Effect of laminectomy and anesthesia upon spinal cord blood flow

PATRICK W. HITCHON, M.D., JEFFREY M. LOBOSKY, M.D., THORU YAMADA, M.D., AND JAMES C. TORNER, M.S.

Department of Surgery, Division of Neurosurgery, and Department of Neurology, University of Iowa Hospital, Iowa City, Iowa

Spinal cord blood flow (SCBF) in 10 sheep subjected to laminectomy at L6-7, T6-7, and C7-T1 was compared to that of 10 control sheep subjected to anesthesia alone. Blood flow was measured using the radioactive microsphere technique, with the PaCO₂ maintained at 40 ± 2 mm Hg. Both laminectomy and control animals showed a decrease in SCBF at a rate of 7% to 16%/hr for the 3 hours following the first blood flow determination. When prelaminectomy and postlaminectomy SCBF values were compared to their counterparts in the control animals, there were no significant differences. Laminectomy does not appear to alter SCBF from control values. Spinal evoked potentials (SEP's) were elicited in the laminectomy group by direct cord stimulation at C-7 and L-7. No changes were noted in amplitude or latency of SEP's over time in either caudal or rostral conduction.

KEY WORDS • spinal cord blood flow • electrical conductivity • evoked potentials • laminectomy

In spite of the extensive utilization of laminectomy, both in clinical and experimental settings, the actual effect of laminectomy upon spinal cord physiology is not uniformly accepted. In our quest to study the effect of spinal cord compression upon spinal cord blood flow (SCBF) and function, exposure of the cord is essential. We elected to study the effect of laminectomy upon the SCBF in anesthetized sheep. This question has already been addressed by others, however, without total agreement. The type of species, the anesthetic technique, and the experimental paradigm may all be contributing factors to conflicting results.

The effects of prolonged anesthesia upon SCBF and spinal cord evoked potentials (SEP's) are also issues worthy of documentation. This is particularly important since experiments dealing with cord compression often extend over several hours. Changes in cerebral blood flow brought about by immobilization and anesthesia have been described. Whether SCBF responds in a similar manner is relevant when attempting to quantitate alterations brought about by trauma, shock, or other interventions.

Materials and Methods

Ten lambs of both sexes, each weighing 20 ± 5 kg, were included in our experimental group subjected to laminectomy. Induction of anesthesia was performed with pentobarbital sodium, 30 mg/kg intravenously, followed by endotracheal intubation. The animals were maintained on a 2:1 mixture of nitrous oxide and oxygen supplemented with pentobarbital sodium in the amount of 25 to 50 mg intravenously every 1 to 2 hours as needed. Muscle relaxation for the control of ventilation and production of spinal evoked responses free of artifact, was provided utilizing metocurine iodine in a dose of 1 mg every 1 to 2 hours. Ventilation was controlled to produce an arterial pCO₂ (PaCO₂) of 40 ± 2 mm Hg. Heart rate, mean arterial pressure, pulmonary wedge pressure, cardiac output, hematocrit, and arterial blood gases were monitored throughout each experiment.

Once the animal's condition had stabilized and the desired PaCO₂ was attained, which required an average of 2 hours, two blood flow measurements were obtained 45 minutes apart. Laminectomy was then performed at L6-7, T6-7, and C7-T1. Diathermy, subperiosteal dissection, and rongeurs were utilized for surgical exposure. Bipolar electrodes, each measuring 5 x 5 mm

* Bipolar electrodes manufactured by Medtronic, Inc., Neuro Division, 6951 Central Avenue, N.E., P.O. Box 1250, Minneapolis, Minnesota.
with 5 mm between the two poles, were then placed in the epidural space at the above-mentioned three laminectomy sites. A fourth cuff electrode, with the cathode 1 cm proximal to the anode, was applied around the sciatic nerve. Stimulation of the lumbar cord was accomplished with a current of 4 mA, duration of 20 μsec, and at a rate of 10.3/sec. The intensity of the stimulus was that above which no further increase in amplitude of the responses could be obtained. Responses with bandpass of 30 to 250 Hz were then measured from the thoracic and cervical cords, and SEP’s were measured immediately after the completion of the three-level laminectomy and at 45-minute intervals for a total of 225 minutes. Since the cord was not exposed, blood flow determinations and blood flow computations were not obtained. The microsphere technique, as has been used by ourselves1 and others,2,9,13,14,21 was employed to determine blood flow. At least 4.5 × 10⁶ microspheres, each measuring 15 ± 3 μm and labeled with one of the six isotopes (scandium-46, neobium-95, strontium-85, tin-113, cerium-141, or gadolinium-153) were injected via a No. 7 French pigtail catheter into the left cardiac ventricle. After the completion of each study, the animal was sacrificed and tissues were obtained for blood flow measurement.

