THE LAMINECTOMY MEMBRANE*

Studies in its Evolution, Characteristics, Effects and Prophylaxis in Dogs

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Re-exploration of the cauda equina after previous laminectomy for removal of a disc often reveals the formation of well organised fibrous tissue surrounding the dura and, at times, binding down the nerve roots to the posterior surface of the disc and the adjacent vertebral body. The only previous study of the source of this scar formation was carried out by Key and Ford (1948), who suggested that the perineural fibrosis found after disc excision in dogs was derived from the surgically damaged annulus fibrosus.

Because perineural fibrosis after operation may pose an important clinical problem, we

FIG. 1

The phenomena after operation represented diagrammatically. A—The fibroblastic activity seen at the surface of the overlying erector spinae muscle mass extends into the haematoma. B—The dense fibrous scar which binds the undersurface of the muscle to the posterior and lateral surfaces of the dura and the nerve roots extends through the surgical defect.

have studied the development of the scar tissue and have attempted to devise a method of diminishing its formation.

EXPERIMENTAL METHOD AND RESULTS

Simple lumbar laminectomy was carried out in eighteen dogs. At the fifth segment the superficial layers of the annulus, as far laterally as the intervertebral foramen, were scarified with a fine curette. Three dogs were killed at three days, one week, three weeks, six weeks, nine weeks and twelve weeks after operation.

A study of the histological preparations disclosed a consistent and sequential pattern of response (Fig. 1). At the third day a haematoma completely filled the laminectomy defect and was in contact with the surface layers of the erector spinae muscles (Fig. 2). The haematoma surrounded the posterior and lateral surfaces of the dura and extended for a variable distance under the intact neural arches above and below the level of the surgical defect.

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At the end of the first week fibroblastic activity was noted at the deep surface of the erector spinae. Fibroblasts could be seen to follow the extensions of the haematoma. A thick fibrous scar gradually formed, starting from the erector spinae and extending over the lateral aspect of the dura to the nerve roots. If at laminectomy the nerve root was exposed as far as the foramen, this fibrous scar also extended out into the foramen. A dense, tough membrane thus formed to fill the defect: this has been termed the "laminectomy membrane" (Fig. 3).

It was noted that the haematoma that formed in the anterior part of the canal in response to the scarification procedure resolved by the third week; in these experiments no significant fibroblastic activity occurred as a result, and the dura and nerve roots did not become adherent to the canal wall. In all the animals except one, the neural structures did not adhere to the posterior surface of the intervertebral disc, in spite of curettage of the annulus. In one dog, as a result of the interference at operation, extrusion of nuclear material occurred, and this was associated with dense scarring which bound the root to the disc, in addition to the scar derived from the laminectomy membrane.

The formation of the laminectomy membrane was a consistent result of every laminectomy performed. The extent of the peridural fibrosis was directly proportional to the size of the laminectomy defect.

At the conclusion of every laminectomy the raw surface of the erector spinae was placed in direct contact with the dura. It seemed logical, therefore, to presume that if an inert membrane was placed between the muscles and the dura, the development of peridural fibrosis would be discouraged.

To study this, in two dogs simple laminectomy was done at the third, fifth and seventh segments. The contents of the spinal canal were lightly manipulated, but the annulus was left untouched. The third segment served as a control. At the fifth segment the surgical defect was packed with Gelfoam.* At the seventh segment the defect was covered with a Silastic† membrane. These animals were killed five weeks later.

It was found that Gelfoam served as an efficient interposing membrane in both animals, preventing entry of the laminectomy membrane into the spinal canal. In neither animal was there any adherence of the scar to the dura or to the nerve roots (Fig. 4). Similar results were obtained where Silastic sheeting had been used as the interposed membrane.

It was believed that perineural fibrosis might also be reduced by surrounding the nerve root with an impervious barrier of Silastic or Gelfoam. This was investigated in eighteen dogs in which the root canals of the fifth and seventh segments were scarified. At the fifth segment the root was surrounded by Gelfoam and at the seventh segment the root was encircled by a split Silastic tube 1.5 centimetres in length with a wall thickness of 1.2 millimetres.

The introduction of Gelfoam into the canals surrounding the nerve roots was followed by a constant sequence of events. Initially, the interstices of the foam filled with the cellular elements of blood (Fig. 5). By the third day the foam began to fragment and a leucocyte infiltration occurred. By the third week, considerable lysis of the Gelfoam had been accomplished and the remaining material was irregular and filiform in appearance. At the sixth week there was no evidence whatever of any remaining Gelfoam. Of significance is the fact that the resorption of this substance is not associated with invasion of granulation tissue, and subsequently no scar tissue replaces it. After six weeks the roots that had been encircled with Gelfoam were all free and mobile in the root canal.

The roots enclosed in a Silastic tube remained free in the tube and isolated from the surrounding scar tissue no matter how dense the scar tissue happened to be (Fig. 6). It was interesting that initially the blood clot extended into the tube, and as the scar matured it formed a thin flat stalk continuous from the outside of the tube to a thin layer of scar tissue

* Gelatin foam, Upjohn.

† Dimethyl siloxane polymer, Dow Corning.

