HOMOGRAFTS AND THE BONE BANK

J. J. Herbert, Aix-les-Bains, France

From the Rheumatism Centre of Aix-les-Bains

The idea of preserving bone for use in surgery is not new. Carrel in 1912 recorded that two Frenchmen, Tüfner and Magitot, had obtained good results by implanting bone and cartilage that had been refrigerated for several months. But, because all the investigations which followed the 1914 war tended to show that homogenous and heterogenous grafts would not generally "take," the idea gained very little root in France. The many successful cases reported by Ollier (1867), Macewen (1912) and others were considered exceptions, and it was thought that an individual could be grafted only with his own bone. As early as 1920, however, Leriche had successfully transferred unpreserved heterogenous bone and also human bone preserved in spirit. But in the main it was the orthopaedic surgeons of New York—particularly Wilson (1947)—who first perceived the advantages of refrigeration, and they greatly advanced the use of preserved bone. It is now known that there is little difference in the behaviour of bone grafts in the body, whether they be autogenous, homogenous or even heterogenous.

EFFECT OF COLD ON BODY TISSUES

In preserving bone tissue it is of paramount importance to protect cellular integrity. Refrigeration engineers have shown that this is best ensured by rapid freezing. If the cooling is slow the water and salts separate, the water freezes, and cells are destroyed by the formation of large ice-crystals. If on the other hand cooling is rapid, separation is prevented, the crystals are smaller, and cellular destruction either does not occur at all or is negligible. Histological examinations made for me by Dr Gerbay suggest that the preservation of cellular integrity depends not only upon the rapidity of the freezing process itself but also on the speed with which it is instituted. For example, if less than half an hour elapses before freezing of the bone is begun, cellular integrity is almost completely maintained; but an interval of more than an hour will cause the destruction of many cells. It is suggested that under the above conditions the tissues are not killed by the low temperature but live again when they are thawed. (In this connection there are interesting reports by commercial fisheries that fish, frozen on leaving the water, can live and swim again months later if they are carefully thawed.) Experience has shown that the best temperature at which to freeze bone lies between −30 degrees and −40 degrees Centigrade.* At lower temperatures an outer layer of the bone is instantaneously frozen but the central parts lose their heat much more slowly.

EFFECT OF COLD ON BACTERIA

It is known that pathogenic bacteria thrive best in a temperature of about 37 degrees and that their resistance to cold varies greatly. Bacillus pyocyaneus, for instance, can resist even −75 degrees (Darsonval and Charvon 1934). Mossu (1934) reported that B. tuberculosis has been plunged into liquid air at −200 degrees without being damaged; and Turner (1938), working on rabbits, showed that the treponema can regain its mobility and virulence even after four months' preservation at −78 degrees. The present writer has preserved colonies of staphylococci for several months at −30 degrees; there was no evidence that their virulence decreased, and growth began again when normal conditions were restored. On the other hand the vitality of B. coli, B. typhus and B. prodigiousus is much reduced by severe cold; and all bacteria, even if they are unharmed, cease to grow when in contact with cold. It is

* Throughout this paper temperatures referred to are on the Centigrade scale.
clear from these observations that although freezing may inhibit the growth of a microorganism it cannot be relied upon to render a graft aseptic; rigid aseptic precautions must be observed in taking and storing grafts, and careful bacteriological control is essential.

**BEHAVIOUR OF A GRAFT PRESERVED BY FREEZING**

It is obviously important to know how a frozen graft will behave after thawing and implanting in the recipient tissue. Ollier (1867), Heitz-Boyer (1918), Leriche and Policard (1928) in France; Macewen (1912) in Great Britain; and Phemister (1930), Campbell (1939), Ghormley and Stuck (1934), Albee (1940), and Inclan (1942) in the United States of America believe that any bone graft dies completely and is replaced by new bone which creeps in from the host. Among other writers, Leriche (1930) believes that the bone cells do not die and that the grafted bone is able to develop partly by its own efforts and partly by those of the host. Leriche thinks, moreover, that the bone graft can serve indefinitely as an internal splint without being replaced by new bone, and he speaks of instances of ivory grafts eighteen years old. I have myself observed a patient who had had a massive graft inserted along the lumbo-dorsal spine twenty years previously, and that graft according to pathological examination was still intact when I operated a second time. I mention this case particularly because refrigeration has enabled us to use amputated bones, which can be of very great size and which I have found most useful in dealing with massive spinal grafts. An entire tibia for example can be stored for later use.

