MODERN advances in the diagnosis and surgical correction of cardiovascular lesions have made the procurement, preservation and implantation of blood vessel grafts an important factor in the success of such surgery.

It soon became evident that survival of cells in a graft after implantation was not an indispensable element for satisfactory functional results in patients wherein growth of the graft is not necessary. Therefore, recent efforts have been made in the direction of determining which method of preservation of vascular grafts is most satisfactory. It should be realized, however, that further investigations are necessary, and that only long-term postoperative observation in human recipients will give a definitive answer on the fate of the various types of vascular and plastic prostheses that have been advocated.

The following recommendations have been prepared with the idea of aiding clinical investigators in the establishment of blood vessel banks under standard conditions and, as far as possible, to adopt a certain uniformity in the procurement and preservation of vascular grafts for future evaluations.

**Vascular Grafts**

- **Introduction**
- **Space Requirements**
- **General Equipment**
- **Procurement of Material**

(A) Legal Aspects

(B) Surgical Techniques

1. Under Sterile Precautions.
2. Without Sterile Precautions.

(C) Evaluation of Donor Material

1. Age of Donor.
2. Cause of Death.
3. Interval between Death and Autopsy.

Sterilizing Agents

Chemical Agents

Physical Agents

**Preservation of Vascular Grafts**

- **Quick-Freezing**
- **Freeze-Drying**
- **Other Methods**

Preparation of Material before Implantation

Histologic and Bacteriologic Controls

**Rigid and Flexible Plastic Prostheses**

- **Introduction**
- **Rigid Prosthesis**
- **Flexible Prosthesis**

Preparation of Flexible Plastic Prosthesis

Surgical Considerations

**Summary**

**Space Requirements**

Depending on the type of preservation to be used, space requirements can be reduced to a minimum of one room, measuring approximately 24 by 16 feet. To lessen possibilities of bacterial contamination, it is desirable to set up a small compartment of about 8 by 10 feet for the manipulation of sterile grafts under ultraviolet light.

For the use of ethylene oxide as a sterilizing agent, the work should be carried out under a hood or in a fireproof cubicle on an adjacent terrace with an exhaust fan for adequate ventilation. This is an important safety measure, because the fumes are highly explosive.

**General Equipment: Sterile or Clean, Depending on the Method of Procurement**

**Glass Flasks.** For the preservation and transportation of the specimens, pyrex glass flasks of about 500 ml. capacity with wide mouth are desirable. The type with rubber sleeve-diaphragm top is adequate. * (See section in freeze-drying process.)

* Fenwal type, obtainable from MacAlaster Bicknell Co., Cambridge, Mass.
Test Tubes. For culture (if sterile technic is employed).

Surgical Equipment. Two Scalpels no. 10 and no. 15 blades, 1 Mayo scissors medium size, 6 hemostatic clamps, 6 mosquito clamps, 1 Metzenbaum scissors, 2 arterial thumb forceps, 2 Harrington retractors, 1 Finocchietto retractor, 2 kidney basins, umbilical tape and towel clips.

Linen. Four towels and four sheets.

Solutions. Ringer's and isotonic Salt. For preservation, a 12 cubic foot deep-freeze unit with supply of dry ice is necessary.

Procurement of Material

(A) Legal Aspects

Depending upon local regulations in different communities, it is generally understood that special permission for the removal of tissues for therapeutic purposes must be signed by the relatives of the deceased. Such a form utilized by the New York Blood Vessel Bank is shown in figure 1 and is supplied with the regular permission for autopsy. The significant increase in the use of these procedures and indoctrination of the public in the importance of cooperation in this regard, will facilitate the fulfillment of legal requirements.

(B) Surgical Technics

Although the removal of blood vessels will be quite similar, whether taken with or without sterile precautions, the former involves several additional requirements in order to avoid contamination.

