the personnel who operate such a laboratory are generally extremely careful in processing these dangerous materials so that the probability of contamination and subsequent infection to the uninitiated should be quite remote.

BLOOD BANKS

The successful operation of a blood bank depends on adequately satisfying three major factors: procurement, storage and the laboratory technical skill to assign blood properly to the recipient. It is fairly obvious that the last of these involves the largest amount of continuously applied human ability which depends in turn upon a good supply of available donors and satisfactory storage or banking facilities or both for successful performance and service. The factor of storage will be discussed.

The technique of blood banking as recognized today is relatively recent and dates in this country to the organization of the first blood bank at Cook County Hospital in Chicago in 1936. With the development of improved preservative solutions, allowing blood to be stored safely and effectively for 21 days following withdrawal from the donor, the blood banking concept spread rapidly and today almost every hospital or medical institution involved in direct patient care has a blood bank. Literally millions of transfusions have now been given and with this remarkably simple means of providing whole blood at a moment's notice, other procedures and the use of dried plasma and other blood volume expanders presently represent a very small percentage of average hospital usage.

The blood storage procedure is relatively simple and by and large depends upon standard refrigeration equipment. The size of the institution or area to be served by the blood bank usually determines the type of equipment. For example, a large medical center may have a good sized walk-in refrigerator to bank its blood and keep the stock of typing sera and other accessories to the blood assignment process. In addition there may be a large refrigerator, generally two-door, of standard dimensions and construction, in which the blood that has been prepared for and assigned to individual patients is kept until requested for use by the physician. Variants of this arrangement will be seen in practically every blood bank.

Blood bank refrigerators should be equipped with forced air circulation, a dependable and sensitive thermostat, an alarm system and a recording thermometer. The recommended temperature is 4 to 6 C.

Certain principles of blood bank refrigeration are listed by Kilduffe and DeBakey.[4] These include in addition to the prescribed warning signals and recording thermometers, a suggestion that the refrigerator be operated on a separate circuit to minimize power failure from mishaps in other apparatus. Also it is recommended that the equipment be inspected and tested regularly by expert maintenance personnel.

Simple devices called *refrigeration indicators* are described by DeGowin and Hardin.[5] These devices rely on a principle of melting points of certain fatty acids which liquefy at room temperature or slightly below permitting colored glass beads to change position in a glass container thereby informing the observer of upward deviations of temperature. These simple indicators would serve a purpose in some areas, but would be unacceptable in blood banks, since more reliable recorders exist.

PATHOLOGY AND ANATOMY LABORATORIES

Morgue Refrigeration

Medical center or hospital morgue refrigeration is usually accomplished by one of two types of construction. The first of these is the walk-in unit with compressor, refrigerating coil and blower of appropriate size and convenient location; the second is a complete unit manufactured for installation, consisting of an insulated outer shell containing slide out drawers or shelves suspended in Ferris-wheel fashion.

The walk-in type unit is generally the most satisfactory, depending of course on the anticipated volume of occupancy. It is equipped with wooden or stainless steel shelves measuring 2 – 2½ × 7 ft, suspended on wall brackets along the length of the chamber. It is customary to place the shelves in two or more tiers to make the most efficient use of the available space. The usual type of walk-in refrigerator door is used and the sill-less type is preferred to facilitate movement in and out of wheeled stretchers. A tile or other impervious floor should be laid and a drain of suitable size is essential to enable easy hosing down or other cleaning.

The second type of installation is used for very large medical facilities or small hospitals which anticipate a maximum accommodation of two or four bodies. These units consist of individual compartments with longitudinal slide drawers measuring about 2½ × 7 ft.

Temperatures are usually in the 4 to 6 C area with enough latitude in the refrigeration apparatus to maintain this temperature while cooling the *maximum capacity* of the unit. Maximum storage time does not usually exceed 72 hours, and if longer storage is contemplated, embalming is usually instituted. If facilities for embalming are not readily available, deep freezing may be resorted to as a preservative measure if appropriate medico-legal or other studies are anticipated.

Cadaver Preservation and Storage

The use of refrigeration as an integral part of cadaver preservation and storage follow the pattern of refrigeration wherever large objects are to be kept cold for varying periods of time. Actually the demand for this sort of application is limited largely to medical schools or other institutions where human or animal anatomical studies are made. Refrigeration is needed subsequent to suitable embalming or other preparation. With the increasing demand for cadavers for medical teaching and study, coupled with the increasing difficulty of procurement as a result of some of the social and economic adjustments of the past, equipment for long term adequate storage is essential.

This is not a field that has stimulated extensive literature, but the basic principles are well understood by those interested or involved in this subject, and each institution probably has its own modifications to suit its needs or views. Saunders[6] presents a detailed description of one type of refrigeration application to this problem which fulfills the needs of his particular situation. In this case the refrigerator is constructed with removable shelves, similar to that described under morgue refrigeration.

A variant of this method in use in many medical institutions involves the principle of suspending the cadaver by a tongs or head harness attached by a chain to a wheeled trolley. The trolley in turn runs on an overhead track which proceeds from above the embalming table into the refrigerator, enabling one attendant to move the cadaver about with ease. This involves an aperture in or above the refrigerator door to accommodate the track.

Refrigeration is supplied by a suitable built-in cooling unit and blower, or more than one as the situation demands. It is estimated that a room 12 × 40 × 8 ft will accommodate 100 cadavers. The desired temperature is 2 to 3 C. The walls, ceiling and floor should be well insulated and painted with a light colored water repellent paint. A tile or terrazzo floor is

satisfactory and a drain or drains in the floor should be provided to facilitate cleaning. The suspended cadavers are usually encased in plastic bags, or sprayed with a vinyl resin having moisture resistance as well as bacteriostatic and fungistatic qualities. The refrigeration aspects of this arrangement aside from some unpleasant aesthetic considerations are similar to those in industrial or other large room refrigeration ventures.

