Deteriorating Stroke Model: Histopathology, Edema, and Eicosanoid Changes Following Spinal Cord Ischemia in Rabbits

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Secondary motor dysfunction is often observed following ischemic episodes in the central nervous system. To study potential mechanisms of posts ischemic motor deterioration, we developed a rabbit spinal cord ischemia model that has characteristics similar to the clinical condition termed deteriorating stroke. In this model, 70% of the rabbits regained substantial motor function by 4 hours after complete hindlimb paralysis during lumbar spinal cord ischemia; however, over the next 20 hours motor function steadily declined to the point where only 30% of the rabbits had minimal hopping function. The role of eicosanoids in spinal cord ischemia was studied by radiolimmunoassay of several prostaglandins (6-keto-PGF$_{1\alpha}$, PGE$_2$, and TxB$_2$) in the spinal cord. After 5 minutes of reperfusion, TxB$_2$ levels were markedly elevated (p<0.05) while 6-keto-PGF$_{1\alpha}$ levels did not change. The TxB$_2$:6-keto-PGF$_{1\alpha}$ ratio was also significantly increased. After 30 minutes of reperfusion, PGE$_2$ levels were also elevated (p<0.05). Tissue edema measured by microgravimetry was also increased after 30 minutes of reperfusion in both gray and white matter. By 4 hours of reperfusion, rabbits regained near-normal hindlimb motor function while PGE$_2$, 6-keto-PGF$_{1\alpha}$, TxB$_2$, and tissue water content were back to normal. However, by 18 hours of reperfusion, when hindlimb function was deteriorating, TxB$_2$ levels were elevated again, and edema in gray and white matter was increased as was the number of necrotic neurons observed by light microscopy. These results suggest that the secondary deterioration of motor neurologic function was due to the excess formation of TxA$_2$ primarily in the late reperfusion phase. However, further studies are necessary to elucidate the relation of TxA$_2$ with ischemic neural injury. (Stroke 1987;18:741-750)

Clinical progression of motor deficit hours or days after an ischemic episode in the central nervous system (CNS) has been termed "deteriorating stroke." The underlying pathophysiological mechanisms of the deterioration after stroke are poorly understood in part due to lack of experimental models designed to focus on the deterioration. Several studies suggest that a number of biochemical and metabolic events contribute to progressive and irreversible cell damage as well as to tissue hypoperfusion after ischemia. Recently, it was suggested that eicosanoids may be involved in the secondary damage observed during reperfusion of ischemic brain. These eicosanoids [prostaglandins (PGs), thrombox-

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Materials and Methods

Surgical Preparation

Fifty-five male New Zealand albino rabbits (Hazelton Labs, York, Pa.) were anesthetized with 50 mg/kg i.m. ketamine hydrochloride and 40 mg/kg i.v. sodium pentobarbital. Under aseptic technique, a transperitoneal incision was made to expose the abdominal aorta, and 0.75-mm o.d. polyethylene tubing was placed around the aorta distal to the renal arteries and was threaded through 2 6.0-mm diam. plastic buttons dorsal and ventral to the aorta to produce a snare ligature. To prevent movement through the incision site, the ligature was passed through a 6.25-mm o.d. vinyl guide tube that was sutured to the abdominal muscles. A custom-made canvas jacket was then placed around the rabbit to protect the incision site and the externally accessible ligature. The experiments reported were conducted according to the principles set forth in the "Guide for the Care and Use of Laboratory Animals," Institute of Laboratory Animals Resources, National Research Council, Department of Health, Education, and Welfare, National Institutes of Health publication number 85-23.

Induction of Experimental Ischemia

Ischemia was induced in the spinal cord using a modification of the stroke model described by Zivin and DeGirolami.14 Approximately 18 hours after surgery, when the rabbits were awake, the aorta was occluded for 25 minutes by pulling on the snare ligature and clamping with a pair of hemostat forceps. This period of occlusion produced paralysis of the hindlimbs in 95% of all control rabbits by 48 hours after reperfusion in the work of Faden and Jacobs.15 Motor function was also evaluated after 15 and 20 minutes of occlusion. After occlusion, the ligature was released and removed with the guide tube through the surgical site. A retaining suture that was placed through the abdominal muscles at surgery was then secured. Postoperative and treatment procedures included monitoring food and water intake, expressing the urinary bladder as needed (Crede's maneuver), and neurologic scoring of hindlimb motor function. A control group consisted of normal or sham-operated rabbits that were not subjected to ischemia.