(1) Under Sterile Precautions. Surgical perforated drums or packs containing instruments and linen must be prepared and sterilized ahead of time. Personnel requirements include two surgeons and a nurse. Strict sterile surgical technic must be followed. The skin is shaved and prepared with Phisohex,* rinsed with water and then with an aqueous solution of benzalkonium chloride, 0.1 per cent, three times.

Sterile sheets are then applied, covering the entire body except the area of incision. This is usually a combined thoracoabdominal incision with a U-shaped thoracic component and an abdominal incision from the xiphoid to pubis. The left thoracic cavity is entered by dividing the ribs at the costochondral junction. The ribs on the right side are similarly sectioned without entering the right pleural space to lessen the possibilities of contamination. A midline abdominal incision is made from the xiphoid to the pubis, passing to the left of the umbilicus. Care is taken not to incise the peritoneum. The surfaces of the left lung, parietal pleura and mediastinum are carefully inspected. A specimen of the pleural fluid is taken for culture. An assistant retracts the left lung and mediastinum to the right. The left diaphragm is incised as close to its insertions as possible and the peritoneum is also retracted to the right for a retroperitoneal exposure of the abdominal aorta. The aorta and its branches are mobilized, sectioning the branches as far as possible from the aorta to facilitate the application of ligatures later when the graft will be implanted. The abdominal aorta at the bifurcation should be handled with extreme care to avoid any traction on the common iliac arteries. The external iliacs are sectioned at the level of the inguinal ligaments. Further incisions are made for resection of femoral or axillary arteries. The carotid arteries can be resected subeutaneously through the chest incision. In all cases a rubber or glass tube is connected to the distal end of each artery and vein in order to facilitate embalm-

* Winthrop Sterns Inc., New York, N. Y.
by the undertaker. The arteries are cleaned of excessive connective tissue but the adventitia must be preserved.

The entire aorta is divided into segments, depending on its future application, in general, (1) entire arch of the aorta, (2) descending thoracic aorta to the diaphragm, (3) abdominal aorta including bifurcation and external and internal iliac arteries and (4) femoral and axillary arteries. If vein grafts are possible, the entire inferior vena cava can be taken through the same incision. Cultures are now taken from the various arterial segments.

Unless the part of the aorta which includes the celiac axis is going to be used as a graft, it is isolated and sent to the laboratory in 10 per cent formalin-Ringer’s solution for studies of fat, elastic fibers and the usual histopathologic sections. A segment of the ascending arch of the aorta is of value in giving further information on the degree of atheromatosis of the vessels.

Although histologic study of segments of the donor’s aorta is not an essential feature in the practical management of a blood vessel bank, it is our belief that information may be obtained which will serve as a guide to delineate possible limitations to the use of arterial grafts.

The grafts are rinsed in Ringer’s solution and placed without further treatment into empty sterile pyrex flasks with rubber tops and transported to the Bank.

The taking of vessels under sterile precautions (as outlined in the preceding section) is usually a nuisance to the pathologist and hence is falling more and more into disuse. It has been found that it is completely acceptable, and is widely practiced, to take the vessels without sterile precautions, so that one can get out of the pathologist’s way, and then sterilize the grafts subsequently by some suitable method.

(2) Procurement Without Sterile Precautions. Only one surgeon and assistant are required for the technical procedure. The same exposure is utilized without cleansing the skin, and draping it is less rigidly practiced. It is important to emphasize, however, that excessive contamination must be avoided, particularly from any gastrointestinal contents and, if possible, the retroperitoneal approach described above should be used. The handling of arteries is the same. However, no bacteriologic cultures are taken at this time.

(C) Evaluation of Donor Material

Three factors must be considered in the evaluation of vascular specimens: (1) age of donor, (2) cause of death and (3) the interval between death and autopsy.

(1) Age of Donor. Although there is some value in establishing a limit on the age of the donor, it is a common observation that there may be little correlation between the donor’s age and the degree of aortic degeneration. A considerable number of persons under 30 years of age have significant pathologic changes in the aortic wall in contrast with some of 50 years or more with surprisingly slight degeneration, especially women. It seems, however, that 45 years is an advisable upper age limit for the great majority of donors. It is important to emphasize at this point, that only a careful pathologic study in each particular case will give a definitive answer to this question.

