Xenogeneic pericardium as a dural substitute in reconstruction of suboccipital dura mater in children

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A 5-year experience with the glutaraldehyde-stabilized freeze-dried radiation-sterilized calf pericardium used as a dural substitute is reported. The structure of pericardium xenograft is compared with other collagenous materials used for duraplasty (allogeneic fascia lata and dura mater) by light and electron microscopy. The special neurosurgical techniques involved in using pericardium xenografts in the reconstruction of suboccipital dura mater in children are presented in detail.

KEY WORDS • dural substitute • xenogeneic pericardium • allogeneic graft • xenogeneic graft • posterior fossa • children

Various collagenous tissues or artificial materials are used to reconstruct dura mater. In our department of neurosurgery, allogeneic fascia lata has been most commonly employed. Our experience with 1061 freeze-dried allogeneic grafts of fascia lata in neurosurgery was published in 1977 by Klen et al. Because of lack of allogeneic fascia lata and dura mater, Hušek and Klen, both from the Tissue Bank of Charles University, Hradec Králové, proposed using xenogeneic glutaraldehyde-stabilized freeze-dried radiation-sterilized pericardium as a dural substitute. In 1971, Ionescu et al, first introduced this glutaraldehyde-stabilized pericardial calf xenograft to human cardiac surgery, in which bovine pericardium was mounted as a three-cusp valve onto a Dacron-covered titanium support frame.

Materials and Methods

Preparation of Pericardium

The pericardium is procured from 1- to 4-month-old specially fed calves slaughtered under veterinary supervision. Tissue is harvested under clean but not sterile conditions immediately after death. The pericardium is rinsed in a sterile physiological saline solution and the subserous fat is removed complete with vessels and nerves. The remaining fibrous membrane is stabilized with glutaraldehyde. Two different stabilization procedures have been applied. Early in its use, the membrane was stabilized in 2% glutaraldehyde for 2 hours at room temperature. Since 1985, the method recommended for stabilizing valvular heterografts has been preferred, using 0.3% glutaraldehyde for 14 days at room temperature. After removal of the remaining glutaraldehyde by repeated washing in sterile physiological saline solution, the tissue is freeze-dried.*

Until 1987, the tissue was rolled on a polyamide texture carrier and freeze-dried in glassware according to the method elaborated by Heger. Recently, it has been freeze-dried flat and subsequently wrapped in plastic bags. Different sizes of pericardial grafts are available for clinical use. Sterilization is performed predominantly by gamma radiation at a dose of 25 kGy. Ethylene-oxide sterilization in peel-sterilization packs† offers an alternative procedure (Fig. 1).

Laboratory Studies

The structure of various collagenous tissues has been described previously. The main differences are illustrated in Fig. 2. Collagen fibers are arranged in parallel in allogeneic fascia lata while allogeneic dura mater has a laminar pattern with bundles of collagen fibers orientated in parallel; however, the direction of the fibers differs in each adjacent lamina. In the xeno-

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* LZ 9 freeze-drying equipment manufactured by Frigera Kolin, Czechoslovakia.
† Peel-sterilization packs available from Wipak Medical, Finland.
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**FIG. 1. Photograph of ethylene oxide-sterilized freeze-dried pericardium xenograft.**

**TABLE 1**

Summary of 160 pericardium duraplasties placed in adults and children, 1983 to 1988

<table>
<thead>
<tr>
<th>Location</th>
<th>Adults</th>
<th>Children</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>posterior fossa</td>
<td>32</td>
<td>43</td>
<td>75</td>
</tr>
<tr>
<td>convexity</td>
<td>53</td>
<td>6</td>
<td>59</td>
</tr>
<tr>
<td>anterior fossa</td>
<td>5</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>middle fossa</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>spinal dura</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>miscellaneous*</td>
<td>12</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>total cases</td>
<td>110</td>
<td>50</td>
<td>160</td>
</tr>
</tbody>
</table>

* Five grafts in transnasal approaches, five in frontal sinuses, and two in aneurysmal wrapping with biological adhesive.

**FIG. 2. Diagram showing the basic organization of collagen fibers in graft material. The collagen fibers run parallel in the fascia (upper), form laminae with crossing layers in the dura mater (center), and have a felt-like orientation in the pericardium (lower).**

Xenogeneic calf pericardium, the bundles of collagen fibers criss-cross to form a felt-like structure. Microfibrillar and amorphous varieties of elastic fibers are also present (Fig. 3).

