Transcutaneous Doppler Measurement of Blood Pressure

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Under some circumstances the standard Korotkoff method of blood pressure measurement is inadequate, particularly in infants and in patients in shock. For several years it has been possible to measure blood flow by Doppler ultrasound techniques.[1,2] Recently, a new method of taking blood pressure, based on the Doppler principle first proposed by Ware[3] in 1965, has been evaluated jointly by the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, the Southwest Research Institute, San Antonio, Texas, and the pediatric, surgical, and anesthesia staffs of Wilford Hall USAF Hospital, San Antonio, Texas.

The theory and early experience in using a specially constructed transducer to detect changes in Doppler-shifted ultrasound generated by arterial-wall motion have been described by Ware.[4,5] The Doppler transducer is placed directly over the brachial artery, and a standard pneumatic cuff is inflated over it as shown in the cross-sectional view (fig. 1).

The transducer contains two chips of lead zirconate–titanate. One of these chips (A) is activated by an 8-mHz oscillator, emitting ultrasound waves which pass through the skin, subcutaneous tissue, muscle, and arterial wall. Nonmoving structures reflect the ultrasound back to the receiving crystal (B) without a change in frequency. Moving structures, such as the arterial wall, however, cause shifts in the frequency of the reflected ultrasound up or down just as the pitch of a locomotive whistle changes as the train approaches and then recedes from an observer.

The small degree of motion of an uncompressed artery does not generate a detectable change in frequency. However, when the pneumatic cuff is inflated to a level above the systolic pressure and then deflated slowly, the opening and closing of the artery with each heartbeat generate distinctive Doppler-shifted frequencies proportional to the velocity of the arterial wall. It is possible to amplify and filter this signal for display on an oscilloscope or direct writer or to reproduce it audibly through a loudspeaker or headphone set. Figure 2 is a schematic diagram of the component parts of the system, and figure 3 is an operational view of a similar model.

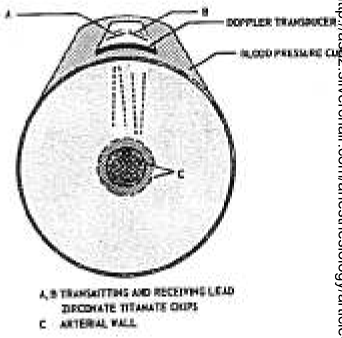

FIG. 1. Diagram of a cross section of a limb with Doppler transducer and blood pressure cuff in place.

The first clinical use of this instrument was reported by Kemmerer *et al.*[6] in a group of ten patients who had indwelling arterial lines for monitoring of blood pressure. Comparison of systolic blood pressures obtained simultaneously from the Doppler system and the intra-arterial catheters revealed a difference of only 0.5 mm Hg. Paired diastolic values differed by only 1.2 mm Hg. A more carefully controlled study of 11 patients who had indwelling brachial artery needles for the analysis of blood gases in pulmonary-function testing was performed by Stegall *et al.*,[7] with even closer agreement between the direct arterial and

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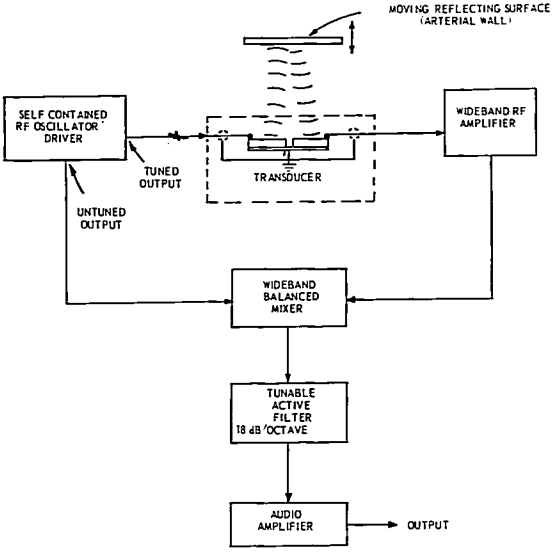

FIG. 2. Schematic diagram of typical Doppler apparatus for recording blood pressure.

Doppler pressures. The error of systolic measurement as determined by the Doppler method was only +0.1 (±2.2) mm Hg, while the diastolic error was −0.3 (±2.1) mm Hg. In both of these studies the subjects were normotensive patients. Use of the Doppler system in a mass casualty situation with many patients in profound shock and no other means of adequate patient monitoring available demonstrated that blood pressure was readily detectable down to 40 mm Hg or less.*

* Kemmerer—personal communication, unpublished data.

FIG. 3. Operational Doppler unit, with standard headphones on the left and Doppler transducer containing sending and receiving zinc titanate–zirconate crystals on right.