(2) Cause of Death. If an atherosclerotic process such as myocardial infarction has been responsible for the individual’s death, then his arteries will not, as a rule, be good donor material. An infectious disease in the donor which might possibly be transmitted by a graft to the host should be excluded. Examples are infectious and homologous serum hepatitis, syphilis, generalized sopis and malaria. Patients dying of one of the collagen diseases should be rejected as donors. When death is due to a neoplastic disease other than a brain tumor, the body is not suitable.

The ideal donor is an individual whose death resulted suddenly from trauma. A second favorable source of material is the drug addict whose death followed an overdose of narcotic. The true limitations of donor material will be delineated, however, only by the utilization of grafts from donors, presently considered unsuitable, and by careful follow-up of the recipients.

(3) Interval between Death and Autopsy. It has been shown conclusively by tissue culture
studies that the viability of cells of the arterial wall is highly reduced if the vessels are removed six hours or more after death, and that the incidence of contamination from the intestinal tract is increased. Although, as previously mentioned, bacterial contamination is not considered of fundamental importance any longer, it is evident that damage to the arteries may occur in a few hours if the body is kept at room temperature, particularly during hot weather. Successful transplantation of blood vessels, taken up to 36 hours after death, have been reported and, as in the case of the donor's age, histologic studies may assist in the evaluation of each particular graft. Nevertheless, it is advisable to remove the vessels within six hours after the death of the subject.

**Sterilizing Agents**

In order to sterilize vascular grafts taken without sterile precautions different methods can be used. It is evident that we as yet do not have the ideal agent which is effective against all forms of microorganisms, spores and viruses and at the same time produces minimal histologic and functional changes in the vascular wall. Sterilizing agents can be divided into chemical and physical.

**Chemical Agents**

Two agents which have been tested extensively both clinically and experimentally will be described.

**Ethylene Oxide. Chemical Data.** This is the simplest epoxy compound, H₂CO—CH₂, boils at 10.8 C. and freezes at −111.3 C., is a gas at ordinary temperatures but is quite easily liquefied; is colorless and has a rather pleasant ethereal odor. It is soluble in all proportions in water and in usual organic solvents and can be obtained* as a liquid in low-pressure steel cylinders or in 100 ml. sealed glass bottles. Storage in electric refrigerators should not be attempted, because of the danger of an explosive mixture with air in all proportions from 3 to 80 per cent.

**Toxicity:** Ethylene oxide produces marked irritation of the respiratory system, and careful avoidance of contact with the skin during manipulation, as described in space requirements, in a well ventilated fire-proof cubicle with exhaust fan capable of changing the total air of the room every two to three minutes or under a hood is important. Clinical cases of accidental poisoning in man after industrial use have been described.

**Way of action:** As postulated by Phillips, action should occur by alkylating free-carboxyl, amino, sulphydryl and hydroxyl groups of the protein keratin, replacing the labile hydrogen on each of these groups with an hydroxyethyl radical.

**Method of sterilization with ethylene oxide:** After the vascular segments, taken without sterile precautions and frozen, are in the bank, they are placed in individual sterile pyrex flasks of 500 ml. capacity, or in the special pyrex tubes for the freeze-drying process. Sufficient liquid ethylene oxide to fill the entire container is added and maintained for 30 minutes. This must be done under a hood or fireproof cubicle as indicated previously. If room temperature is above 30 C., the flasks are placed in an ice bath (2 to 4 C.). The vessels must be completely immersed in ethylene oxide during the entire period of sterilization and more should be added if evaporation is too rapid.

