INFLIGHT PATIENT MONITORING/BLOOD PRESSURE MEASUREMENT DEVICE

SCHOOL OF AEROSPACE MEDICINE

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The blood pressure measurement device was designed to meet an urgent operational requirement for a method of monitoring vital signs of acutely ill patients while in flight. The high noise and vibration levels of most aircraft make the indirect measurement of blood pressure extremely difficult using the conventional approach. The Military Airlift Command (MAC) requested development of a device which would overcome these constraints. A method using an ultrasonic monitoring device, that employs the Doppler shift principle to detect blood flow

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20. ABSTRACT (Continued)

and arterial wall motion, was developed by USAFSAM. The inflight blood pressure measurement device consists of a commercial ultrasonic Doppler shift monitor and a standard sphygmomanometer which has been modified by placing a transducer mount through the cuff and bladder. The device is employed similarly to an acoustic stethoscope and sphygmomanometer. However, systolic and diastolic values are determined by monitoring arterial wall motion rather than detecting Korotkoff sounds. This device has proven to be extremely effective in eliminating the effects of inflight noise and vibration, and is sufficiently sensitive to determine the blood pressure of patients in shock. The Doppler ultrasonic device for inflight blood pressure determination is a significant advancement in the clinical management of patients. This technique provides medical crewmembers with a practical means of measuring systolic and diastolic blood pressures in flight.

NOTICES

This final report was submitted by personnel of the Biomedical Systems Branch, Clinical Sciences Division, USAF School of Aerospace Medicine, Aerospace Medical Division, AFSC, Brooks Air Force Base, Texas, under job order 4054-14-01.

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This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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INFLIGHT PATIENT MONITORING/BLOOD PRESSURE MEASUREMENT DEVICE

INTRODUCTION

In June 1970, the Military Airlift Command (MAC) requested development of an indirect blood pressure measurement device for use on medical evacuation aircraft. The high noise and vibration levels of most aircraft make the use of conventional acoustic methods for indirect blood pressure determination impractical.

The device described herein overcomes the effects of noise and vibration and for the first time allows medical crewmembers to monitor this vital physical parameter during flight.

DESIGN CRITERIA

A panel composed of physicians, flight nurses, medical technicians, and engineers was formed to specify the minimal functional requirements and physical characteristics of a device designed to measure patient blood pressure, by an indirect method, in aeromedical evacuation aircraft. The agreed upon specifications are presented below.

SPECIFICATIONS

Functional -- The inflight blood pressure measurement device must:

1. Enable medical crewmembers to conveniently obtain systolic and diastolic blood pressures by a noninvasive means using the device in conjunction with a standard blood pressure cuff (adult arm).

2. Be capable of measuring the full range of blood pressures of hypotensive, normotensive, and hypertensive individuals aboard USAF aircraft, at flight lines, and similar environments where extraneous noises cannot be controlled.

3. Be easily transferrable from one patient to the next, and one medical user to the next.

4. Be configured so that the placement of a sensor shall not be more critical than the positioning of a stethoscope diaphragm in conventional acoustic method of indirect blood pressure measurement.

5. Provide a binaural output of sufficient magnitude to allow the determination of blood pressure to an accuracy of ± 5 mmHg by medical field personnel.

6. Provide an auxiliary output jack so that the output signal may be displayed and measured on a standard oscilloscope.

Physical Characteristics -- The device must:

1. Be small enough to hold in one hand and/or fit in medical flight crew bag.

2. Be lightweight and portable enough to be carried by flight nurse conveniently.

3. Be electrostatically shielded sufficiently to pass standard EMI tests for devices used aboard aeromedical airlift aircraft.

4. Be constructed ruggedly enough to withstand dropping, packing, and shipping in the U.S. Postal Service.

Power Source Requirements --

1. The power supply shall be self-contained (preferably dry cell batteries) and capable of easy replacement from commercial sources of supply.

2. If dry cell batteries are used, the compartment must be so fabricated as to minimize the spread of battery contents should leakage occur.

3. Minimal operating time before renewing power source should be 20 hours.

DEVELOPMENT AND TESTING

The original design consisted of a Parke-Davis Ultrasonic Monitor, "Hemosonde" Model 2300 Doppler Probe, and a standard sphygmomanometer.

A transducer mount was constructed which allowed the Doppler probe to be attached to the arm over the radial artery. This arrangement proved to be unsatisfactory. Both systolic and diastolic pressure determinations could be made on normal subjects, but diastolic readings were difficult to determine without considerable training of the operator. In addition, conditions such as high peripheral vascular resistance could cause inaccuracies in the diastolic readings because of limited radial artery wall motion.

To circumvent these problems, a sphygmomanometer was modified to allow placement of the transducer probe directly over the brachial artery. A hole was cut through the cuff midway between the rubber tubes for bulb and manometer 2.35 inches from the distal side of the cuff, and a transducer mount was designed and fitted to the cuff (Fig. 1).