Neurologic Examination

Hindlimb motor function was graded at hourly intervals during the first 24 hours after occlusion. The following ordinal grading scale was used: 0, complete paralysis; 1, minimal functional movement, severe paresis; 2, functional movement, cannot hop; 3, hopping, ataxia and paresis; 4, hopping, mild ataxia and/or paresis; and 5, normal. Rabbits were also categorized as hoppers (neurologic score of 3, 4, or 5) or nonhoppers (neurologic score of 0, 1, or 2). Two investigators evaluated the rabbits independently.

Physiologic Measurements

Mean arterial pressure (MAP) and heart rate (HR) were continuously measured via a catheter placed in an ear artery and connected to a Narco Bio-Systems Model 1500i pressure transducer (Houston, Tex.) coupled to a Narco Bio-Systems Model MK-JV physiograph. Core body temperature (T) was monitored via a rectal thermistor connected to a telethermometer (Yellow Springs Instruments, Inc., Yellow Springs, Ohio). PaO2, PaCO2, and pH were measured at T with an Instrument Model 1303 automated blood gas analyzer (Dayton, Ohio).

Biochemical Measurements

At 5 and 30 minutes, 4, 18, and 24 hours after occlusion, rabbits were killed with 100 mg/kg i.v. sodium pentobarbital, and the spinal cord was rapidly removed from the spinal canal within 45 seconds and processed by slicing the lesion area for analysis of biochemistry by freezing on dry ice, edema by immersion in kerosene to prevent water evaporation, and histopathology by immersion fixation in 10% buffered formalin. Venous blood was collected in tubes containing 20 μl of 10^-4 M indomethacin, centrifuged, and frozen for TXB2 and 6-keto-PGF1α analysis by radioimmunoassay (RIA).

TXB2, the (stable metabolite of TxA2), 6-keto-PGF1α (the stable metabolite of PGI2), and PGE2 were extracted from the spinal cord using a technique previously described.9 Tissue concentrations of these metabolites were determined by RIA using specific antibodies purchased from Dr. Lawrence Levine (Brandeis University, Waltham, Mass.) with cross-reactivity of <1.0% with other cyclooxygenase metabolites. [3H]TXB2, [3H]6-keto-PGF1α, and [3H]PGE2, 100–200 Ci/mmol, were purchased from New England Nuclear (Boston, Mass.). Samples were incubated with antibody and the corresponding radioligand for 18–24 hours at 4°C. To separate bound and free ligands, 200 μl of 1% activated Norit-GSX charcoal (Sigma Chemical Co., St. Louis, Mo.) coated with 0.1% dextran (Kodak, Rochester, N.Y.) was added to the sample and centrifuged at 1000g for 10 minutes. Five milliliters of Redisolv scintillation fluid (Beckman, Palo Alto, Calif.) was added to the decanted sample and radioactivity was determined by liquid scintillation counting (Model 1218, LKB, Gaithersburg, Md.). The sensitivity of the assays was 16 pg/tube. Protein content of the sample was determined by the method of Lowry et al.16 Plasma concentrations of the metabolites TXB2 and 6-keto-PGF1α were determined with commercially available RIA kits from New England Nuclear.

Microgravimetry for Measuring Tissue Edema

To measure edema in different regions of the spinal cord, the specific gravity (SG) of 1-mm³ tissue segments (punches) was determined by means of a density gradient column according to a method previously described.17,18 Two solutions of different SG were prepared from kerosene and bromobenzene (SG = 0.79 and 1.49, respectively; Fisher Scientific, Silver Spring, Md.). A flask containing 200 ml of Solution A (SG = 0.975) was positioned to slowly siphon down
43 cm of polyethylene tubing into a flask containing 200 ml of Solution B (SG = 1.065). As the two mixed, the mixture was siphoned down 40 cm of polyethylene tubing into the gradient column, which was constantly lowered to maintain a uniform gradient at the surface of the column. In this way, a linear density gradient ranging from SG = 1.065 to 1.020 was established, which encompasses the range of both normal and edematous spinal cord tissue. The column was allowed to stabilize for 1 hour and was then calibrated with 3-μl drops of a previously prepared graded series of NaCl solutions of known SG from SG = 1.025 to 1.057. The drops served as SG reference points and verified the linearity of the density gradient. If a correlation coefficient of \( r \geq 0.995 \) was not reached, the column was discarded.