The residual ethylene oxide is decanted and the vessels rinsed in sterile Ringer's solution to eliminate any trace of the agent and transferred aseptically to a sterile tube. A segment of the vessel is taken at this moment for histologic studies and bacteriologic cultures for aerobes and anaerobes. If the segment is freeze-dried, the high vacuum in the system will eliminate all of the ethylene oxide and the rinsing process is not necessary.

**Beta-Propiolactone. Chemical data.**

\[
\text{H}_2\text{C}—\text{CH}_2—\text{C}==\text{O}
\]

* From Carbide & Carbon Chemical Corp., Passaic, N. J. also from Distillation Products Industries, Division of Eastman Kodak, Rochester, N. Y.
This substance is a viscous liquid with a specific gravity of 1.149, water soluble to the extent of 37 per cent by volume at 25 C. It is stable in concentrated form up to 10 months, when stored in refrigerator in sealed ampules. *  

Toxicity: It hydrolyzes very rapidly to nontoxic compounds, although it itself is quite toxic. The degradation products of this compound are relatively nontoxic in the concentrations that are necessary here. At 37 C its half-life is approximately 45 minutes. Avoidance of using concentrate solution in contact with the graft is of utmost importance because it is quite caustic. 

Way of action: It reacts with hydroxyl, amino, carboxyl, sulfhydryl and phenolic groups, all associated with proteins.  

Method of sterilization with beta-propiolactone: The vessel taken without sterile precautions is placed in a pyrex flask containing nonsterile:  

- Isotonic sodium chloride: 200 cc.  
- Sodium carbonate (0.2 molar): 3.36 Gm.  
- Phenol red: 10 mg.  

To the flask is now added, slowly and with vigorous stirring at room temperature, 20 cc. of 10 per cent solution of beta-propiolactone made by adding 0.88 Gm of beta-propiolactone to 100 cc. of distilled water at 4 C. which must be maintained under constant refrigeration in order to minimize hydrolysis.  

The flask is placed in water bath for two hours. At the end of this time, the graft is washed in a 0.2 molar phosphate buffer (pH 7.4) and transferred to a storage flask, after taking specimens for pathologic and bacteriologic studies. As the compounds formed after hydrolysis of beta-propiolactone are strongly acid, care must be taken to check the pH of the solution through the phenol red indicator during the sterilizing period. The fact that the degradation products have no appreciable action upon the tissues is a safeguard on the overaction of the drug which is not the case with ethylene oxide.  

Following either of the above methods of sterilization, the grafts are now ready for storage either by the quick freezing method or the freeze-drying technic. 

Physical Agents  

High intensity electrons and gamma-ray irradiation are two physical methods for the sterilization of blood vessel grafts which have been demonstrated, both clinically and experimentally, to be satisfactory. 

Sterilization by High-Voltage Cathode-Ray Irradiation. A high voltage cathode ray machine, such as the one constructed by Dr. Trump at the Massachusetts Institute of Technology, is necessary. 

The segment of artery which has been taken without sterile precautions is placed in a plastic bag made of polyethylene film, sealed by heat at its ends, and is frozen in dry ice. When convenient, (days or weeks later) the grafts are sterilized by placing on a moving belt which carries the frozen packages through a beam of electrons 4 cm. in width, with a total irradiation of 2.5 million Roentgen equivalent physical units (R.E.P.). 

In centers where high-voltage cathode-ray machines of 3 million volts or more are available, this method seems to be useful and simple. It is important to emphasize that this procedure produces drastic alterations of the irradiated tissues unless they are in a frozen state during the entire period of irradiation. After sterilization, the vessels can be maintained frozen in dry ice for long periods of time. 

Sterilization by Gamma-Ray Irradiation. In the recent studies made by Carlson and co-workers, the source of gamma-rays was a tube of cobalt metal 13.5 inches long, 2.3 inches outside diameter and 1.7 inches inside diameter. Gamma-ray irradiation has a bactericidal effect and, at higher doses, also destroys tissue. 