My observations have led me to believe the following: 1) sometimes the graft dies and is replaced in its entirety by new bone; 2) sometimes the graft dies only partly with replacement to that extent; 3) sometimes the graft dies entirely and is only partly replaced; 4) sometimes the graft dies and is not replaced but remains as an inert internal splint. Although in the course of subsequent operations I have observed that the bone graft may bleed—an evident sign of vitality—and although in children I have noticed growth in the length of bone grafts—particularly those inserted in the spine—most of the knowledge of the process of replacement depends on radiological observations. At the end of about two months the grafts appear to have been decalcified; about the fourth month invasion by new bone is in progress, and at the end of about six months replacement appears to be complete.

**PRACTICAL ASPECTS OF THE BONE BANK**

**Obtaining the grafts**—In practice we have mostly taken our bone from amputated limbs, but it can equally well be taken from cadavers directly after death. The donor should be known to have had a negative Wassermann reaction, to have had no blood dyscrasia, and to have been free from disease of the bones. The experiments of Brooks and Hudson (1920) on animals show that it is theoretically preferable for the donor to be (or to have been) young. But, in the present writer's experience, grafts taken from elderly subjects are satisfactory. Neither the blood group nor the Rhesus factor is of any importance.

**Storing the grafts**—The American practice is to put the graft into a steel tube which is then itself sealed inside a sterilized bottle. It is argued that better asepsis is so achieved; but in the writer's opinion it has the grave defect of lessening the speed of freezing. I believe that one properly sealed tube is an effective protection, and have never had a graft become septic. I put my grafts into sterilized tubes, which are hermetically sealed with a layer of rubber and then labelled and dated. The graft must be transferred very rapidly to the tube in order to prevent contamination by air-borne organisms and deterioration of the bone tissue. The tubes are immediately placed in the freezing chamber of the refrigerator and later transferred to the preserving compartment. There is, in my opinion, no limit to the time that the graft can be safely stored. I have, without subsequent cause of regret, used grafts that had been preserved for more than five months.
FIG. 1
Equipment for storing bone and blood. The bone bank (left) has two compartments—one for the initial "quick freeze" at −35°C, and the other for storage at −20°C. The blood bank (right) has a separate compressor. Switches, thermometer dials, thermostats, pilot lights and alarm lights are grouped on a single panel.

FIG. 2
Figure 2—The sealed tubes containing bone grafts are suspended in liquid. The photograph also shows the blood bank's separate entrance. Figure 3 (inset) shows bone in a sterile glass tube, sealed with rubber and labelled, ready for refrigeration.
Technical details—Early American and other investigators, including myself, used an ordinary refrigerator capable of creating a very low temperature. The tubes containing the bones were placed in this refrigerator at a temperature of \(-30\) degrees to \(-35\) degrees. But since still air is a very poor conductor the freezing process was slow. Sicard and Binet (1950) improved the apparatus by arranging that the material to be frozen was placed very close to the icing chamber. Theoretically the rate of freezing (in hours) is the figure obtained by multiplying the difference between the temperature of the refrigerant and that of the specimen by the distance which separates the two, and also by a constant which depends on the refrigerant and the specimen. Among other factors, the rate of freezing depends upon what elements are in contact. It is known that freezing occurs much more rapidly if conduction is by a fluid than if conduction is through air. In practice the best results are obtained if the tubes containing the specimens are plunged into a mixture which remains liquid at the low temperature required. A mixture of ethyl glycol and water is suitable for this purpose. The apparatus used by the writer has two compartments: in one part the temperature is maintained at \(-35\) degrees and in the other at \(-15\) degrees. The graft is sealed in the tube as quickly as possible and plunged into the glycol mixture in the colder part of the apparatus; after a few minutes the tube is moved to the less cold compartment, where it is preserved and can remain indefinitely (Figs. 1 to 3).

**OPERATIVE TECHNIQUE AND RESULTS**

When the size of the intended graft has been estimated, an appropriate piece of bone is taken from the bank and is placed in a physiological solution containing penicillin. The graft bed is prepared, and the graft is cut to fit and placed in position with some small cancellous fragments to serve as "cement."