FIG. 2

FIG. 3

Figure 2—On the third day after laminectomy the surgical defect is filled with a haematoma, which extends from the outside of the canal through the defect into contact with the dura and the nerve roots along their posterior and lateral surfaces. (Masson's trichrome stain, $\times 0.7$.) Figure 3—The mature laminectomy membrane is seen in blue. It fills the surgical defect and has posterior attachments to the erector spinae muscle mass and anterior attachments within the spinal canal, where it adheres to the dura and nerve roots. (Masson's trichrome stain, $\times 3$.)

FIG. 4

FIG. 5

Figure 4—Cross-section of the spine showing that an interposing membrane of Gelfoam inserted into the laminectomy defect is capable of limiting the laminectomy membrane to the exterior of the spinal canal. (Masson's trichrome stain, $\times 3$.) Figure 5—A mass of Gelfoam is noted to be in contact with the nerve root on the right. Its interstices are filled with blood clot. (Masson's trichrome stain, $\times 0.7$.)

FIG. 6

The nerve root on the right has been encircled by a tube of Silastic. A stalk of scar enters through the slit in the tube and is continuous with a fine layer of scar immediately about the root. The tube serves as an efficient barrier against the laminectomy membrane which approaches it posteriorly. (Masson's trichrome stain, $\times 3$.)

FIG. 7

FIG. 8

Figure 7—Cross-section of a nerve root which has been enclosed in a Silastic tube for twelve weeks. The architecture of the root is intact, and the arterioles supplying it are seen to be filled with micropaque, indicating ante-mortem patency. (Haematoxylin and eosin, $\times 100$.) Figure 8—Positive reproduction of a radiograph of the arterial anatomy of spinal cord and roots, injected with micropaque. The arterial supply of the root enters from the antero-lateral margin of the spinal cord and courses longitudinally. The arteries of the roots are noted to be patent within the Silastic tubes. ($\times 2$.)

that surrounded the root. Between this thin layer of scar and the wall of the tube there was always a free space.

The effect of Silastic tubing on the viability of the nerve was studied in nine further dogs one week, two weeks and three weeks after implantation of the Silastic tube. Just before the animals were killed the nerve roots were exposed by laminectomy. Electrical stimulation showed the motor latency time and the root conduction time to be normal in every instance.

Microangiographic studies showed that the microvascular pattern had not been disturbed (Fig. 7). On histological examination the arterioles were noted to be filled with micro-opaque granules, indicating that they were patent. The myelin sheath was shown to be intact by the Marchi stain (Fig. 8). In the dogs studied we could not find evidence of any adverse reaction to ensheathing the nerve with a Silastic tube.

DISCUSSION

Although it was shown by Key and Ford (1948) that perineural adhesions might be formed from the annulus after excision of a disc, our experiments suggest that a major source of peridural fibrosis is the raw surface of the muscles overlying the dura. This is in accord with clinical experience. Re-exploration of the spine commonly reveals dense scar tissue at the site of the previous laminectomy. This fibrosis engulfs the dura and sometimes extends under the adjacent portions of intact laminae. Periradicular fibrosis is always seen to be in continuity with the scar that extends around the dura from the laminectomy defect.

These experiments demonstrated that the fibrous response was always more marked when a wide operative exposure was employed. The presence of a large epidural haematoma favoured the extension of the peridural fibrosis beyond the limits of the laminectomy defect. The experiments corroborated previous reports on the benign nature of Gelfoam (Correll, Prentice and Wise 1945; Pilcher and Meacham 1945; Reynolds and Ford 1953) which in the animals studied was completely successful in limiting the laminectomy membrane to the exterior of the spinal canal.

Though Silastic tubing was shown to be effective in preventing periradicular adhesions after extensive dissection around nerve roots in the foramina, since it is not resorbed its clinical application must await a more detailed study of the microvascular pattern of human lumbar nerve roots.

Gelfoam, however, was shown to be effective during the period of fibrous tissue response and was completely resorbed by the fifth week. Though it is always difficult, and at times dangerous, to translate the findings of experimental investigation into the sphere of clinical experience, these experiments on the formation of the laminectomy membrane suggest that the following precautions should always be undertaken at operation: 1) the laminectomy should be as restricted as possible, consistent with thorough decompression of the involved nerve; 2) a dry field should be obtained and maintained; and 3) at the conclusion of the decompression extensively exposed nerve roots, and the dura, should be separated from the raw surface of the erector spinae muscles by a barrier of impervious material.

SUMMARY AND CONCLUSIONS

1. Standard lumbar laminectomy was performed at multiple levels in thirty dogs, and manipulations were carried out in the spinal canal to observe their effects on periradicular adhesion formation. The canal was scarified, packed with Gelfoam, or treated with three varieties of Silastic membranes. The results were serially assessed from three days to twelve weeks by gross observation, nerve conduction studies, histological examination of transverse sections of the spine, myelin study of lumbar roots and micropaque study of the arterial supply to the roots.

2. The results were consistent biologically. The principal source of scar is dorsally in the fibrous tissue elements of the erector spinae muscle mass. This scar, the laminectomy membrane, covers the laminectomy defect and extends into the canal bilaterally to adhere to the dura and nerve roots.
3. Gelfoam does not contribute to scar formation, but instead acts as an effective interposing membrane. Silastic membranes are capable of providing protection against nerve root adhesions without interfering with the anatomical or physiological integrity of the nerves.
4. Certain clinical implications of the study are discussed.

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