The fate of autogenous grafts to the spinal dura

An experimental study

JEFFREY T. KELLER, PH.D., STEWART B. DUNSKER, M.D., JOE M. MCWHORTER, M.D., CARLOS M. ONGIKO, M.D., MARY C. SAUNDERS, B.A., AND FRANK H. MAYFIELD, M.D.

The Christ Hospital Institute of Medical Research, Department of Neurosurgery, The Christ Hospital, and Department of Anatomy, College of Medicine, University of Cincinnati, Cincinnati, Ohio

An experimental study was designed to compare the efficacy of autogenous fat and Gelfoam in minimizing scar tissue attachment to the dura and nerve roots. A multiple level lumbar laminectomy was performed in 20 dogs, and Gelfoam and autogenous fat were placed in the epidural space at two laminectomy sites, over the dura, interposed between the overlying paraspinal muscles and the dura. A third lumbar laminectomy site in each dog served as a control. The animals were sacrificed after different time periods (3, 6, 12, 18, and 24 weeks), and the specimens were examined histologically and histochemically. The colloidal iron-periodic acid Schiff-Bismarck brown-picric acid (CI-PAS-BB-PA) and high iron diamine-Alcian blue 8Gx (HID-AB) techniques were used to demonstrate connective tissues and glycosaminoglycans.

The scar at the laminectomy sites where Gelfoam was placed and at the control sites was composed of dense irregular connective tissue. Examination of the laminectomy sites where autogenous fat was used revealed less scar tissue. In addition, there was a layer of fat with a slight increase in intercellular connective tissue fibers interposed between the overlying erector spinae musculature and the dura. Our results indicate that autogenous fat interposed between the dura and the overlying paraspinal musculature serves as a barrier limiting the growth of connective tissue into the spinal canal. We could find no evidence that Gelfoam prevented the ingrowth of scar tissue into the operated area.

KEY WORDS: lumbar vertebra, laminectomy, dura mater, cicatrix, laminectomy membrane, fat graft

After laminectomy in humans, scar forms between the dura and overlying paraspinal muscles. In patients who must have another operation the scar makes the procedure difficult. It is thought by many to bind the roots and to compress the dural tube sufficiently to cause disabling symptoms. Autogenous fat transplants from the subcutaneous area have been used in this clinic for more than 14 years to cover the dura after laminectomy in the lumbar area in the hope of minimizing or inhibiting the development of constricting cicatrix formation. The fat transplants were cut to cover the exposed...
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dura as onlay unsutured grafts with a layer thick enough to fill the space from the dura to the outer margin of the adjacent lamina (3 to 10 mm). Concern that the bulk might itself compress the dura or interfere with wound healing was quickly eliminated by experience, and we have used thicker transplants (10 to 15 mm) in the human for several years.

Wounds reopened after 3 months to 14 years verified that the grafts did survive and were readily identified. Cleavage planes were easily established between the overlying muscles and the free fat grafts. The fat shrank to about 50% of its original thickness.

We have also used fat grafts to reconstruct the dura while repairing meningoceles and for preventing cerebrospinal fluid leaks. The results with human material alone, however, cannot determine the fate and effectiveness of the fat transplant. We therefore performed comparable operations on the dog. Wounds reopened at intervals of 3 and 6 weeks after transplant confirmed that the response was similar to that seen in humans in that the fat survived but was smaller.

Because LaRocca and Macnab proposed that Gelfoam reduced the amount of scar following laminectomy we planned to compare the effectiveness of fat and Gelfoam.

Material and Methods

Surgical Procedure

Twenty mongrel dogs weighing 10 to 15 kg were used in this experiment. A midline vertical incision was made in the lumbar region and the paraspinal musculature stripped subperiosteally to expose six laminae. A laminectomy (1.5 × 1.0 cm) was performed at each of three non-contiguous levels. Subcutaneous (autogenous) fat was placed in the first opening. The graft varied in thickness but was approximated to fill the space between the lamina and the spinal dura (1.5 × 1.0 × 0.5 cm). The fat graft always extended 1 to 2 mm above the lamina. Gelfoam was placed in the second opening, while nothing was placed in the third opening, which served as a control. Four animals were sacrificed at each of 3, 6, 12, 18, and 24 weeks after graft placement.

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 then decalcified in 5% nitric acid. Vertebral blocks were cut at 20 to 35 μm and examined histologically with hematoxylin and eosin stain. Snook's reticulum stain was used to examine for the presence of reticular fibers. The colloidal iron-periodic acid Schiff-Bismarck brown-picric acid (CIPAS-BB-PA) technique was used to demonstrate connective tissue fibers and glycosaminoglycans. Determination of sulfated versus non-sulfated glycosaminoglycans was made using the high iron diamine-Alcian blue technique.

Results

Scar tissue was seen at all laminectomy sites, but it was less where autogenous fat was
Fig. 2. Cross section of a site of Gelfoam graft (left) and a control laminectomy site (right), illustrating dense scar tissue formation 3 weeks post-laminectomy. The scar extends from the overlying paraspinal musculature down to the dura to which it is bound. CI-PAS-BB-PA, × 2.

