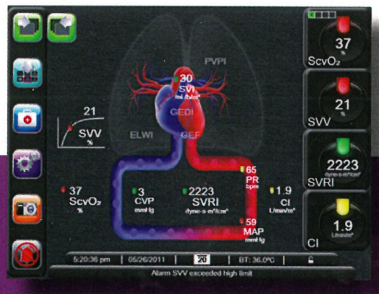
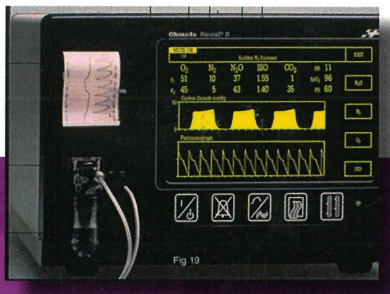
Jan Ehrenwerth • James B. Eisenkraft • James M. Berry

ANESTHESIA EQUIPMENT

Principles and Applications





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ANESTHESIA EQUIPMENT: PRINCIPLES AND APPLICATIONS

Second Edition

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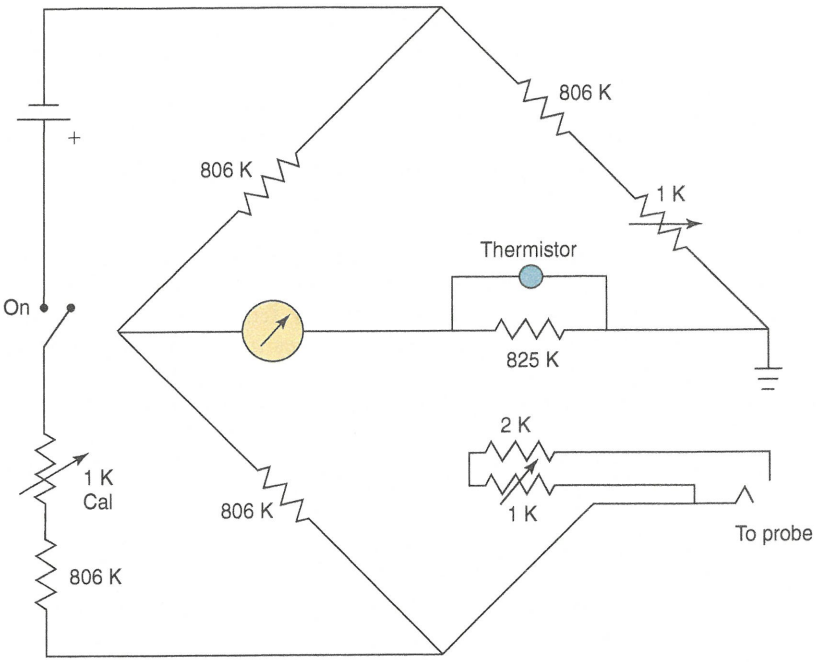

FIGURE 14-13 ■ Circuit for thermistor temperature monitor. This is a simple battery-powered bridge circuit.

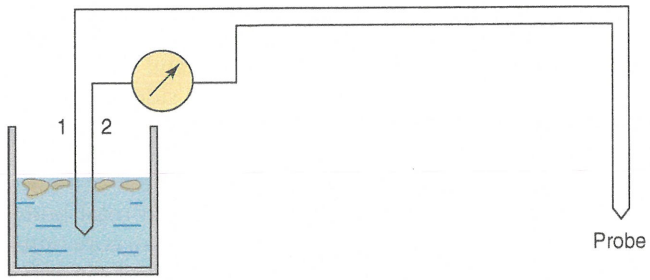

FIGURE 14-14 ■ Circuit for thermocouple thermometer. The probe consists of two different metals (*1* and *2*) that conduct heat differently, which results in the generation of a current that can be measured on the meter (*arrow*).

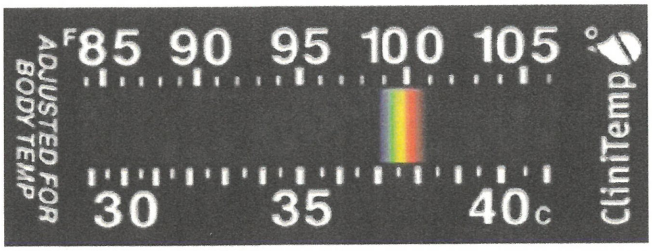

FIGURE 14-15 ■ An example of a skin temperature liquid crystal monitor (Sharn Anesthesia, Inc., Tampa, FL).

easily measured with an amplifier. Although an outside power source is not required, in practice the apparatus is more complicated than the thermistor thermometer. The reference junction can be kept in an ice water bath, in a heated or cooled oven, or even in contact with semiconductor circuits, measuring its temperature and applying an appropriate compensation. Probes are less expensive and also are available in very small sizes. Carefully made junctions are likely to be stable and accurate to 0.1° C.