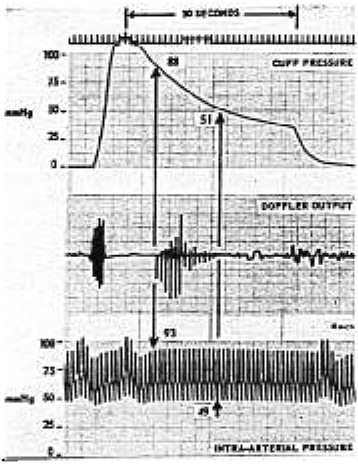

Fig. 4. Simultaneous dynograph recording of pneumatic cuff pressure (top), Doppler pressure (middle) and direct intra-arterial pressure (bottom) (Patient 1). The initial dark portion of the Doppler tracing represents cuff inflation artefact. The appearance and disappearance of the Doppler-shifted ultrasound recording, representing systolic and diastolic pressures, respectively, are clearly demonstrated and correspond to the cuff and direct pressures indicated by the arrows. For purposes of accurate recording the respirator was turned off to avoid respiratory variations in the blood pressure.

This report presents the results of further evaluation and refinement of the previously-described techniques in a group of patients whose blood pressures were unobtainable by standard methods.

Case Reports

Case 1. A 35-year-old woman was brought to the emergency room comatose and apneic following an automobile accident. No blood pressure was obtainable. Following initial resuscitative efforts she was taken to the operating room, where exploratory laparotomy revealed massive hemorrhage from the liver and spleen and a ruptured diaphragm. Following adequate hemostasis and the immobilization of several extremity fractures she was taken to the postoperative intensive-care unit. Despite administration of large volumes of blood and Ringer's lactate solution, the blood pressure remained unobtainable by palpation or auscultation. A Doppler transducer was then placed over the right brachial artery, and several blood pressure determinations in the range of 30/20 to 40/26 mm Hg were clearly obtained. A right femoral artery cutdown was performed and a teflon catheter inserted and connected to a Statham P23dB transducer whose output signal was recorded on the oscilloscope and direct writer of an Offner 8 channel dynograph. The pneumatic cuff was connected to a second strain gauge and the signals from it and the Doppler transducer were monitored simultaneously on the recorder. With the continued administration of blood and fluids and the intermittent use of isuprel and neosynephrine, the blood pressure gradually rose and stabilized at 90/50 mm Hg. Even at this level no Korotkoff sounds were audible. Continuous monitoring with the Doppler apparatus and the direct arterial catheter showed close agreement through the entire range of blood pressure determinations. A sample tracing of the direct arterial, Doppler, and pneumatic cuff pressures is shown in figure 4.

Case 2. A 36-year-old man underwent neurosurgical clipping of an intracranial aneurysm. He was anesthetized with halothane and oxygen, and a teflon catheter was inserted percutaneously into the right radial artery. The catheter was attached to a Statham P23dB transducer and the arterial pressure continuously monitored with a Mayo model 80-3 three-channel recorder. A Doppler transducer and pneumatic cuff were placed over the right brachial artery. Deliberate hypotension was induced and maintained with an Arfonad drip. Throughout the entire procedure Doppler and direct measurements never differed by more than 2.0 mm Hg systolic, even when the blood pressure was inadvertently lowered to 24/20 mm Hg. The patient recovered uneventfully.

We have used the Doppler system in several other situations in which it was impossible to obtain blood pressure by conventional means and facilities for direct intra-arterial measurements were not available. These patients included a 68-year-old man in severe shock from a superior mesenteric artery thrombosis, whose blood pressure was followed down to a systolic value of 42 mm Hg immediately prior to death and a 43-year-old man in terminal hepatic coma whose blood pressure was 32/28 mm Hg (pulse rate 3–4/min).

A modified Doppler transducer has been used with great success in newborn infants whose blood pressures under the best of conditions are practically impossible to obtain. We have found it particularly useful in monitoring infants and very small children under-

going certain cardiac surgical procedures such as ligation of a patent ductus arteriosus or formation of an aortico-pulmonary shunt. Our recovery room nurses and technicians have used it in the postoperative monitoring of these patients without any difficulty.

Our feeling is that the measurement of blood pressure by the Doppler technique described greatly enhances the anesthesiologist's monitoring capabilities. The method is simple, nondestructive, and extremely accurate. It is not intended to replace conventional methods, but rather to supplement them in specific instances such as those described. A commercial instrument similar to the units we have used is available at a reasonable cost.¶ Complete circuitry diagrams and specifications of one of our units are included in a technical report recently published by Ware *et al.*[5]

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Methylphenidate for the Treatment of Hiccups during Anesthesia

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Hiccups in a patient under anesthesia cause problems for both surgeon and anesthetist, since they disrupt the surgical field and may interfere with ventilation. Many methods have been proposed for treatment of hiccups, but none has been entirely satisfactory. Macris *et al.*[1] recently suggested giving 10–20 mg of methylphenidate (Ritalin®) intravenously, which was found to stop hiccups within three minutes of the injection. In many cases hiccups stopped while the drug was being injected. Vasiloff *et al.*[2] had similar results with similar doses of the drug: hiccups in 12 of their 22 patients stopped during injection of the drug. Our initial experience was that the hiccups stopped before the drug could be mixed and injected. Therefore, we undertook a double-blind study using methylphenidate and a placebo to determine the drug's efficacy in the treatment of this condition.

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