Fig. 3. Cross section of Gelfoam site illustrating invasion of the scar into the spinal canal. Arrow indicates extension of scar into the lateral aspect of the spinal canal in the region of the spinal roots. CI-PAS-BB-PA, × 2.

Fig. 4. Cross section of a site where autogenous fat had been placed over the dura. A layer of fat was still present between the dura and the overlying paraspinal musculature 3 weeks following this procedure. The scar has not invaded the spinal canal or bound down the dura. CI-PAS-BB-PA, × 2.
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applied over the dura. At 17 of the 20 sites (85%) where Gelfoam was placed in the epidural space and in 10 of the 20 areas (50%) where no exogenous material was placed (control site) dense scar bound the paraspinal muscles to the dura (Fig. 1). The scar was composed of dense irregular connective tissue (Fig. 2). The ground substance was an acidic glycosaminoglycan, probably chondroitin-4-sulfate. Using the high iron diamine-Alcian blue technique, confirmation of the sulfated glycosaminoglycans was obtained. Lateral extension of the scar with encroachment of the spinal nerves occurred in 14 of the 40 sites (33%) (Fig. 3).

Examination of the laminectomy site where the autogenous fat was used, however, revealed a layer of fat interposed between the overlying paraspinal muscles and the dura in 18 of 20 animals (90%) (Fig. 4). The fat grafts were always thinner than the original piece of fat, but they covered the dura and extended over the entire laminectomy site. The percent- age of reduction could not be estimated. The grafts retained the characteristic appearance of viable fat. There was no inflammatory response or necrosis, and the fat of the grafts was indistinguishable from epidural fat.

FIG. 5. Photomicrographs comparing the density of scar at a control laminectomy site (upper left), Gelfoam graft (upper right), and autogenous fat graft sites (lower). The density of the scar was always greater at the control and Gelfoam sites than at the fat graft site. Arrow indicates dura; S = scar; F = fat. H & E, × 25.
In 18 dogs (90%), the scar formation at the fat graft sites was confined to the space between the muscle and the graft, and it was less dense than that seen with Gelfoam or control sites (Fig. 5). The scar stopped at the dorsal edge of the lamina in 15 of 20 dogs (75%). The scar never encroached on the spinal nerves at any fat graft site.

The pattern of scar tissue development was established at 3 weeks. Each of the sites studied at 6, 12, 18, and 24 weeks (Fig. 6) differed only in the degree of the maturation of the scar tissue.

Discussion

Clinical experience with free fat grafts to cover exposed spinal dura suggested that fat decreased spinal dural scar formation. Early reports of fat transplants indicated their usefulness in cosmetic operations of the orbit.16,17 Lexer13 and Rehn and Eden4,22,23 used fat grafts in wrapping nerves and tendons to prevent fibrosis of these structures, in the restoration of movement in joints following injury, and to fill defects in brain tissue. The end result of fat transplants on rats, rabbits,28 and humans is the same: the autogenous fat is revascularized and survives although it is reduced in size.5,3,14

Fig. 6. Cross sections of lumbar vertebra and spinal cord at a control laminectomy site (upper left), Gelfoam graft (upper right), and autogenous fat sites (lower) at 24 weeks. The fat is viable 24 weeks after grafting and is not replaced by scar, thus preventing the dura from being bound down with connective tissue. CI-PAS-BB-PA, × 2.
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Various graft materials have been used experimentally and clinically, including Gelfoam, fibrin, silicon-coated Dacron, and polyethylene to prevent meningo-cerebral adhesions. However, relatively little study has been done on the reduction of post-operative cicatrix in the spinal canal.

Key and Ford studied the source of scar formation in dogs after lumbar laminectomy and discectomy. They found that dorsally the scar bound the dura to the overlying muscles. Ventrally the dura was attached by scar to the discectomy site. There was no scar in the lateral epidural space.

Recently, LaRocca and Macnab reported that Gelfoam served as an efficient, interpolating membrane to prevent entry of scar tissue which they termed the "laminectomy membrane" into the spinal canal of the dog. We, however, have found Gelfoam to be associated with an increased fibrotic response while fat seems to prevent the scar tissue from binding to the dura.

Others have also shown this increased fibrotic response in the presence of Gelfoam. Pilcher and Meacham observed that when gelatin sponge was applied to the region of the superior sagittal sinus in dogs, it became firmly adherent to the underlying dura. In an excellent study using rabbits, Kiviluoto compared the effectiveness of Spongostan (gelatin) and transplanted fat in reducing scar tissue following laminectomy. He found that gelatin was replaced with scar tissue and bone and was bound to the dura. On the other hand, transplanted fat was found on the dura and was sometimes divided into smaller septa by connective tissue. Cortisone had no effect on the fat transplant. These results also show that the fat graft is preserved and is associated with less scar formation than that seen with gelatin.

On the basis of our clinical and experimental studies, autogenous fat interposed between the dura and the overlying paraspinal musculature serves as a barrier limiting the growth of connective tissue into the spinal canal. The definition of the size of an adequate fat graft requires further study, but the exact size is not critical. Moreover, we recommend that fat grafts be laid in the epidural space, without compressing the dura or the roots, at the conclusion of a laminectomy and discectomy.

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References


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