Segments of lumbar, mid-thoracic, and cervical cord, as well as tissue from both renal cortices, were obtained. The cervical and lumbar enlargements were of sufficient size to separate into gray and white matter and allow for accurate regional SCBF measurement. All results were analyzed by the general linear models analysis of variance, and significance was accepted at the p ≤ 0.05 level. Grouping of means was done by the Duncan multiple range test.

Results

The depth of anesthesia and ventilation was controlled during each experiment, such that the only parameter to show any significant change in the laminectomy group was the heart rate (Table 1). Heart rate increased from 141 ± 10 beats/min before laminectomy to 166 ± 13 beats/min after laminectomy. This tendency for heart rate to increase continued over the 2 hours postlaminectomy. This change in heart rate was associated with an increase in hematocrit and a decrease in mean arterial pressure over the duration of the experiment; however, these changes did not attain statistical significance. Control animals, on the other hand, showed a significant decrease in mean arterial pressure and cardiac output from baseline values of 119 ± 5 mm Hg and 159 ± 16 ml/kg/min to 104 ± 5 mm Hg and 130 ± 13 ml/kg/min, respectively, at the termination of the experiment. Heart rate and hematocrit increased from 169 ± 9 beats/min and 30.9 ± 1.0 vol% to 178 ± 11 beats/min and 32.2 ± 2.2 vol%, respectively.

Spinal cord blood flow measurements in the laminectomy group showed a decrease over the 45 minutes...
Spinal cord blood flow in experimental laminectomy

**TABLE 2**

*Response of spinal cord blood flow to laminectomy*

<table>
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<tr>
<th>Measure-</th>
<th>Cervical Spine</th>
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<th>Lumbar Spine</th>
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* Values are means ± standard error of the mean in ml/100 gm/ min. No. = number of observations.
† Preoperative 1 and 2 = prelaminectomy blood flows, 45 minutes apart. Postoperative 1–4 = postlaminectomy blood flows at 45-minute intervals. There was no significant difference between prelaminectomy flows 1 and 2 in any of the sampled tissues.

Prior to laminectomy, a tendency which continued for 2 to 3 hours after the first flow determination (Table 2, Fig. 1). This decrement in SCBF eventually became of such magnitude that when pre- and postlaminectomy flows were compared, a statistically significant difference was noted in the cervical and lumbar white matter only (Table 2). Renal blood flows, although showing a decrease over time, were not significant, however. Blood flow in control animals followed a similar decline for 3 hours after the first flow measurement, as was noted in the laminectomy group (Fig. 1). The decreases in SCBF in the lumbar white and gray matter, cervical white matter, and thoracic cord were all significant. Likewise, renal blood flow showed a significant decrease from an initial value of 866 ± 98 to 528 ± 69 ml/100 gm/min at 225 minutes. When comparable SCBF values from the laminectomy and control groups are analyzed together, there appears to be no significant difference between the groups. The two prelaminectomy SCBF measurements are not dissimilar from the first two determinations in the control group. Likewise, the four postlaminectomy SCBF values are not significantly different from the last four measurements in the control group.

Spinal evoked potentials recorded from the thoracic and cervical cord, and the nerve action potential recorded from the sciatic nerve following lumbar cord stimulation are illustrated in Fig. 2. In view of the dorsal position of our electrodes, and the short latency of our spinal evoked responses, we believe that the SEP's reflect the potentials transmitted rostrally in the dorsal columns.6,16 The sciatic nerve potential elicited by spinal cord stimulation may be produced by either orthodromic transmission along efferent motor fibers, or the more likely antidromic transmission in afferent sensory fibers. The tracings at each level consist of the four responses obtained after each blood flow determination following laminectomy. The reproducibility of these potentials in terms of both amplitude and latency of the negative component (N) of the triphasic wave is appreciated. It follows that the conduction velocity in the sciatic nerve (57 ± 2 m/sec), thoracolumbar cord (44 ± 3 m/sec), and upper thoracic cord (59 ± 6 m/...
be reliable, reproducible, and comparable to other tech-

dogs, 1~ and cats. 2 The technique has been found to

assuring an adequate number of active microspheres in

each sample of tissue, proper mixing of the micro-

rances among investigators are difficult to resolve, par-

particular, diathermy for the local increase in SCBF. We used diathermy in

they incriminated the surgical technique and, in

consequence of laminectomy or of the preparation and

in the basis of unmeasurable water loss. The magnitude

of these changes was, however, so small that changes

in SCBF cannot be attributed to them in view of spinal
cord autoregulation. Autoregulation has been shown to

be operational in the spinal cord down to a mean
arterial pressure of 40 to 60 mm Hg. 7,11

