Repair of spinal dural defects

An experimental study

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The search for an ideal substance for duraplasty has stimulated clinical and experimental investigations. To date a large number of materials have been employed for dural repair, although there is as yet no unanimity regarding the ideal material. Most of these studies have been concerned with cranial dura, and spinal duraplasty has received less attention. This study was designed to examine the repair of spinal dural defects in the dog. The materials chosen for this experiment were autologous fat, a polyester fiber mesh (Mersilene) and silicone-coated Dacron (Dura Film). Nineteen dogs were used in this study. Following lumbar laminectomy and the excision of elliptical pieces of dura (1.0 × 0.5 cm) at three noncontiguous levels, each of the defects was repaired using one of the three materials. Groups of animals were sacrificed at each of 3, 6, 12, and 24 weeks after dural repair. The lumbar region was removed en bloc and prepared for histological examination. Repair of the dural opening was achieved in all cases. The polyester fiber mesh was quite effective for dural repair, serving as a scaffold through which a neomembrane grew and united the dural edges. The results with autologous fat were similarly favorable. On the other hand, results with silicone-coated Dacron showed encapsulation by connective tissue, with the ventral aspect of the graft frequently compressing the underlying cord.

KEY WORDS · dura mater · dural substitute · fat autograft · polyester · silicone · spinal cord

The search for materials to close dural defects extends back to the latter part of the 19th century. In part, the variety of materials studied is due to divergent opinions as to the purpose of a dural substitute, even as to whether a substitute is necessary. Differences in criteria for the ideal material have contributed to the lengthy list of potential dural substitutes studied.

The vast majority of data is derived from reports of cranial dural repair, with a noticeable lack of information on spinal dural repair.

This present study was designed to examine the repair of spinal dural defects in the dog. The materials chosen for this experiment were autologous fat, a polyester fiber mesh (Mersilene), and a silicone-coated Dacron (Dura Film). Autologous fat was chosen because previous reports have described its efficacy in reducing postoperative cicatrix and because one of us (F.H.M.) has used this material to successfully repair a pseudomeningocele in the lumbar region in several patients. The polyester mesh would appear to serve as a scaffold, allowing connective tissue fibers to grow between fibers of the mesh, uniting the dural edges. Silicone-coated Dacron was chosen because it is a material commonly used in the repair of dural defects.

Materials and Methods

Surgical Procedure

Nineteen mongrel dogs weighing 10 to 15 kg were used in this study. A midline vertical incision was made in the lumbar region and the paraspinous musculature stripped subperiosteally to expose six laminae. Laminectomies were performed in each of three noncontiguous levels with the aid of a surgical microscope.

Excision of an elliptical piece of dura (1.0 × 0.5 cm)
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Fig. 1. Left: Cross section of a lumbar vertebra 24 weeks following repair of a dural defect with autologous fat. H & E, bar = 5.0 mm. Right: Photomicrograph from the same section illustrating neodural membrane uniting the edges of the dura. H & E, x 17; bar = 500 μ.

was performed at each of these sites. At the same time that the dura was opened, the arachnoid membrane was also incised and the escape of cerebrospinal fluid (CSF) was observed in each case. The dural defects were repaired using autologous fat, silicone-coated Dacron (Dura Film), and polyester fiber mesh (Mersilene). Each of these materials was sutured to the edges of the dural opening using a 4-0 Vicryl suture. Following this procedure, autologous fat was placed over the graft sites according to our previously described technique.52 Five animals were sacrificed at each of 3, 6, and 12 weeks and four animals at 24 weeks following repair of the dural defect.

Histological and Histochemical Techniques

The lumbar region of the vertebral column was removed en bloc and placed in 10% neutral buffered formalin for 48 hours. The specimens were decalcified in 5% nitric acid, processed for paraffin embedding, and sectioned at 40 μ. Sections were examined histologically with hematoxylin and eosin stain (H & E). The colloidal iron-periodic acid-Schiff (PAS)-Bismarck brown-picric acid technique was used to demonstrate connective tissue fibers and glycosaminoglycans.

Results

Repair of the dural opening was achieved in all cases. By 3 weeks, a neodural membrane had formed regardless of which material was used. Proliferation of connective tissue dorsally was limited by the placement of fat over the graft sites.52 At only one laminectomy site (Mersilene graft, 12 weeks) was the dura bound to the overlying musculature by connective tissue with no interposing fat.

The appearance of autologous fat grafts was similar for all time groups (Fig. 1). A neodural membrane of dense regular connective tissue fibers, equal in thickness to normal dura, effectively closed the dural defect. While loose connective tissue was also found interspersed within or surrounding the fat, the graft was never totally replaced by connective tissue.