The use of cobalt 60 tubes and the irradiation of vessels, taken without sterile precautions, with 2 to 3 million Roentgen Equivalent Physical units have proven to be satisfactory in its bactericidal action. It presents the advantage, over the previous method, of being less ex-
pensive and easier for transportation. The half-life of the cobalt\(^{60}\) is 5.3 years.*

**Preservation of Vascular Grafts**

The arterial and vein segments obtained under sterile precautions or after sterilization by one of the recommended methods, are now ready for preservation. Two methods which are satisfactory and are relatively simple will be described. Further studies are being made to improve upon these and other techniques of preservation.

**Preservation by Quick-Freezing**

**Principle.** As demonstrated by Tanmann (1898), living matter can be frozen in the amorphous state by very rapid cooling, thus preventing fundamental cell damage of crystallization that occurs in slowly cooled material.

**Technic.** Grafts taken under sterile precautions or sterilized with beta-propiolactone or high voltage cathode ray irradiation are placed in sterile empty pyrex tubes with rubber stoppers and are rapidly immersed in a mixture of equal parts of dry ice and alcohol (\(-75\) C.) or acetone (\(-78\) C.) for 15 minutes and then placed for storage in a deep freezer until the moment of utilization (see preparation of grafts). If the grafts are kept in envelopes of plastic film, they are then frozen in the same containers to avoid further manipulation. Current opinion is that these grafts can be maintained for a period of at least one year. Whether this period can be extended is still to be determined. Sterilization in beta-propiolactone and quick-freezing seems to be one of the most practical methods for preservation of vascular grafts in small hospitals.

**Preservation by Freeze-Drying**

**Principle.** Passage from the frozen state to gas, i.e., sublimation, does not denature the proteins of a tissue if this takes place below a critical temperature which is specific for each protein. Thus, it is possible to store tissues, with preservation of normal histologic structure, in a desiccated state at room temperature, if the water is removed by sublimation. As the rate of drying is in direct proportion to the rate at which heat can be applied to the specimen, all factors being constant, the speed of the drying cycle depends on the maximum temperature at which the tissues can be processed (Clayperon equation). This is determined by its eutectic point which, in the case of blood vessels being below the freezing point, is necessarily long.

A freeze-drying unit consists basically of four elements:

1. A vacuum system generally accomplished by the use of a mechanical oil-sealed rotary pump with or without the attachment of an oil diffusion pump to augment the vacuum.
2. A manifold connection to attach the flasks containing the frozen material to be processed.
3. A condenser or cold trap, kept cold by an external coolant, connected between (1) and (2) to prevent water vapors from reaching the vacuum system which reduces greatly its efficiency.
4. A vacuum gage (McLeod, Pirani or Phillips type) to measure the pressures in the system.

Based on these principles, there are several types of apparatus available on the market and further work is being done in order to simplify them. The model described by Hufnagel, Rabil, and Reed (1954) has proven to be efficient and easy to operate.*

**Technic.** The specimens are frozen in the dry ice-acetone mixture, the container is connected to the system and the mechanical vacuum pump is started. If the vessels have been sterilized with ethylene oxide which freezes at \(-111.3\) C., liquid nitrogen must be used to cool the condenser and to solidify the sublimated ethylene oxide.

If other methods of sterilization are used, the dry ice-acetone mixture has been shown to be sufficient. It is convenient to keep the

---

* Abbott Radioactive Pharmaceuticals (after fulfillment of regulations established by the Isotope Division of the Atomic Energy Commission, Oak Ridge, Tenn.)

* Biological Vacuum, Arlington, Va.
specimens frozen with dry ice-acetone during the early period of processing.

When all the air has been evacuated from the system, the vapor pressure of the tissue water closely approximates the total pressure of the system and becomes an index of its temperature, which will assume the temperature of the environment only after the process of sublimation is over, which usually takes from 6 to 10 hours at a pressure of 1 to 0.5 microns. To achieve such a pressure, careful avoidance of any leaks within the system is indispensable. There are two types of leaks: "virtual" and "actual"; the virtual ones are due to the presence of foreign substances whose vapor pressure is higher than the desired vacuum and can be eliminated by careful cleaning of the entire system. On the contrary, actual leaks must be found by the use of a high frequency coil and then closed with high vacuum seal.