Liquid Crystal Thermometers

Liquid crystals have complicated structures with large-scale order.[55] Liquid crystal thermometers use cholesteric liquid crystals, which have an ordered layer structure with directional asymmetry in the plane of each layer. The orientation of this asymmetry gradually rotates with each succeeding layer, yielding a periodicity that may be the size of a wavelength of visible light or larger. This structure makes the substance optically active; it rotates the plane of polarized light. The optical properties are highly sensitive to temperature; when liquid crystals are encapsulated in thin films or used with polarizers, the color changes with temperature. Optical changes with phase transitions between various structures also can be used for displaying temperature. These devices are readily applied to measure skin surface temperature. Two forms are available: one displays the actual temperature measured, and the other has a built-in offset so that the temperature displayed estimates core temperature (Figure 14-15).[36] However, under rapidly changing conditions, there is a significant discrepancy between core and skin temperature.[56]

Infrared

The infrared thermometer is a noninvasive device that collects radiation emitted by a warm object. The radiation sensed is converted to a temperature on the basis of an empirical calibration. A small probe covered with a disposable, transparent cover is inserted into the external auditory meatus, where the infrared detector can "see" the tympanic membrane. This method provides a prompt, accurate measure of core temperature.[57] Newer probes have been made for use over the forehead (Fig. 14-16). These infrared devices are placed in the center of the forehead and are scanned along the hairline over the temporal artery. This has become an increasingly popular method for determining temperatures in the PACU because it

FIGURE 14-16 Temporal Scanner (Exergen, Watertown, MA) infrared forehead temperature-measuring device, which scans the temporal artery.

provides a quick and noninvasive approximation of core temperature.[58] The accuracy of the device was found to be clinically insufficient in one study, but a later updated study found the device to be suitable for clinical use.[59,79]

TEMPERATURE MONITORING SITES

The site for monitoring temperature during anesthesia depends on the surgical procedure, the type of anesthesia used, and the reason for temperature monitoring. When significant changes in body heat are expected, core temperature should be monitored.

The gold standard for measuring core temperature is the temperature of pulmonary arterial blood. The temperature of pulmonary arterial blood correlates well with tympanic membrane temperature, distal esophageal temperature, and nasopharyngeal temperature. When a pulmonary arterial catheter is not otherwise necessary, any of these other sites usually suffices.[60]

The tympanic membrane is close to the carotid artery, and the temperature of the blood supplied to the tympanic membrane approximates that at the hypothalamus.[61] The placement of a temperature probe on or near the tympanic membrane risks perforation and bleeding, especially with heparinization.[62] The external auditory meatus is safer for this purpose but works well only if adequately insulated from the outside temperature.[63]

Nasopharyngeal temperature may reflect the same blood supply as the hypothalamus but is more subject to error from displacement or leakage of respiratory gases and resultant cooling.[64] The insertion of nasopharyngeal temperature probes also can result in epistaxis.[65]

The esophagus is a safe,[66] easily accessible, and accurate site for core temperature measurement during anesthesia. A combination stethoscope and temperature probe is easily passed to a position near the heart; the optimal position for the sensor in adults is 45 cm from the nose.[67] The temperature must be measured in the distal third or quarter of the esophagus to avoid cooling by respiratory gases in the trachea, even though this position may not be optimal for auscultation.

The use of rectal temperature monitoring was more popular in the past, although such readings are affected by heat-producing organisms in bowel, insulation by the feces, and blood returning from the lower limbs. Not only do rectal temperatures not accurately reflect core temperature,[54,68] a small risk of perforation exists with this method. Rectal temperature changes too slowly to follow intraoperatively, and contraindications include obstetrics, gynecologic, and urologic procedures.

Bladder temperature correlates with core temperature well and is easily measured with combination Foley catheter–themistor probe devices.[69] When urine flow is high, correlation between bladder and core temperature increases.[70] During cardiopulmonary bypass, temperature changes too rapidly for the bladder temperature to follow core temperature.[71]

Axillary temperature over the axillary artery with the arm adducted can give a reasonably accurate core temperature and is most reliable in infants and small children.[72] It should not be used on the same side as a blood pressure cuff on the upper arm. Similarly, sublingual temperature, although subject to error, is still useful, and awake patients tolerate the thermometer well.

Although skin temperature contributes to total body heat, it reflects peripheral perfusion rather than core temperature.[73] Total body heat can be calculated via estimates of mean skin temperature measured at multiple sites but is too cumbersome for routine use. Skin temperature, with a 2° C compensation, is a fair estimate of core temperature except in rapidly changing conditions such as malignant hyperthermia.[56,74] Skin temperature is most commonly measured at the forehead because it is easily accessible, has good blood flow, and has very little underlying fat. Readings can be affected by ambient temperature, skin-surface warming devices, and regional vasoconstriction.[74] Skin temperature monitoring also can be used as an indicator of a successful nerve block by observing an increase in temperature. It also can be used in microsurgery to indicate adequate blood flow by seeing an increase in temperature in that area.

Other sites may be of value in special situations. Myocardial temperature is readily measured with a needle probe during cardiopulmonary bypass, and skeletal muscle temperature provides the earliest indication of temperature change with MH.[75]

GUIDELINES FOR TEMPERATURE MONITORING

Although no absolute requirements for routine intraoperative temperature monitoring have been established (except in New Jersey), several guidelines have been proposed by various groups. Sessler,[76] an expert in