Recent Advances in Instrumentation for Clinical Medicine

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Recommended Citation
Cholvin, Neal R. (1965) "Recent Advances in Instrumentation for Clinical Medicine," Iowa State University Veterinarian: Vol. 27: Iss. 3, Article 3.
Available at: http://lib.dr.iastate.edu/iowastate_veterinarian/vol27/iss3/3

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The array of equipment available to the practitioner for use in diagnostics and therapy is continually augmented by new developments in various technological fields. This paper reviews several relatively recent outgrowths of medical instrumentation research. Several of the devices which are discussed already are in use in clinical medicine and surgery. One device (plasma scalpel) is still in the developmental and feasibility study stage.

ULTRASONIC DEVICES

Ultrasound therapeutic instrumentation has been used for many years with varying degrees of success in the treatment of some joint, nerve and muscle ailments. In the past few years, however, new diagnostic instrumentation utilizing ultrasonic principles has been found useful for some specific purposes.

The principle upon which ultrasonic devices operate is as follows: high frequency sound waves (1 to 4 million cycles per second), when propagated into the body, are reflected from interfaces where there is a sudden change in tissue characteristics. These interfaces occur wherever there is a liquid-to-solid boundary or a solid-to-solid boundary at which there is a change in tissue density and/or tissue elasticity. At these boundaries the change in tissue physical characteristics produces a change in acoustic resistance. The reflected sound waves can be "sensed" by the same transducer head from which the waves are generated. The "echoes" are then displayed on a special oscilloscope screen which is calibrated to give an indication of the location of the tissue interfaces. The surface of the body and all internal interfaces appear as upward deflections of the trace on the oscilloscope face. The scale on the screen is calibrated in centimeters of tissue thickness. The image does not resemble that seen in x-radiography because it only represents the narrow beam which is reflected back into the sensor.

In some respects this instrumentation has the tissue-delineating capability of x-ray fluoroscopy. In other cases its versatility is less. There are some advantages to using this device. First, it can be used in daylight. The image which appears on the oscilloscope face can be made quite bright. Second, only a very small amount of energy is actually beamed into the body. Although the hazard from sonic radiation has not been fully evaluated, it appears that the actual power involved is very much less than that deemed damag-
ing. One shortcoming of this instrumentation is that the actual appearance of deep structures is not shown. Only the spacing between interfaces and a relative evaluation of the magnitude of tissue density change (by the amplitude of the deflection) is shown.

The echo-encephalograph has been used for rapid examination of traumatic head injuries for fractures, hematomas and internal displacements. It is also useful in the detection of brain tumors, hydrocephalus and cerebrovascular disease. In cardiovascular diagnosis it has proven useful for the visualization of the heart valves and of the pulsations of arteries deep in tissues. It has been used for determination of various organ and bone dimensions, in the latter instance for determination of pelvic canal size. In addition, it has been used in the diagnosis of mammary tumors and of specific ocular conditions.

Transistorized models of this equipment are being developed. Being relatively small in size and having low power requirements, this type of equipment is useful for rapid diagnosis of traumatic injuries in emergency situations.

**CARDIAC DEFIBRILLATORS**

The treatment of ventricular fibrillation is always extremely difficult. Cardiac ventricular fibrillation occurs when, for some reason, the myocardium has increased irritability and when its metabolic state has declined due to hypoxemia. These changes might occur during surgery and as a result of drug depression. Fibrillation also commonly results from electric shock when an appreciable electric current flows through the heart muscle itself.

The most successful treatment for ventricular fibrillation is electric countershock. Electric defibrillation, if applied successfully, converts the asynchronous mechanical activity of the fibrillating ventricles to a state of complete arrest known as cardiac stoppage. In order for the countershock to be effective, the myocardial tissue must be in a state of adequate oxygenation. This is accomplished by providing adequate ventilation of the lungs and instituting manual cardiac compression, either compressing the heart directly or by compression of the chest wall. Once the properly nourished myocardium has been electrically shocked into inactivity, the natural pacemaker beat of the sino-atrial (S-A) node will trigger the onset of regular synchronous ventricular contractions.