Mersilene induced formation of an organized continuous membrane only slightly thicker than the dura (Fig. 2). The neodural membrane was formed by proliferating connective tissue weaving through and around the mesh fibers, thus uniting the dural edges. Only in the one case mentioned above did scar tissue bind the dura to overlying structures.

At some fat and Mersilene graft sites, a slightly thickened connective tissue membrane involved the disrupted arachnoid membrane. This thickened area was composed of cellular connective tissue, loosely arranged and vascular, limited to the region of the dural incision. There was no difference in the scar tissue, whether examined after 3 or 24 weeks. In addition, there were no indications of arachnoiditis.

The neodural membrane at Dura Film graft sites was made up of a dense regular connective tissue membrane involving the disrupted arachnoid membrane. This thickened area was composed of cellular connective tissue, loosely arranged and vascular, limited to the region of the dural incision. There was no difference in the scar tissue, whether examined after 3 or 24 weeks. In addition, there were no indications of arachnoiditis.

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sites, the encapsulated graft lay directly in a concave deformity on the dorsal aspect of the spinal cord (Fig. 4). In nine other cases, the connective tissue bulge and spinal cord were separated, but the spinal cord was irregular in shape, corresponding to the overlying mass.

Discussion

Early investigations of materials for dural replacement were primarily concerned with meningoencephalocoele adhesions and possible resultant posttraumatic epilepsy.
Repair of spinal dural defects

By the turn of the century, gold foil, \(12^{13}\) thin rubber tissue, \(12^{13}\) platinum foil, \(40\) and silver foil \(49\) had been implanted in areas of the cortex in an attempt to reduce cicatrix formation between the cortex and meninges. Although the list of materials for duraplasty continues to expand, no one substance (either organic, inorganic, metallic, synthetic, or any miscellaneous material) has received universal acceptance (Table 1).

Significant observations were made during the first half of the 20th century regarding regeneration of the meninges. \(35^{56}\) Experimental studies on the regeneration of the meninges led to the conclusion that the dura mater would repair itself, regenerating without adhesions to surrounding tissue, provided the pia-arachnoid membrane was not disrupted. Violation of the integrity of this membrane would result, on the other hand, in the formation of dense adhesions. \(35^{56}^{62}\) Penfield \(45^{46}\) believed that, if injury occurred to the brain parenchyma and pia-arachnoid membrane, adhesions formed no matter what type of covering was used, although there was a need for an absorbable membrane for dural repair. On the other hand, Glaser and Thiennes \(24\) concluded from their experimental and clinical studies that heteroplastic or autoplastic grafts for the repair of dural defects were unnecessary.

We believe that in some situations a watertight closure of the dura is desired. A number of criteria have been proposed for the material to be used for duraplasty. \(3^{26}^{34},45,46,54,59\) There is consensus that the material be readily available and handled with relative ease. However, there are differences and contradictions concerning other qualities, such as the use of absorbable versus nonabsorbable material. Based on a review of the literature and our own experimental and clinical experience, we propose the following criteria for material for dural repair: 1) that the material not induce scarring or at least minimize cicatrix formation leading to compression and/or irritation of neural tissue; 2) that the material prevent CSF leakage and pseudomeningocele formation; 3) that the infection rate not be increased using this material; 4) that the material be relatively easily handled; 5) that the material be readily available and economical.

Repairs of dural openings were achieved in all instances with the three materials applied in our experimental study. Mersilene (polyester fiber mesh), the only material not previously used for duraplasty, was quite effective. This material is readily available in any size or shape. The mesh acts as a scaffold permitting and directing the growth of connective tissue fibers without the development of excessive scars. There was no evidence of CSF leakage. Scar formation was restricted to the area uniting the cut edges of the dura. The underlying neural tissue was free of adhesions, and there was no evidence of adhesive arachnoiditis.

Autologous fat has been used by previous investigators with variable results. \(16^{37}^{46}^{51}\) We have previously reported favorable results with fat used for the prevention of postoperative cicatrix following lumbar laminectomy and spinal dural repair in experimental \(32\) and clinical studies. \(38^{39}\) Our experimental results with autologous fat for duraplasty have been excellent. A neodural membrane is formed through the fat uniting the edges of the dura. The fat is viable although reduced in.

![Fig. 4. Left: Cross section of a lumbar vertebra 6 weeks following repair of dura with Dura Film illustrating impingement of ventral neomembrane on the spinal cord. H & E, bar = 5.0 mm.](Image)

![Right: Photomicrograph from the same section. H & E, × 17; bar = 500 μ.](Image)
size as previously reported. In some instances, connective tissue fibers within the graft were loosely bound to the underlying arachnoid membrane, but there was never any indication of the formation of arachnoiditis.

