A SELF-CALIBRATING BLOOD-PRESSURE MONITORING SYSTEM

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MONITORING during surgical procedures has become standard practice, particularly during operations on the heart and the vascular system. Initially, the electrocardiogram alone was monitored; it gave useful information relative to the development of arrhythmias but few other data of clinical value. Monitoring the electroencephalogram may be helpful in determining at any particular moment the level of anesthesia and the adequacy of cerebral blood flow.

A notable decrease in arterial blood pressure may occur during anesthesia, without the development of clinical signs of hypotension or abnormality in the electrocardiogram or in the electroencephalogram. Although the anesthesiologist periodically records the arterial pressure indirectly, a continuous record is highly advantageous because changes in pressure may be sudden and critical. Under some circumstances, induced hypotension may be utilized to facilitate surgical procedures; during the hypotensive phase the arterial blood pressure may be difficult or impossible to determine by the indirect method. Strain gauges and other transducers have been used to record the arterial pressure directly. The level of pressure must be determined by reference to a calibration, and recording must be done on paper. This method of recording requires the presence of trained personnel. A need for a method of recording the arterial blood pressure continuously and displaying it instantaneously without reference to previous calibration has become apparent. It should be possible to display the record on the screen of a cathode-ray oscillograph.

We are reporting the development of a measuring and monitoring system in which a number of pressures are sequentially sampled by valving these pressures to a common chamber that is covered by a diaphragm coupled mechanically to a simple linear transducer (Fig. 1). The blood pressure and calibration information are reproduced on a cathode-ray tube or on a suitable paper recorder.

In its simplest form, three pressures are used. Two of these are accurately known static pressures that are continuously adjustable and measurable by means of mercury manometers. The third is the direct arterial pressure communicated to the valve-transducer system by means of a nylon tube or catheter. By sequentially sampling the accurately known pressures and the arterial blood pressure, the system is continuously calibrating itself ten times per second at two pressure levels (Fig. 2). The arterial pressure is effectively superimposed on these calibration points, permitting accurate measurement or observation of the complete arterial pressure curve and measurement of systolic and diastolic pressures. Venous pressure also may be measured by this method.

The basic element of the pressure scanner is the stainless-steel, high-precision,
all-metal, motor-driven valve that opens in sequence between the transducer pressure chamber and four pressure sources (*Figs. 3 and 4*). The timing is so arranged that the previously sampled pressure is completely turned off an instant before the succeeding pressure to be sampled is turned on. Each sampling of pressure in its proper turn therefore actuates the ceramic piezoelectric transducer. The transducer chamber with its heavy, stainless-steel diaphragm is bolted directly to the valve body, forming a gasketless seal between precision-honed metal surfaces. The transducer element is cemented directly to the diaphragm. This element is lead zirconium titanate (PZT), a high-sensitivity piezoelectric ceramic material that is unaffected by temperatures up to 300 C.

The necessary operations of filling the valve and tubing with sterile liquid and of removing air are performed with the aid of three, standard, four-way stopcocks. The static calibrating pressures and a standard syringe provide the means of forcing the sterile liquid through any part of the system selected by the positions of the stopcocks. All air is released from the valve through the air-release
port, which is capped by a standard Luer slip plug. The static-pressure ports are each kept open one fourth of a valve revolution (Fig. 5). In the simplest form, this allows one half of a revolution in which the arterial pressure is in communication with the transducer.

Since actuation of the transducer depends on deflecting a small, extremely stiff, stainless-steel diaphragm one-eighth inch in thickness, the frequency response depends entirely on the size of the inside diameters and the expansion rigidity of the catheter system. In actual operation, as the scanning valves open and close, the pressure in the transducer chamber is changed and precisely measured in less than one thousandth of a second, forty such changes occurring each second. These pressure changes and measurements take place entirely independently of the external catheter system and represent a maximum attainable frequency response of several thousand cycles per second.

This system eliminates the need for direct-current amplifiers and centering controls. The read-out automatically returns to center on the cathode-ray screen. It is independent of transducer or amplifier calibration, and does not require extremely high-gain amplifiers. The system is simple to operate. It can be sterilized by autoclaving or with chemicals.

Fig. 2. Diagram of transducer output. The straight lines represent static pressures, and the curved lines represent intravascular pressures.

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Fig. 3. Photograph of valve.

Fig. 4. Diagram of valve.
Fig. 5. Diagram of transducer. The circles represent cross sections of the stator, showing: 1—high pressure standard closed, to open in one-half turn; 2—blood pressure closed, to open in one-quarter turn; 3—low pressure standard, about to register; 4—blood pressure registering at end of dwell.

To facilitate autoclaving, to avoid special parts, and to provide hydraulic shock absorption, standard latex heavy-wall rubber tubing is used to connect the system of standard stopcocks to the scanning valve. With this unsupported rubber tubing, reliable frequency response of more than 10 cycles per second is available with a catheter consisting of six feet of nylon tubing, with a 0.078-inch inside diameter, terminating in a No. 18 needle. This response is adequate for accurately recording the arterial blood pressure. With a larger diameter and more rigid catheter system, much higher frequencies can be obtained.

