown in figure 1. The venous pressure transducer was connected to a Beckman strain gauge coupler, Type 9872, in which one of the connections carried an excitation voltage of as much as 15 volts dc with respect to ground. The arterial transducer was connected to a Type 9803 coupler in the same recorder. The point at which the shielding wire had broken in the venous pressure transducer cable is indicated in figure 1. If the shielding wire in the plug contacted the pin carrying the excitation voltage, this transducer housing would be raised to 15 volts with respect to the arterial transducer which was at ground potential. This