Sealing of large diameter pyrex tubes is difficult and details for the sealing technic must be obtained from the manufacturers of each freeze-drying apparatus. Periodic control of the vacuum by the use of the high frequency coil is necessary, and all specimens that have lost their vacuum must be discarded. It is the general opinion that freeze-dried grafts, maintained under proper vacuum, can be stored indefinitely but an arbitrary period of two years is recommended for clinical use.

Other Methods

Since the pioneer work of Guthrie in 1912, numerous attempts have been made to utilize vascular grafts taken without sterile precautions and fixed with chemical fixatives. Clinical use of arterial homografts preserved in formalin has been reported; experimental work carried out by Peirce and associates with aortic segments fixed in 4 per cent neutral formalin has shown, however, that formalized grafts do not do as well as those preserved by other methods. Reports come from Japan indicating that 70 per cent alcohol is an excellent sterilizing agent and fixative because of its simplicity.

Preparation of Material before Implantation

Material Preserved by Quick-Freezing. The specimens that had been transported from the Bank in dry ice are rapidly thawed by immersing the containing flask in a water bath maintained at 35 C. for 10 minutes. After cleansing the rubber top of the pyrex flask with an antiseptic, the specimen is removed from the flask with sterile precautions and placed in a kidney basin, containing Ringer's solution 500 ml., dihydrostreptomycin 100 mg., penicillin "G" 100,000 units and heparin 50 mg. Antibiotics are used to increase the safety of manipulation and the heparin to lessen the possibility of thrombosis during implantation.

All branches are carefully eliminated with transfusion sutures of no. 5 zero silk on an atraumatic needle. It is useful to test the graft for any possible leakage with a 20 ml. syringe and the above mentioned solution, being extremely careful to avoid any damage to the intima of the graft.

Freeze-Dried Grafts. The vacuum sealed tubes are immersed in Bard-Parker Germicide* or in 5 per cent iodine solution at room temperature for 30 minutes and then the end of the tube, distal to the graft, is opened with a sterile file. The specimen is removed and placed in a kidney basin with saline solution at room temperature for reconstitution. This process usually takes from 30 to 45 minutes depending upon the size of the specimen. It is important to avoid any manipulation during this period as the vascular wall is easily fractured in this state. After reconstitution, the vessel resembles the fresh graft prior to lyophilization. It is now handled in a similar fashion as the graft described in the preceding paragraph.

Histologic and Bacteriologic Controls

Specimens taken immediately after procurement with sterile precautions, or after sterilization by any other method described above, are used for microscopic studies and cultures. As previously mentioned, a circular segment of the upper abdominal aorta at the level of the celiac axis is usually studied. It is convenient to have, at the same time, a segment of the ascending part of the arch of the aorta for control. The specimen is rinsed in sterile saline which is used to inoculate routine bacteriologic cul-

* Bard-Parker Sol., A. E. Aloe Co., St. Louis, Mo.
tures for aerobes and anaerobes, as well as the samples taken from the pleural cavity of the donor during procurement under sterile precautions.

The cultures are observed up to a week after inoculation; the most common contaminants being Staphylococcus aureus, Streptococcus alpha, Bacillus coli and Cl. welchii as well as fungi. All contaminated material must be discarded. It is advisable not to sterilize the vessels for a second time, as the action of chemical agents, in particular ethylene oxide, have been shown to produce extensive damage to the arterial wall by prolonged immersion.

Although it is not absolutely essential to carry out histologic studies in the practical management of a blood vessel bank, ideally such studies are desirable as they are the only method of evaluating grafts prior to implantation.