The noise level of the complete scanner system is less than the equivalent of a pressure at 1 mm. of Hg. Therefore, pressures of less than 10 mm. of Hg can be satisfactorily monitored and measured.

An excellent paper record of the pressures can be made with any photographic recorder having a frequency response of 300 cycles per second or more (Fig. 6). Most of the standard direct-writer recorders will also produce an accurate and satisfactory record. A recording can also be made by removing the green or amber
filter of an oscilloscope and photographing the screen with an ordinary camera by holding the camera open for the duration of one sweep.

Summary

A new transducer system for recording the direct arterial blood pressure has been developed, by means of which it is possible to display continuously known pressures and the arterial pulse curve on the screen of a cathode-ray oscilloscope, and to record the curves by means of a suitable galvanometer.

Acknowledgment

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Reference

ENDOTRACHEAL ANESTHESIA USING A MODIFIED WIS-FOREGGER LARYNGOSCOPE BLADE

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ENDOTRACHEAL intubation is widely employed during general anesthesia. This technic provides definite advantages to the patient, the surgeon, and the anesthetist. However, skillful use of the laryngoscope is essential to avoid injury to the patient's teeth and pharynx during intubation. Although such injuries are accepted hazards of the procedure, they may be avoided by the use of a laryngoscope with a modified blade.

Technic of Laryngoscopy

Laryngoscopy for intubation must be done with gentleness and precision. While the standard laryngoscopic procedure is modified and individualized by each anesthetist, the fundamental principles of the technic remain unchanged. The patient's head is held in progression by elevating it from the pillow. Such manipulation relaxes the anterior muscles of the neck, and straightens the normal anatomic curves of the pharynx. The blade of the laryngoscope is lifted upward and forward to carry forward the epiglottis and the base of the tongue to expose the larynx and the vocal cords. The endotracheal tube then can be easily inserted into the trachea under direct vision. Should the laryngoscope be used as a lever, with the upper incisor teeth acting as the fulcrum, there is risk of damaging the teeth and of traumatizing the epiglottis.

Difficult Intubations

Anatomic variations of the mouth and the pharynx occur frequently. Many of them are the cause of difficulty in exposing the larynx and in intubating the trachea. The problem is exemplified in patients who have any of the following features: a small mouth, a short thick neck, an anteriorly placed trachea, a short thick epiglottis, a recessed mandible, a "frozen" temporomandibular joint, protruding upper incisor teeth. In these patients, difficult intubation is common, and the unfortunate traumatizing of the pharynx or damaging of the teeth is apt to occur. The anesthetist should be forewarned that disfigurement from damaged teeth may well provoke litigation against him by the patient.

Modification of the Wis-Foregger Blade

The regular blade of the Wis-Foregger laryngoscope* (infant, child, adult, long sized blades) is detachable, and forms a right angle with the Foregger handle. Figures 1 and 2 illustrate the differences between the regular and the modified Wis-

Fig. 1. Photographs of A, the regular, and B, the modified Wis-Foregger laryngoscope blades (top and side views).

Fig. 2. Sketches of A, the regular Wis-Foregger laryngoscope blade, and B, the modified blade with tapered contour (side view).
consin blades. In the modified blade, the inferior surface of the blade has been cut away to a distance of 7 cm. while maintaining a gradual taper. Removal of that portion of the blade does not jeopardize the strength of the instrument.

The clinical advantages of the modified blade are apparent. For visualization of the larynx, the blade requires an upward and forward lifting force; therefore, the handle of the laryngoscope does not become a lever nor do the teeth act as the fulcrum for the blade in exposing the larynx. Should the blade be permitted to rest on the teeth, visualization immediately becomes impossible (Fig. 3).

![Fig. 3. Sketches showing technics using A, the regular Wis-Foregger laryngoscope blade, and B, the modified blade.](image)

Trauma to the undersurface (posterior) of the epiglottis is minimized by applying the proper lifting force. Moreover, the alteration in design of the blade reduces
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the amount of bulk put into the mouth of the patient, thus providing better visibility.

Legal Aspects of Injury to the Teeth

As mentioned previously, injury to the teeth during laryngoscopy for endotracheal intubation is not uncommon. Frequently, a difficult intubation cannot be anticipated; permanent dentures may complicate the technic. The anesthetist should do everything possible to avoid such injury, and the modification of his equipment is a simple but effective step in this direction.

As a general rule, it may be stated that the law recognizes the possibility of complications, and places the risk of their occurrence upon the patient, so long as there is no negligence on the part of the anesthetist. By such a premise, the anesthetist does not have license to extract teeth needlessly during intubation. Despite this legal immunity, it behooves the anesthetist to protect the patient’s teeth during intubation. This may be accomplished with the rubber tooth protector, and by modifying the potentially dangerous parts of existing equipment. These precautions constitute the exercise of reasonable care.

Conclusions

The modification of the blade of the Wis-Foregger laryngoscope facilitates intubation by averting trauma to the patient’s teeth, the dental prostheses, and the epiglottis. When used incorrectly—as a lever, with the teeth as the fulcrum—the modified laryngoscope blade obscures the anesthetist’s view of the larynx, and intubation under direct vision becomes impossible. Therefore, the only manner in which the instrument can possibly be used to intubate a patient is the correct, nonnegligent way.

References