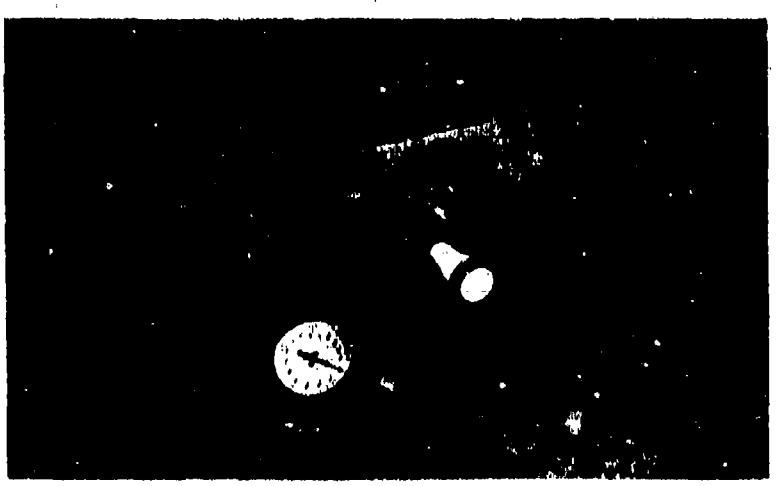

Figure 1. Modified standard sphygmomanometer.

The probe holder was designed to prevent the Doppler transducer from acting as a point source of pressure against the brachial artery, while at the same time preventing the cuff from ballooning out around the probe. When acting as a point source, the Doppler probe would occlude the brachial artery before the pressure in the cuff had risen to the normal occlusion point. Therefore, the systolic and diastolic pressures would be underestimated. If the cuff balloons out around the Doppler probe, the probe becomes separated from the arm, resulting in a reduction of

pressure over the brachial artery. Thus, the cuff will require a greater than normal pressure to occlude the brachial artery and the systolic and diastolic pressures will be overestimated.

It is apparent that a properly designed cuff-probe holder assembly should not allow either error to occur. In order to insure the proper design, we monitored the pressure under the Doppler probe and compared probe pressure with cuff pressure. The monitoring system consisted of a water-filled bladder, placed under the probe and connected to a Statham pressure transducer, and a Statham pressure transducer connected directly to the cuff. The signal from each transducer was coupled to a Beckman amplifier and displayed on a heated stylus strip-chart recorder. It was therefore possible to verify that the pressure under the Doppler probe was equal to cuff pressure.

The "Hemosonde" is composed of three interconnected units which present a problem in holding and using the device (Fig. 2). The operator needs both hands to apply the cuff and probe, and flight uniforms do not have adequate pockets for carrying the amplifier unit. A leather shoulder strap was added to the amplifier unit to allow easy access to all controls and to free the operator's hands.

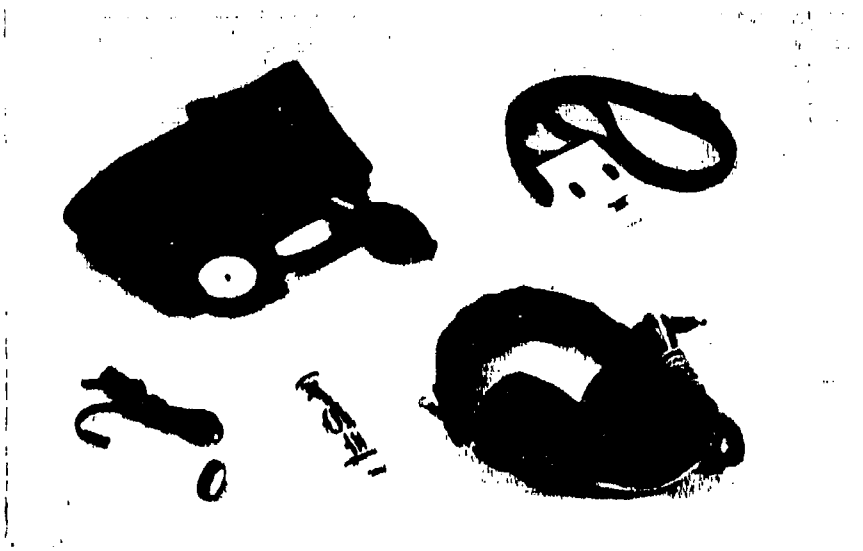

Figure 2. Components: Inflight blood pressure determination device utilizing the Parke-Davis "Hemosonde" 2300 Ultrasonic Monitor and modified sphygmomanometer.

During the developmental effort, the following tests were performed on the device to assure its suitability for use as an inflight blood pressure measurement system:

Accuracy Tests

Several subjects and operators were used in a series of tests to determine the accuracy of the Doppler system compared to a standard sphygmomanometer and stethoscope. The subjects were selected to provide a diversified range in arm size. Simultaneous measurements, using a standard cuff on one arm and the ultrasonic device on the other, were made on each subject by several operators. The measurements were within 5 mmHg on all tests.