It is sometimes advantageous to provide a deep freeze room as part of this major cadaver storage for the preservation of certain unembalmed materials to be kept for further study. This unit should be contrived as a room opening into the larger storage area with a deep freeze type door and equipped with a cooling system and blower to provide a temperature of about −20 C. Usually a space of approximately 8 × 8 × 8 ft lined by 12 in. wall shelving at convenient intervals to the ceiling will suffice and allow for segregation and cataloguing of the specimens.

REFRIGERATION IN CLINICAL MEDICINE

Medical applications of refrigeration are confined largely to laboratories as indicated above. Clinical medicine which is concerned with the immediate diagnosis, treatment and care of the patient by the physician has used direct refrigeration very sparingly, confining it largely to the traditional ice pack for sprains, headaches, and other local analgesia, and the use of solid CO_2 in the removal of certain skin blemishes. Recently a whole new field of clinical refrigeration—*hypothermic anesthesia*—has been opened and is presently under intense exploration.

Hypothermic Anesthesia

In 1950, McQuinston[7] introduced the concept of lowering the body temperature during anesthesia to reduce oxygen demand, especially in children undergoing cardiac operations. First use of hypothermia in open heart operations was reported by Lewis and Taufic[8] in 1953, and was employed in the closure of atrial septal defects (communicating holes in heart chambers). In 1953 also, Dundee et al[9] set forth a series of indications for hypothermia including (1) the desirable hypotension (low blood pressure) to control hemorrhage for either the patient or for the surgeon because hypothermia might more safely lower the pressure and also diminish the oxygen demand, (2) patients with severe anemia which could not be corrected preoperatively, (3) operations on the heart and great vessels in which cerebral circulation may need to be stopped, (4) thyrotoxicosis (excessive activity of the thyroid gland) which could not be controlled by medical treatment, (5) neurosurgery, and (6) hyperpyrexia (high fever) of pituitary (gland) or post-operative origin or in thyroid crises. It has been used in a number of difficult major procedures in poor risk patients.

The hypothermic state is produced in three ways: by immersing the anesthetized patient in ice water; by surrounding the patient with plastic bags containing flaked ice; and by cooling the patient with water-antifreeze admixture, precooled by refrigeration, and pump-circulated through a tube coiled within a rubber blanket which surrounds the patient. The first method using immersion in ice water requires 30 to 60 min for effective cooling. Temperature continues to drop after the patient is removed from the tub, and the continuing fall is approximately ⅔ as much as that which occurs while the patient is in the ice water. This ratio, however, is not constant, a disturbing factor not solved to date. The patient is ordinarily left in the tub until the temperature has dropped about 60 percent of the desired value to about 31 C, effecting a final temperature of about 27 C. Continuous electrocardiography (tracing of heart electric potentials) is employed to provide information regarding the condition of the heart of the patient throughout the procedure.

Pulse rate and blood pressure decrease as the patient cools. Shivering is controlled by relaxing drugs such as curare or cyclopropane anesthesia. When the patient's temperature reaches 30 to 28 C, the need for further anesthetic agents is markedly reduced.

When the estimated temperature is achieved (60 percent of the desired fall) the patient is removed from the ice water thoroughly dried with bath towels. The patient is then carefully and protectively wrapped. In some cases diathermy coils are carefully applied to the hips and abdomen, to be used to avoid a dangerously low temperature or stand ready for prompt warming in the event of weakening of the heart. Its greatest use is to warm the patient at the conclusion of the operation. Warm water immersion can also be used for this latter purpose.

The second method using plastic bags containing flaked ice is also satisfactory and the general principle is the same. It is not quite as rapid as the immersion method, but faster than the third method which uses the precooled circulating fluid. To be most effective the bags must be placed all over the body, covering all but the face. An important feature of this method is an adequate source of flaked ice.

The last method mentioned involves the use of a mobile apparatus which has both heating and cooling units, as well as a fluid tank and a circulating pump. The machine operates on the principle of compressor and coil cooling of a water-antifreeze mixture in the built-in tank. This cooled mixture is then circulated by a pump through a rubber blanket, which is inlaid with rubber tubing forming a continuous connected U pattern, similar to the wiring of an electric blanket. Sponge rubber cylinders of diameter equal to that of the rubber tubing fill the interstices between the tubing as it undulates through the blanket. The tank of water is large enough to supply continuous cooling to two of these blankets, laid underneath and on top of the patient and joined laterally by zippers. The blanket thus surrounds the patient's body and is further covered by wool blankets to provide additional insulation. This system will drop the temperature of a small child about 1 deg C every 6 min, and of the adult about 1 deg C every 24 min. Precautions regarding continuing downward temperatures are similar to those described above under the ice water immersion method. The first two methods are faster although the last method has many advantages of convenience and ease of application.

This same unit may also be used for warming the patient. The heating unit is activated and the fluid mixture warmed and circulated through the blanket. The top blanket is removed during the operation, although some models have longitudinal slits which may be opened and through which the operation may be accomplished.

Recent problems with extracorporeal circulation relating to maintenance of a satisfactory safe level for an appropriate time interval have led to development of a system of very rapid deep hypothermia for special cases using a heat exchanger in which body core temperature can be reduced approximately 1 C deg per minute.

The heat exchanger as described by Drew et al[10] consists of four stainless-steel tubes (¼ inch internal diameter), each of which is five feet in length and highly polished on the inside. The tubes are arranged in parallel and connected together with Y-shaped stainless steel connectors and short lengths of polyvinyl ethylene chloride tubing. (This arrangement is preferred to a coil because it offers less resistance and the straight tubes are easy to clean.) The tubes are suspended in