Immediately after the spinal cord was removed, a 1-mm slice was immersed in kerosene to prevent evaporation of water. Tissue punched from various regions of the spinal cord including the ventral horn (VH) gray matter, lateral (LW), dorsal column (DC), and ventral (VW) white matter tracts using a blunt 15-gauge needle was then carefully placed on top of the density gradient column. After 3 minutes, the samples reached a stable position within the column, and SG of the punches was measured in relation to the NaCl standards.

Light Microscopy for Determining Histopathologic Changes

After removal, the lumbar spinal cord was immersion-fixed in 10% formalin with 10% glycerin (Fisher Scientific) by vol. for at least 72 hours. The tissue was dehydrated in graded alcohols, embedded in paraffin (Fisher Scientific), and cut in 7-μm transverse sections with a Sorvall JB-4A rotary microtome (Wilmington, Del.). Sections were stained with hematoxylin and eosin (Fisher Scientific) and Luxol fast blue (Sigma Chemical Co.). The spinal cord lesions were evaluated by an investigator unaware of reperfusion time using the following criteria: 3, no lesion observed; 2, gray matter contained 1-10 necrotic neurons with 33% of the cross-sectional area involved; 1, gray matter contained 10-20 necrotic neurons with 33-66% of the cross-sectional area involved; and 0, gray matter contained >20 necrotic neurons with >66% of the cross-sectional area involved. Vacuolation of the neuropil was observed in most rabbits with lesions; however, vacuolation was not quantifiable or as sensitive an indicator as neuronal necrosis. Histopathologic changes following ischemic injury are fairly predictive of neurologic outcome and can be readily assessed using ordinal scoring methods.15,19,20

Data Analysis

Data are presented as means ± SEM. Eicosanoid and tissue edema levels in ischemic rabbits were compared with normal rabbits using analysis of variance (ANOVA) followed by the Dunnett’s test.21 Physiologic data were evaluated by repeated-measures ANOVA.21 Eicosanoid concentrations in hopping and nonhopping rabbits were compared using Student's \( t \) test. Frequency analysis was performed using Fisher’s exact probability test.22 Spearman’s rank correlation test was used to measure the association between neurologic and pathologic scores.22 Values for all of the above statistics were considered significant at \( p < 0.05 \).

Results

Neurologic Function

A clear correlation between the duration of ischemia and the functional outcome is presented in Figure 1A. Most rabbits subjected to 15, 20, or 25 minutes of ischemia regained hopping function by 4 hours after reperfusion but underwent deterioration of function sometime thereafter. The degree of motor deterioration depended on the duration of the ischemia, with rabbits in the 25-minute group most severely affected (Table 1). The 25-minute group was selected for fur-
Table 1. Effect of Duration of Lumbar Spinal Cord Ischemia on Hindlimb Motor Function as Neurologic Score in Rabbits During Reperfusion

<table>
<thead>
<tr>
<th>Minutes of ischemia</th>
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<th>4 hrs after reperfusion</th>
<th>8 hrs after reperfusion</th>
<th>12 hrs after reperfusion</th>
<th>22 hrs after reperfusion</th>
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<th>48 hrs after reperfusion</th>
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<td>10</td>
<td>4</td>
<td>10</td>
<td>3</td>
<td>4</td>
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Neurologic scores during the 48-hour reperfusion period (see “Materials and Methods”). Numbers are percent of rabbits with each score. N, number of rabbits.

ther analysis because rabbits deteriorated from a hopping (Score 3, 4, or 5) to a nonhopping status (Score 0, 1, or 2).

Within 60 seconds of aortic occlusion, all rabbits had complete hindlimb paralysis, which remained for the duration of the 25-minute ischemic period. Ten rabbits were scored hourly during the 24-hour reperfusion period. Within 4 hours of reperfusion, 70% of the rabbits regained substantial hindlimb function and were capable of hopping (Figure 1B). However, 12–18 hours after reperfusion, a secondary decline in hopping function was observed. By 24 hours after reperfusion, 70% of the rabbits were unable to hop. Hindlimb function changed very little after 24 hours and never improved (unpublished results).