**TABLE 1**

<table>
<thead>
<tr>
<th>Spinal fusion</th>
<th>Other bone grafting operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idiopathic scoliosis</td>
<td>Arthrodesis of hip</td>
</tr>
<tr>
<td>Paralytic scoliosis</td>
<td>Pseudarthrosis of hip</td>
</tr>
<tr>
<td>Tuberculous disease</td>
<td>Sacro-ilia arthritis</td>
</tr>
<tr>
<td>Vertebral osteotomy</td>
<td>Radio-carpal arthrodesis</td>
</tr>
<tr>
<td>Fracture of spine</td>
<td>Reconstruction after excision of</td>
</tr>
<tr>
<td>Sciatica</td>
<td>bone tumours</td>
</tr>
<tr>
<td>Lumbar</td>
<td>Non-union of fractures</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>Mal-union of fractures</td>
</tr>
<tr>
<td>Dural compression</td>
<td>Lengthening of femur</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
</tr>
</tbody>
</table>

To date, eighty-seven stored grafts have been used on eighty-two patients. Eighty of the grafts were homogenous and seven were heterogenous. Homogenous grafts are of course easier to obtain than heterogenous grafts, especially if cadavers are used, for then as many as thirty to forty grafts can be obtained at once; moreover, the asepsis of heterogenous bone is apt to be uncertain. (Heterogenous bone has been found to "take" well, despite the foregoing theoretical risk.) In cases where autogenous grafts have been combined with homogenous grafts, no difference in progress between the two has been observed, and this is true also for the other combinations of homogenous, heterogenous and autogenous bone.

A list of the conditions for which grafting with stored bone was done is given in Table 1. Cases of scoliosis and of paraplegia with Pott's disease are illustrated in Figures 4 to 10.

* Since this list was first prepared the total has been increased by more than thirty cases of grafting with preserved homogenous bone.
Case 1—Paralytic scoliosis, before correction.

Case 1. Figure 5—Immediately after operation. The graft extends from the sacrum to the mid-thoracic level; it is held in position with wire and packed round with bone chips. Figure 6—Thirteen months after operation. The graft has been partly resorbed, but is still perfectly in position, and correction has been maintained.
Case 2—Radiographs of a case of paraplegia with Pott's disease. Laminectomy was done at the level of the curve; two massive homogenous grafts were inserted, their ends fixed well into the spinous processes and additionally secured with wire. Paraplegia improved and finally disappeared after operation; spinal correction was satisfactorily maintained.

Case 3—Radiographs of a sixteen-year-old boy with scoliosis. Figure 9—Before operation. Figure 10—Postoperative anterior and lateral views. Correction is maintained with two massive homogenous grafts firmly fixed with wires which pass under the vertebral laminae. The space between the graft, the laminae and the spinous processes has been filled with cancellous bone. One of the two grafts is almost an entire tibia, the other is part of a tibia.
In conditions such as scoliosis—particularly paralytic scoliosis—where massive grafts are necessary, the bone bank, providing as it does very long pieces of cortical bone and abundant cancellous bone, has proved of the greatest value.

Observation of these eighty-two grafts during their period of incorporation has not brought to light any defects attributable to methods of obtaining or storing the bone. In five cases the graft fractured, but the cause was in each instance due to insufficient support of a very long graft. Where such an incident has occurred it was sufficient either to immobilise the part for a little longer or to place a small amount of cancellous bone around the fracture. I am so satisfied with stored bone as a grafting agent that its use is now my usual practice and I no longer entertain the idea of any other source of bone for my grafts.

**SUMMARY**

The technique of storing bone by refrigeration is described and the following advantages are indicated: 1) A patient avoids a second wound and the loss of bone from some other part of the body; this is a very important matter for patients in whom poliomyelitis has affected both legs. 2) Almost unlimited bone is available to the surgeon and he is consequently able to insert very large grafts and so obtain better results.

**REFERENCES**


Darsonval and Charvon (1934): In Techniques de conservation des Dentées par M. Piettre.


Herbert, J. J. (1949): De l'utilisation des os conservés comme greffes. La banque d'os. Mémoires de l'Académie de Chirurgie, 75, 60.


