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Animal Model for Studying the Chronic Effects of Herniated Disks and Spinal Surgery

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A successful model to study both herniated intervertebral disks and spinal operations such as laminectomy has not been described. Two procedures were developed in nonhuman primates: One produces an elevated nerve root simulating a herniated disk; the second is a laminectomy that simulates the operation in humans. Twenty-five surgical procedures were performed with no complications. A myelographic abnormality typical of a disk herniation results from the simulated disk herniation. The chronic effects of herniated disk and spinal surgery can be studied with this model.

Excessive surgical mortality and complication rates have limited the usefulness of the previously described animal models of lumbar disk disease and spinal surgery [1–3]. Our objective was to model herniated disk and laminectomy in animals. Postoperative infections, wound complications, paraplegia, or high mortality were considered unacceptable for a chronic model. Nonhuman primates were chosen for the model since they had been used effectively to study experimental myelography [4].

Materials and Methods

Adult bonnet, cynomolgus, and stump-tail macaque monkeys weighing 2–15 kg were used after a 40 day quarantine period, negative stool culture, and microbacterial skin testing. All procedures were performed in the Allen-Bradley Medical Research Laboratory operating rooms at the Medical College of Wisconsin. All operations were performed by a board-certified surgeon (C. R. B.) with clinical and veterinary experience. The instruments, sutures, and supplies were chosen from the standard operating room supplies; techniques were modified from standard human procedures to accommodate the monkey's smaller size and slightly different anatomy. For the procedure, each animal was anesthetized with ketamine 10 mg/kg and supplementary doses as needed, shaved, and scrubbed with Betadine in the preparation room. In the operating room, strict sterile preparation and technique were used. After the surgical procedure, the smaller monkeys were placed in heated, humidified, oxygenated chambers for 24 hr; the large monkeys were returned directly to their cages. No antibiotics were used. The specific surgical techniques are described below.

Laminectomy

The skin was incised in the midline over the selected vertebral level. Subcutaneous bleeding was controlled and the fascia over the spinous processes was incised. The paraspinal muscles were elevated bilaterally with a periosteal elevator, the interspinous ligaments were incised, and then the spinous process removed with a gooseneck rongeur. Ligamentous attachments to the lamina were incised, and a plane of dissection was developed beneath the lamina with a small dental periosteal elevator.

The laminae were removed with small gooseneck and curved, single-action rongeurs. The ligamenta flava were identified and resected or retracted. The facet joints and dura were identified and inspected. The dural sac was gently retracted medially and exiting nerve root examined. Bleeding from bone edges or other sites was controlled with pressure and Gelfoam

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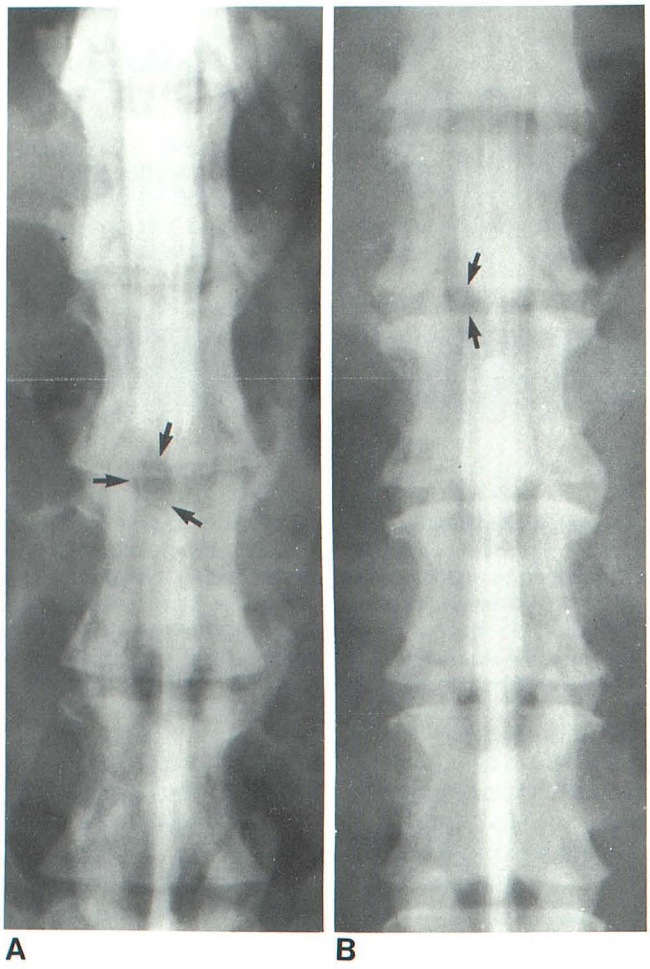

Fig. 1.—Myelographic deformities produced by simulated disk herniations in two monkeys. **A,** Deformity in dural sac opacification (*arrows*) suggests posterolateral herniation. **B,** Extradural process (*arrows*) suggests more lateral herniation.

sponges. Epidural fat was replaced over the dura. The wound was closed in layers. Muscle bundles were approximated in the midline and sutured with interrupted 4–0 Dexon sutures. The fascia was reapproximated in the midline using 3–0 cotton sutures. The skin was closed with a running subcuticular 4–0 Dexon suture. The wounds were then covered with an aerosol spray dressing.