The pathologic studies are carried out by fixation of arterial segments in 10 per cent formalin-Ringer’s solution. Frozen sections are made and stained with Sudan black B which reveals fat and deposition of complex lipids. Other segments are imbedded in paraffin for routine staining with hematoxylin-eosin, Vorhoeff’s stain for elastic fibers and Masson’s trichrome stain for smooth muscle cells and connective tissue.

Since rupture and dislocation of elastic fibers of the media have proven to be the main reason for failure of aortic homografts, a careful study of the elastic fibers is made. Fat deposition in the subintima and atherosclerotic plaques are reasons for discarding the vessels. It is difficult at the present time to give exact criteria for histologic selection of the most suitable specimens. It is advisable, however, to utilize only those with a normal histologic picture and with well-preserved elastic fibers and relatively small amounts of fat in the intima and subintima.

Rigid and Flexible Plastic Prostheses

The difficulties of procurement and preservation of vascular grafts in small communities have led to an increased interest in the replacement of vascular segments by nonbiologic products, which could be easily prepared to any required shape or size. The human recipient’s reaction to these prostheses, constructed from several different materials, is still unknown over long periods of time. Early results seem, however, satisfactory when employed under proper conditions. The prosthesis may be classified into two groups: rigid and flexible.

Rigid Prostheses

Of many different materials that have been utilized in the construction of plastic tubes, methyl-methacrylate (Lucite*) has been one which has yielded the best results.

One of us (C. H.) has summarized the necessary criteria for the selection of rigid plastic prostheses as follows:

1. The material employed should be relatively biologically inert.
2. It should have adequate strength.
3. It must resist clotting.
4. The internal surface of the prosthesis must be extremely smooth.
5. The junction between the vessel and the prosthesis must also be extremely smooth.
6. The anastomosis between the tube and the vessel must be effected by a method which does not produce necrosis of the arterial wall at the point of junction. Tubes made out of methylmethacrylate and anastomosed with rings made of Nylon with fixation by multiple point pressure on the circumference of the arterial wall, thus avoiding circumferential pressure, have been satisfactory in selected locations, as the aorta, where the variation in diameter of its different segments is relatively slight. There are two main difficulties in the use of rigid prostheses: (a) Because of the rigidity of the tube, it is impractical where there is flexion of the vessel or where there are branches of variable size, shape and angulation. (b) As there must be a close approximation between the size of the prosthesis to the vessel above and below, a large selection of tubes of different diameters and lengths must be available.
7. The potential “cul de sac” which is present between the fixation ring and the end

*DuPont de Nemours & Co., Wilmington, Del.
of the prosthesis should be obliterated to prevent thrombosis.

Flexible Prostheses

Because of the limitation of rigid types of plastic prostheses, many flexible materials have been used beginning with the work of Voorhees, Jaretzki, and Blakemore with Vinyon "N" cloth. Several materials have been successfully implanted in man.

1. Vinyon “N” cloth, 27 denier, 144 by 90 strands per square inch.*
2. Woven Nylon, 241 F, 277 by 240 strands per square inch.†
3. Orlon 81 fiber, 75 by 100, or 100 by 100 weave (Hufnagel).‡
4. Daeron cloth.§

Preparation of Flexible Plastic Prostheses

The tubes are constructed by sewing the fabric, preferably on a sewing machine, with the same thread of which the fabric is made and with a very fine needle (no. 8, Singer). Straight tubes and branched tubes are made, including Y bifurcations of different lengths and diameters, flaring the ends slightly in order to make a cuff. Seamless tubes and some of the new types of cloths are now being studied.||

Prefabricated Nylon tubes were recently devised by Sterling Edwards. A portion of the tubes is crimped in order to permit flexibility where the defect in an artery is adjacent to a joint. However, at the present time the tube does not have longitudinal stretch. It is joined to the end of the artery by the usual method of arterial suture. A number of successful clinical cases have been described.

Due to present difficulties in obtaining fabrics with known biologic action in the recipient, it is important to immerse the cloth in a jar with 10 per cent aqueous solution of a detergent¶ for 12 hours in order to eliminate oil and foreign matter which accumulates during processing. The cloth should be rinsed at least three times in distilled water or saline.