Silicone-coated Dacron has been used experimentally and clinically for the repair of cranial and spinal dural defects. In our experiments, the graft material was always encapsulated by connective tissue, with the ventral thicker portion of the capsule projecting inferiorly and frequently compressing the underlying spinal cord. Although none of our animals exhibited neurological deficits, this consistent ventral protrusion of the underlying arachnoid membrane, but there was never any indication of the formation of arachnoiditis. Silicone-coated Dacron has been used experimentally and clinically for the repair of cranial and spinal dural defects. In our experiments, the graft material was always encapsulated by connective tissue, with the ventral thicker portion of the capsule projecting inferiorly and frequently compressing the underlying spinal cord. Although none of our animals exhibited neurological deficits, this consistent ventral protrusion of the underlying arachnoid membrane, but there was never any indication of the formation of arachnoiditis.

Recent case reports by Banerjee, et al., and Adegbite, et al., of unusual complications following implantation of silicone-coated Dacron in humans corroborate our concern about the continued use of this material. In addition, we have reported two cases in which complications developed following the use of silicone-coated Dacron. One patient (Case 1) developed a thick encapsulation of the graft by connective tissue, which simulated a recurrent tumor, and the other (Case 2) developed an acute hemorrhage beneath the dural graft, initially believed to be an acute subdural hematoma. We believe autologous fat or Mersilene fulfills requirements for spinal duraplasty and that Silicone-coated Dacron, on the other hand, is not suitable for this purpose.

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**TABLE 1**

Materials used by different authors as dural substitutes

<table>
<thead>
<tr>
<th>Substance</th>
<th>References</th>
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<th>References</th>
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<tr>
<td>alkyl 2-cyanoacrylate</td>
<td>Papadakis &amp; Mark, 1980</td>
<td>mica</td>
<td>Crandall &amp; Batzdorf, 1966</td>
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<td>isobutyl 2-cyanoacrylate</td>
<td>Chao, et al., 1940</td>
<td>Orlon</td>
<td>Rosomoff &amp; Malinin, 1976</td>
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<td>allantoic membrane (insultoic membrane)</td>
<td>Chao, et al., 1940</td>
<td>peristeum (pericranium)</td>
<td>Chao, et al., 1940</td>
</tr>
<tr>
<td>aluminum foil</td>
<td>Chao, et al., 1940</td>
<td>platinum foil</td>
<td>Huertas, 1955</td>
</tr>
<tr>
<td>amnioplastin (human amniotic membrane)</td>
<td>Penfield, 1940</td>
<td>polyethylene (polythene)</td>
<td>Kirschner, 1909</td>
</tr>
<tr>
<td>fixed amnioplastin</td>
<td>Penfield, 1942</td>
<td>polylactin 910 (Vicryl) mesh</td>
<td>Wallace &amp; Meirovsky, 1960</td>
</tr>
<tr>
<td>attenuated fresh autologous fat</td>
<td>Penfield, 1942</td>
<td>polyvinyl alcohol films</td>
<td>McCoB, 1989</td>
</tr>
<tr>
<td>cat gut (plain)</td>
<td>Penfield, 1942</td>
<td>polyvinyl sponge</td>
<td>Brown, et al., 1947</td>
</tr>
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<td>cellophane</td>
<td>Penfield, 1942</td>
<td>rubber</td>
<td>Ingraham, et al., 1947, 1947</td>
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<td>celluloid or celloidin</td>
<td>Penfield, 1942</td>
<td>silver foil</td>
<td>Busch, et al., 1948</td>
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<td>collagen film</td>
<td>Chao, et al., 1940</td>
<td>sterile olive oil</td>
<td>Chao, et al., 1940</td>
</tr>
<tr>
<td>collagen fabric film</td>
<td>Chao, et al., 1940</td>
<td>tautalum</td>
<td>Prime, 1909</td>
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<td>egg membrane (vitelline membrane)</td>
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<td>Teflon</td>
<td>Chao, et al., 1940</td>
</tr>
<tr>
<td>fascia</td>
<td>Chao, et al., 1940</td>
<td>Teflon cloth (unbleached)</td>
<td>Teng &amp; Papathodorou, 1963</td>
</tr>
<tr>
<td>fibrin film</td>
<td>Chao, et al., 1940</td>
<td>Teflon (bleached) coated with methyl-2-</td>
<td>Teng &amp; Feigin, 1955</td>
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<tr>
<td>Gelfoam (gelatin film)</td>
<td>Chao, et al., 1940</td>
<td>cyanoacrylate</td>
<td>Vinyon-N</td>
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<td>gold foil</td>
<td>Chao, et al., 1940</td>
<td></td>
<td></td>
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<tr>
<td>lyophilized dura</td>
<td>Chao, et al., 1940</td>
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