Sound Chamber Tests

Tests were performed on the inflight blood pressure measurement device in an acoustical chamber in which the noise spectra and intensities of three multipurpose aircraft were duplicated. Operators made blood pressure determinations on subjects while subjected to the background noise of C-130, C-131, and C-141 aircraft. The output of the device and the acoustical isolation provided by the air cushion type headsets proved to be more than adequate. The background noise was "worst case," being the highest level encountered in the operation of these aircraft and in some cases exceeding 130 dB.

Clinical Tests

Several patients in the Coronary Care and Intensive Care Units of a local hospital were used to determine the accuracy of blood pressure readings obtained with this device. The readings were found to be accurate, and the personnel using the device were favorably impressed.

Electromagnetic Compatibility Tests

The unit was tested in accordance with MIL-STD 461A and met the criteria for airborne electronic equipment.

Patient and Operator Safety Tests

The device is electrically and acoustically safe. It operates on internal batteries and the patient is electrically isolated from all circuitry, which eliminates the worry of shock hazard. The acoustical power output of the device is less than 1 mW/cm^2 and is not hazardous to the subject.

Flight Tests

Flight tests were made on C-9, C-130, C-131, C-141, and UH-1B aircraft. The unit performed satisfactorily in all tests. Two main problems were encountered: (1) the unit is subject to signal breakup due to aircraft vibration being transmitted to the litter frame and patient's arm, and (2) the unit is subject to interference from some of the aircraft UHF and VHF transmitters. The first problem is alleviated by isolating the arm from the litter with a pillow. The second could not be avoided; however, this difficulty is not of sufficient magnitude to prevent acceptance of the unit. Testing indicated interference was intermittent, of short duration, and did not disrupt patient care.

Finally, the inflight blood pressure measurement device was operationally tested on aeromedical airlift missions with MAC, PACAF, and USAFE. Clinically, it provided the capability to determine systolic and diastolic blood pressures in the noise and vibration environments of the C-9, C-130, and C-141 aircraft.

PRINCIPLES OF OPERATION

The inflight patient monitoring/blood pressure measurement device consists of a Parke-Davis Ultrasonic Monitor, "Hemosonde" Model 2300, and a standard sphygmomanometer modified by placing a transducer mount through the cuff and bladder. The mount allows the Doppler transducer to be positioned directly over the occluded segment of the brachial artery. Operation is similar to that of an acoustic stethoscope and sphygmomanometer (Fig. 3).

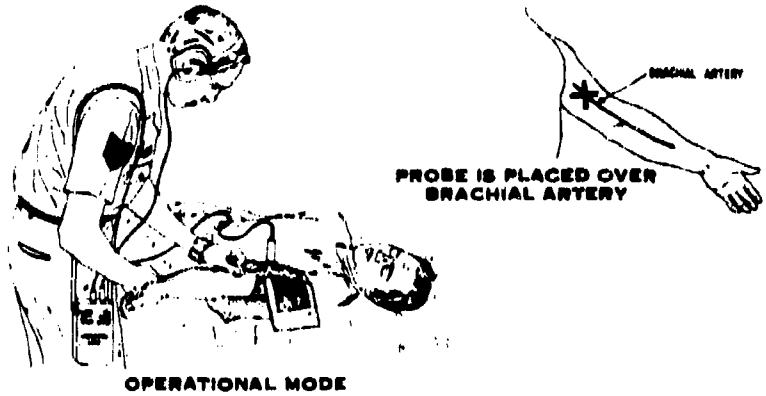

Figure 3. Inflight blood pressure measurement device in use.

Continuous ultrasonic energy is used to detect motion within a subject. According to the Doppler principle, when ultrasonic energy is reflected from a moving object, it is shifted slightly in frequency. The frequency shift is proportional to the speed of the object. For the present, application movement of the brachial artery will act as the moving object and reflect the ultrasonic energy.

For blood pressure measurements the pneumatic cuff with attached sphygmomanometer is secured around the arm, and the ultrasonic transducer is centered over the brachial artery. Proper positioning is established when the wall motion signal from the Doppler is maximum.

Wall motion is made audible since the arterial wall is moving relative to the ultrasonic transducer. Thus, the received signal is a slightly different frequency from that originally transmitted. The monitor detects this Doppler shift and converts it to an audible sound indicating arterial wall motion.

Having been properly positioned, the pressure cuff is inflated above systolic pressure; cuff pressure is then slowly reduced. When systolic pressure is reached, the arterial walls under the cuff will begin pulsating leading to audible "clicks" from the Doppler. Doppler signals appear and disappear in a manner similar to that of Korotkoff sounds heard during conventional blood pressure measurements. Thus, the only change from conventional blood pressure measuring techniques is that a Doppler is substituted for the stethoscope enabling the operator to hear wall motion in a high noise environment.

CONCLUSIONS

The Doppler ultrasonic device utilizing the Parke-Davis "Hemosonde" 2300 and modified sphygmomanometer for inflight blood pressure determination is a significant advance in the clinical management of patients. This technique provides medical crewmembers with a practical means of measuring systolic and diastolic blood pressures not possible by using a conventional approach. The item met the design objectives and was accepted by aeromedical crewmembers.