Simulated Herniated Disk

After the laminae were exposed, a small laminotomy was performed at the selected disk level with a small, curved, single-action rongeur. The dural sac was retracted medially and the exiting nerve root identified. The anulus fibrosus over the dorsal aspect of the intervertebral disk was identified. A fragment of bone and fascia estimated to be the size of a herniated disk in such animals was removed from the spinous process with a gooseneck rongeur and inserted under the nerve root sheath to elevate and stretch it. Bleeding was controlled with pressure and Gelfoam, and the wound was irrigated with saline. The wound was then closed in layers as described for the laminectomy procedure.

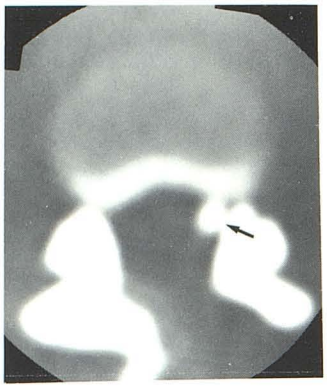

Fig. 2.—Axial computed tomographic (CT) image at operative level demonstrates position of block of bone and fascia placed to simulate a disk herniation (*arrow*).

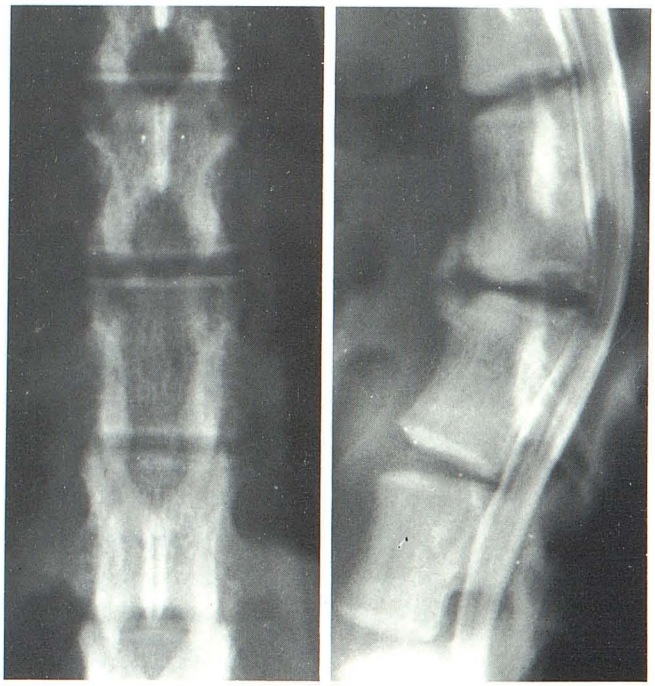

Fig. 3.—Posteroanterior radiograph of spine demonstrating L4 laminectomy.
Fig. 4.—Lateral radiograph from metrizamide myelogram 4 months after laminectomy. Moderate kyphosis and anterior osteophytes have developed.

Results

To date, 25 spinal operations have been performed on 23 animals with no surgical mortality, wound infection, or evidence of neurologic deficit. Bone fragments were placed in six animals through a laminotomy incision to simulate a herniated disk (figs. 1 and 2). Two of these animals were reexplored 3 months later, at which time the nerve roots appeared stretched and elevated by the bone fragments, which were removed. The fragments were still in place and the herniated disk still simulated.

Seventeen laminectomies were performed without complication (fig. 3). The wounds healed by primary intent. Postop-

erative analgesics were not needed or given. Animals developed mild kyphosis after laminectomy (fig. 4) but not after laminotomy and simulated disk herniation. One stump-tail monkey died on postoperative day 2. Autopsy revealed gastric and splenic volvulus but no evidence of wound infection, hematoma, or complication at the operative site. A second animal died of hypothermia several months after surgery. These two deaths were unrelated to the procedures. All the other animals survived without complication, and the animals in the laminectomy model were sacrified and examined.

Discussion

Experimental disk degeneration in dogs has been reported to have a high incidence of chronic infection and mortality [1]. Disk surgery in dogs has been complicated frequently by postoperative pneumonia, wound infections, and paraplegia or paralysis [2]. In a rabbit model of disk pathology, paraplegia, mortality, and wound infections were significant problems [3]. Nonhuman primates theoretically would be more suitable for modeling lumbar disk herniations since they have a humanoid cauda equina. In primates, a small surgical incision in the anulus firbosus produced a disk herniation, but too frequently caused paraplegia (S. J. Larson, personal communication).

The lack of surgical mortality and complications in our animals is partly from the technique and partly from the monkey's spinal anatomy. Because they have a cauda equina, monkeys may be less likely than other experimental animals to develop paraplegia from lumbar spinal surgery. Postoperative infection was avoided by careful preoperative and operative sterile technique, minimizing bleeding and tissue damage during surgery. Postoperative hypothermia in the smallest animals was avoided by keeping them in a chamber with warm humidified air.

Placing a bone fragment under the nerve root successfully simulated the root compression of a herniated disk. The myelographic and CT appearance of the fragment was similar to the extradural deformity produced by a herniated nucleus pulposus. The simulated herniation, lacking the chemical constituents of the nucleus pulposus, may not affect the nerve roots and sheaths in the same way as a herniated disk, but avoids the complications of an experimentally induced defect in the anulus.

Up to this time, a successful animal model of human disk disease has not been reported to our knowledge. With our model, numerous clinical questions can be studied. Myelography, laminectomy, and herniated disk have all been considered causes of arachnoid fibrosis. The relative role of these factors in so-called postmyelographic arachnoiditis or postsurgical complications can be studied experimentally and then correlated with clinical experience. Our model, which duplicates the anatomic derangements and surgical manipulation in herniated disk and in spinal surgery, promises to contribute significantly to the study of low back syndromes and perhaps "failed back surgery."

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