The first cardiac defibrillator units utilized alternating current applied for short periods of time depending upon how long a pushbutton or similar device was held down by the operator. In many cases, under proper conditions, alternating current defibrillation is successful. A number of investigations have been conducted to determine the optimum type of stimulation which will stop ventricular fibrillation. It appears that a direct current impulse of extremely short duration might be the best stimulus. Contemporary devices ordinarily consist of high energy storage capacitors capable of storing charges up to 1000 volts, used in conjunction with circuitry to charge these capacitors and timing devices which automatically limit the duration of capacitor discharge across the defibrillator electrodes. Depending upon the voltage applied, these devices can be used for either direct stimulation of the heart or stimulation through the thoracic wall using large paddles. This latter capability has obvious advantages in cases where the thorax is not already open.

**PHOTOCOAGULATORS**

The coagulation of tissue in surgery can be accomplished by a variety of means. Heat scalpels similar to soldering irons were developed many years ago. Tissue coagulation has also been accomplished by the application of extreme cold. Radio frequency current generators have found wide use as surgical scalpels. This device produces less tissue damage than do heat scalpels. Another type of coagulator device utilizes a spark gap generator.

With the development in technology of laser beam generators, surgeons have investigated the utilization of a new, extremely high energy visible light laser device for surgical applications. The laser converts electrical energy into light energy.
of several specific wavelengths, the wavelength depending upon the nature of the generator and the conditions under which it is operated. The light energy thus produced by a ruby crystal source can be concentrated in an extremely narrow beam. Great quantities of energy are transmitted from ruby lasers and the control of the quantity of energy is accomplished by limiting the output to extremely short pulses.

Laser coagulators are being investigated for use in treatment of detachment of the retina. These very fine beams of light energy can be focused on a number of areas of detached retina to produce microburns. The body’s response to this controlled coagulation is to “cement” down the separated tissue by connective tissue proliferation. Some of the results of the use of this device to treat detached retina have been very promising. In addition, lasers are being evaluated in radiation therapy of neoplastic tissue on the body surface or where the tissue has been exposed by surgery.

**ELECTRICAL ANESTHESIA (ELECTRONARCOSIS DEVICES)**

Another relatively new device for use in surgery is an electrical stimulator which produces depression of the central nervous system. A great deal of effort has been expended in the last decade to investigate the practicality of electrical anesthetic devices. Many devices have been reported in the literature. The operating parameters which have been used are quite varied. The type of electrical stimulation has ranged from continuous direct current, to alternating sine wave or square wave stimulation to combined direct and alternating currents. One difficulty in this method of anesthesia is achieving good electrode contact between the stimulating electrodes and the subject. Various electrode placements have been used. These include bitemporal, longitudinal placement on the median line and spinal placement.

Obvious advantages of this type of anesthesia are rapid induction and rapid recovery. In many instances experimental animals are fully conscious and capable of coordinated movements within a minute or so following cessation of the stimulatory current, providing that preanesthetic sedation had not been given. Some of the untoward effects that have been observed during electronarcosis are the following: respiratory arrest during the induction phase, cardiac arrest (initial), poor muscular relaxation, salivation, rise in blood pressure, urination, defecation, disturbed temperature regulation (hyperthermia) and variation in responses between animals of the same species.

**PLASMA SCALPEL**

A unique application of the use of hot ionized gases is presently under investigation. In physical technology, plasmas are being investigated for such uses as propulsion in vehicles used outside the earth’s atmosphere. Medical researchers are investigating this type of device as a surgical scalpel. A device is being developed which will control the exhaust pathway of a plasma source to dimensions practiced for consideration in surgery. Although the hot ionized gases are at unbelievably high temperatures, the total energy contained in a thin stream of these gases is sufficiently low that minimum tissue damage occurs adjacent to the beam path. The gases that can be used are nontoxic to tissues. This device holds interesting promise as a scalpel which will incise tissues with complete absence of hemorrhage.