Physiologic Measurements

T, MAP, Pao2, pH, and Paco2 did not differ from control values during ischemia or the 24-hour reperfusion period (n = 5, Figure 2). HR increased significantly during early reperfusion but was within the physiologic range after 12 hours of reperfusion (repeated-measures ANOVA followed by Dunnett’s test, F = 2.956, p = 0.040, n = 5). The physiologic ranges for HR, T, MAP, Pao2, pH, and Paco2 were determined in resting, unrestrained rabbits (range = mean ± SD, n = 15).

Eicosanoid Tissue Concentrations

Five minutes after reperfusion (early phase), tissue TxB2 concentration in the lumbar spinal cord increased almost threefold (ANOVA, F = 8.32, n = 31, p < 0.01; Figure 3). Concentrations of 6-keto-PGF1α, however, did not change during reperfusion. The increase in TxB2, but not 6-keto-PGF1α, at 5 minutes led to a 2.5-fold increase in the TxB2:6-keto-PGF1α ratio (ANOVA, F = 7.16, n = 31, p < 0.01). Thirty minutes after reperfusion (early phase), PGE2 concentra-

![Figure 2. Effects of 25-minute aortic occlusion on heart rate (HR), core temperature (Tc), mean arterial pressure (MAP), arterial pO2, pH, and pCO2 in rabbits. Shaded area represents ischemic period. ——, physiologic range for each variable (mean ± SD, n = 15); * statistical significance (p < 0.05; repeated-measures ANOVA followed by Dunnett’s test, n = 5 for HR, Tc, and MAP; n = 4 for pO2, pH, and pCO2).](http://stroke.ahajournals.org/lookup/doi/10.1161/01.str.18.4.744#fig2)
tions were > twofold higher compared with controls (ANOVA, \( F = 3.42, n = 51, p < 0.05 \); Figure 4). At 18 hours (late phase), the tissue concentration of TxB\(_2\) was again higher than baseline (ANOVA, \( F = 3.62, p < 0.05 \); Figure 3), whereas no change in 6-keto-PGF\(_{1\alpha}\) concentration was observed. Further analysis revealed that nonhopping rabbits (Scores 0, 1, or 2) had higher tissue concentrations of TxB\(_2\) than hopping rabbits (Student’s t test, \( t = 6.12, n = 53, p < 0.001 \); Figure 5). Furthermore, rabbits with lumbar spinal cord concentrations of > 500 pg TxB\(_2\)/mg protein had lower motor function scores than hopping rabbits (Fisher’s exact probability test, \( n = 53, p = 0.0081 \)). Only 10.7% of the hopping rabbits had TxB\(_2\) levels of > 500 pg/mg protein, whereas 87.5% of the nonhopping rabbits had TxB\(_2\) levels of > 500 pg/mg protein.

Concentrations of PGE\(_2\) did not change during the late phase (Figure 4).

Assays for TxB\(_2\) and PGs were also performed on spinal cord T10–T12 segments, which did not include the ischemic lesion. No significant changes were observed at these sites, which demonstrates that the TxB\(_2\) and PG increases were confined to the ischemic zone (\( n = 40, \text{Table} \ 2 \)). Plasma concentrations of TxB\(_2\) were not different from control levels (Table 3). Plasma 6-keto-PGF\(_{1\alpha}\) levels were not detectable.

**Tissue Edema**

A significant decrease in SG was observed as early as 30 minutes after reperfusion in both gray (VH) and white (DC and VW) matter (ANOVA; \( F = 11.58 \) for VH, \( F = 8.01 \) for DC, \( F = 9.12 \) for VW; \( n = 53, \)
p < 0.01 for each, Figure 6A). However, by 4 hours after reperfusion, tissue water content returned to near-
normal levels in all regions. At 18 hours after reperfusion, a second decline in SG was first observed in VH,
followed by a further decrease in SG at 24 hours in VH, DC, VW, and LW columns (ANOVA, F = 3.49
for LW, n = 53, p < 0.01). The pattern of tissue water content changes appeared to follow the pattern of
neurologic change during reperfusion (Figure 6B). Therefore, we categorized rabbits as hoppers or non-
hoppers and grouped the SG measurements. For non-
hopping rabbits (SG = 1.0378 ± 0.0006), SG of VH was lower than that of hopping rabbits (SG = 1.0411 ± 0.0004) (t test, t = 4.27, n = 53, p < 0.01).
SG of white matter tracts was also different between hopping and nonhopping rabbits (t test; t = 4.99 for
VW, t = 3.55 for DC, t = 3.11 for LW; n = 53, p < 0.01 for each).