The mechanical properties of xenogeneic pericardium have been investigated extensively because of its use in cardiac surgery.6,7 In preparation for clinical application, the physical properties of various collagenous tissues, suture materials, and needles have been studied experimentally.16 Various materials (collagenous or artificial) were sutured into fresh dura and the tissues were stretched between two glass cylinders 50 mm in diameter. Water was poured into the superior glass cylinder and air was insufflated into the inferior cylinder to test the sutures, suture materials, needles, and quality of materials, and whether they were watertight. The atraumatic 4-0 USP suture used with half-circle 17-mm cutting, reverse cutting, tapered, and diamond needles was best.† To perform watertight closure of the most pliable tissue (frozen allogeneic fascia lata), interrupted or continuous suture could be used, but for the most rigid tissue (such as xenogeneic pericardium) a continuous suture is best. An absolutely watertight suture with experimental duraplasty was impossible.16

Pericardium grafts were introduced in clinical practice in 1983 after Klen and coworkers performed experiments with this material in rabbits (unpublished data). Grafts implanted subcutaneously showed encapsulation without evidence of acute inflammatory response or elimination.

**Clinical Application**

**Neurosurgical Series**

During the 40 years from 1948 to 1988, 347 bilateral suboccipital craniectomies and posterior atlantectomies were performed in children aged up to 15 years treated at the department of neurosurgery of Charles University, Hradec Králové. The diagnosis included: medulloblastoma (122 cases), cerebellar astrocytoma (120 cases), brain-stem tumor (mainly astrocytoma) (41 cases), aqueductal stenosis (20 cases), ependymoma (19 cases), pinealoma (three cases), and miscellaneous (22 cases). From 1948 to 1971, the operations were performed by Professor Petr. Fifteen cases were treated with dura sutured, 44 with the dura left open, and 288 with dural reconstruction. The majority of grafts were prepared in the institution's Tissue Bank and included

† Diamond needles manufactured by Ethicon Ltd., Edinburgh, Scotland; B. Braun Melsungen AG, Material Clinico Sa, Barcelona, Spain.
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211 allogeneic grafts (183 of fascia lata, 22 of dura mater, four of pericardium, and two of amnion) and 56 xenogeneic grafts (43 of pericardium and 13 of fascia endothoracica). In clinical practice the authors did not find any difference between allogeneic and xenogeneic grafts with respect to the healing process or to the need of postoperative shunts for hydrocephalus or pseudomeningocele.

Pericardium was first used in reconstruction of suboccipital dura mater in children; later it was also used in other locations and in adults. By the end of July, 1988, 160 grafts had been used (Table 1). In the repairs, the pericardial edges were buried intradurally and continuously sutured with atraumatic needles.

Complications

Morbidity. In 43 children, two reoperations were performed for infarction of residual tumor with incision and partial suture of the graft.

Infection. An 11-year-old girl had a posterior fossa contusion and laceration of the neck. Healing was complicated by an extradural infection (Pseudomonas aeruginosa). The tip of the graft protruding from the wound was resected and the wound healed. The pericardium proved to be an effective barrier against intradural spread of infection.

Mortality. Four children died from their primary tumor without complications from the graft. The case of a fifth child who had an unusual clinical course is summarized briefly. This 11-year-old boy underwent surgery for medulloblastoma 4 months before his present admission. Dural reconstruction was performed with xenogeneic pericardium. Broad-spectrum antibiotics were given prophylactically. His course of x-ray therapy was repeatedly interrupted, and he later developed anemia. He underwent repeated punctures of pseudomeningocele for tumoral and bacterial (Enterococcus) meningitis and eventually died of these complications. Autopsy specimens demonstrated that tanning with 2% glutaraldehyde had dramatically reduced the biological properties of the collagen to promote the ingrowth of surrounding tissue into the graft. The host tissue could grow only into the filamentous edges and fissures of the graft and into perforations produced by the suturing needle (Figs. 4 and 5).

Discussion

Calf pericardium was introduced in 1971 as cardiac valve substitute in human cardiac surgery. This is the first report of its use as a dural substitute. The authors suggest that allogeneic dura mater could be considered an optimal material for duraplasty. Nevertheless, in some situations it is advisable to use fascia lata for its pliability or in other instances pericardium for its...
firmness and strength. Mineralization of glutaraldehyde-stabilized connective tissue represents the most common cause of dysfunction in cardiac valvular bioprosthesis; however, some observed calcifications in our cases were beneficial for reinforcing the duraplasty. The pericardium proved to be a good dural substitute in posterior fossa surgery as a permanent encapsulated prosthesis. Similar results were obtained in an experimental study by Gallo, et al., who used glutaraldehyde-treated porcine and bovine pericardium to close defects in the diaphragm of dogs. Except for the two patients mentioned above, all of our 160 patients were cured without complications. Broad-spectrum antibiotics were administered prophylactically. The density of the grafts facilitated postoperative monitoring by ultrasonography or computerized tomography.

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