Comparison of prelaminectomy and postlaminec-
tomy SCBF's with the first two and last four SCBF
values in the control animals yields no differences. These
findings are not dissimilar from those of Ande-
son, et al.,12 who showed a significant reduction in
postlaminectomy SCBF of the anesthetized cat. Al-
though laminectomy was performed at L-3 in Ande-
son's study, the reduction in SCBF was noted 15 min-
tutes later along the entire length of the spinal cord,
gradually becoming insignificant at 24 hours postlami-
nectomy. Their findings, however, disagree with those
of Hales, et al.9 In the latter study, five of the eight
sheep subjected to laminectomy at T-9 showed a 30%
to 200% increase in whole-cord SCBF at the operative
site. When cord segments were divided into gray and
white matter, only one of the six animals in which this
was performed showed an increase in white matter
blood flow of 30%. Five of these six sheep, however,
showed an increase of 30% to 100% in central cord
segments, most of which was gray matter. These diffe-
rences among investigators are difficult to resolve, par-
ticularly since labeled microspheres were used by all
three.

Anesthesia consisted of pentobarbital sodium induc-
tion followed by supplemental doses in both the studies
of Anderson, et al.,2 and Hales, et al.9 Anesthesia in
our sheep was induced with pentobarbital sodium fol-
dowed by a 2:1 nitrous oxide to oxygen mixture for
maintenance. Nitrous oxide added to the inspired gases
reduced the requirement for barbiturate, and metocu-
rine iodide provided for ventilatory control and im-
proved quality of evoked responses. It is unfortunate
that Anderson, et al.,2 did not include in their study a
separate group of cats subjected to anesthesia alone
without laminectomy. Their data as presented fail to
indicate whether the decrease in SCBF noted was a
consequence of laminectomy or of the preparation and
anesthesia. As for the changes noted by Hales, et al.,9
they incriminated the surgical technique and, in
particular, diathermy for the local increase in SCBF.
This, they hypothesize, results from local increase in
metabolic demand of the cord in response to elec-
trical stimulation by the current. We used diathermy in
our dissection, yet did not observe an increase in local
SCBF.

The decrease in segmental SCBF noted in our lami-
nectomy group (Table 2) was similar to that occurring in
the control group (Fig. 1). The magnitude of this
decrement in the laminectomy group ranged from 7%
Spinal cord blood flow in experimental laminectomy

to 13%/hr, over the 3 hours following the first blood flow measurement. The equivalent value in control animals was 8% to 16%/hr. These changes over time in SCBF of the anesthetized, immobile sheep are expected. Similar changes in cerebral blood flow of anesthetized dogs have been described using both intracarotid krypton-86 and direct sagittal sinus blood volume measurement. The magnitude of this drop varied from 6% to 12%/hr using halothane-supplemented anesthesia. Although the anesthetic technique used in those studies was different than in ours, we think that this decrement in blood flow is a function of prolonged anesthesia and immobilization. A plausible explanation for this decline is given by Takeshita, et al., who invoked surgical manipulation as being responsible for the high values encountered initially. With the passage of time, the effects of stimulation by surgery gradually subside and vascular resistance increases.

Cauda equina stimulation has been shown to produce SEP's of markedly higher amplitude when compared to peripheral nerve stimulation. Furthermore, direct recordings from the epidural space result in SEP's of greater amplitude and complexity as compared to surface recordings. It is for these reasons that peripheral nerve stimulation was forsaken for direct cord stimulation at L-7. Our calculated conduction velocities of 44 ± 3 and 59 ± 6 m/sec from L-7 to T-6 and from T-6 to C-7, respectively, are comparable to the figures presented by others. Cracco has shown in man that spinal cord velocity is not linear, but that it is faster in more rostral segments. The reproducibility of SEP configuration over time, as generated in our model, promises to be a potentially reliable index of spinal cord integrity.

Summary

Our data, from 10 sheep subjected to laminectomy and 10 controls subjected to the same anesthetic agents, reveal a decrease in SCBF of 7% to 16%/hr for about 3 hours following the first blood flow measurement. There were no significant differences in SCBF between pre- and postlaminectomy values when compared to their counterparts in the control group. Spinal evoked potentials are reproducible over time in the uninjured cord, and may thus constitute a useful clinical and research index of cord function.

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References


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Address reprint requests to: Patrick W. Hitchon, M.D., Division of Neurosurgery, Department of Surgery, University of Iowa Hospital, Iowa City, Iowa 52242.