For sterilization, each particular fabric must be handled individually in respect to the method used. Orlon type material and Daeron should be autoclaved. Nylon and Vinyon “N” on the contrary, must be sterilized by boiling for 10 to 15 minutes.

Surgical Considerations

The prosthesis is sutured to the blood vessel by the usual method of arterial anastomosis with an over and over suture which, in the instance of arteriosclerotic vessels, is preferable to an evertting mattress suture. The needle should pass from the outside of the prosthesis to the lumen and then through the artery from inside out in order to maintain apposition of the intima to the media of the sclerotic vessel.

After the prosthesis has been placed and the blood allowed to enter the tube, some bleeding may occur, depending on the type of cloth that is used. Voorhees and Blakemore have avoided this difficulty with Vinyon “N” by predlotting the tube, using the recipient’s blood so that fibrin would be deposited in the interstices of the cloth and prevent excessive bleeding. It is important to express all of the clot from the lumen of the tube before implantation.

In general, all these prostheses are more difficult to suture than arterial homografts, because of absence of elasticity of the cloth. At the present time, diagonal weaves are being studied in order to increase the elasticity of these fabrics.

The prosthesis should be fitted precisely to the defect because additional length will result in buckling and thrombosis. If more than three anastomoses must be performed then the use of a prosthesis may be associated with serious difficulties.

Summary

Recent advances in the diagnosis and treatment of segmental lesions of large blood vessels have created a need for storage of arterial and venous grafts and plastic prostheses. It has been the purpose of this paper to describe in some detail the problems and technics of procurement, sterilization, preservation and util-

---

* Union Carbon and Carbide Co., New York, N. Y.
† Stehli Co., Inc., New York, N. Y.
‡ Cadillac Textiles, New York, N. Y.
§ A. Lamport and Bros., New York, N. Y.
|| C. P. Braining Corp. Central Valley, N. Y.
¶ Alconox-Wetting Agent, Alconox, Inc., Jersey City N. J.
ization of arterial and venous grafts. Emphasis has been placed on the need for bacteriologic and histologic safeguards in the maintenance of a blood vessel bank. A brief section was devoted to the current status of plastic prostheses.

Finally, it is of considerable importance to recognize the fact that this is a new field which is being subjected to intensive study and that advances and modifications will be forthcoming. Therefore, this paper represents an interim rather than a final report.

COMMITTEE MEMBERS

Jere W. Lord, Jr., M.D., Chairman

Robert E. Gross, M.D.

Charles A. Hufnagel, M.D.

Abel A. Lazzarini, Jr., M.D.

SUMMARIO IN INTERLINGUA

Progressos recente in diagnosto e tractamento de lesiones segmental del major vasos sanguineo ha resultate in le necessitate de immagazinar graffos arterial e venose e prostheses plastic. Le objective del presente articulo es describer in detalio le problemes e technica del procuramento, sterilisation, preservation, e utilizacion de graffos arterial e venose. Es subliniate le necessitate de mesuras protective bacteriologic e histologic in le mantenentia de un banco de vasos sanguineo. Un breve section del articulo es dedicate al stato currente del prostheses plastic.

Finalmente, il es del plus alte importantia recognoscer que il se tracta hie de un nove campo que es le objecto de intense studios de manera que progressos e modificationes es a expectar. Consequentemente le presente articulo es un reporto interime plus tosto que final.

REFERENCES


Report of Committee on Blood Vessel Banks: Recommendations for the Establishment and Maintenance of a Blood Vessel Bank
JERE W. LORD, JR., ROBERT E. GROSS, CHARLES A. HUFNAGEL and ABEL A. LAZZARINI, JR.

_Circulation_. 1956;13:270-280
doi: 10.1161/01.CIR.13.2.270

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1956 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/13/2/270

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to _Circulation_ is online at:
http://circ.ahajournals.org//subscriptions/