Histopathologic Changes
The major histopathologic changes observed after 25 minutes of ischemia in the rabbit spinal cord were
neuronal necrosis and vacuolation of the neuropil (Figure 7). Neuronal necrosis was first observed in 43% of
the rabbits 4 hours after reperfusion and was limited to the intermediate gray area. Eighteen hours after reper-
fusion, neuronal necrosis was present in the intermediate gray and DH areas, with occasional degenerate
neurons in VH of all rabbits. In addition, vacuolation of the neuropil was observed in the intermediate gray
and VH areas in 25% of the rabbits. At 24 hours after reperfusion, lesions were similar to those observed at
18 hours, although usually more severe; vacuolation of the neuropil was present in all rabbits (Figure 7).
Correlation between the histopathologic changes and hindlimb motor function changes was highly signifi-
cant (Spearman’s rank correlation test, r_s = 0.642, p < 0.01, n = 23; Table 4).

Discussion
A distinct advantage of the present model to study events after ischemia is that an integrated CNS func-
tion can be monitored. This model has characteristics similar to deteriorating stroke,23 which includes stroke-
in-evolution.24 During reperfusion, 70% of the rabbits regained substantial motor function within 4 hours;
however, over the next 20 hours, motor function stead-

Table 2. Concentrations of TxB_2, 6-keto-PGF_10, and PGE_2 in Rabbit Lumbar Spinal Cord Segments T10-T12
After Ischemia

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>5 min</th>
<th>30 min</th>
<th>4 hr</th>
<th>18 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>TxB_2</td>
<td>521 ± 25</td>
<td>413 ± 30</td>
<td>609 ± 99</td>
<td>389 ± 42</td>
<td>627 ± 90</td>
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<tr>
<td>6-keto-PGF_10</td>
<td>255 ± 43</td>
<td>233 ± 15</td>
<td>306 ± 23</td>
<td>215 ± 31</td>
<td>327 ± 57</td>
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<tr>
<td>PGE_2</td>
<td>1093 ± 87</td>
<td>928 ± 32</td>
<td>1163 ± 101</td>
<td>763 ± 76</td>
<td>1036 ± 59</td>
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</table>

Concentrations as pg/mg protein ± SEM at various times after reperfusion were compared by ANOVA. No significant
differences at p < 0.05.
Eicosanoids and Spinal Cord Ischemia

Table 3. Plasma Concentrations of TxB₂ and 6-keto-PGF₁₀ in Rabbits Subjected to 25 Minutes of Aortic Occlusion

<table>
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<th>Time after ischemia</th>
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<th>Ischemia</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>TxB₂</td>
<td>6-keto-PGF₁₀</td>
</tr>
<tr>
<td>5 min</td>
<td>92.7 ± 24</td>
<td>ND</td>
</tr>
<tr>
<td>30 min</td>
<td>67.1 ± 11</td>
<td>9</td>
</tr>
<tr>
<td>4 hr</td>
<td>70.4 ± 20</td>
<td>8</td>
</tr>
<tr>
<td>18 hr</td>
<td>109 ± 58</td>
<td>8</td>
</tr>
<tr>
<td>24 hr</td>
<td>89.2 ± 39</td>
<td>5</td>
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</table>

Values as mean ± SEM. ND, not detectable; N, number of rabbits at each time. Statistical analysis was performed by ANOVA; no significant differences at p<0.05.

illy declined to where only 30% of the rabbits had minimal hopping function. This model is highly reproduceable in producing a consistent functional outcome as observed in previous studies. 15,19

The present study demonstrated that spinal cord concentrations of TxB₂ in rabbits increased immediately on reperfusion, similar to reports of brain ischemia models in which TxB₂ tissue concentration was temporarily elevated on reperfusion in several species. 6,9,25 At 30 minutes after reperfusion, PGE₂ concentrations were also increased, whereas TxB₂ levels were decreased. The differential changes in eicosanoids in our model vary from recent studies in which reperfusion of ischemic gerbil and rat brain caused an immediate increase in all cyclooxygenase metabolites measured. 6,9,25 In the rabbit model, only TxB₂ was elevated while 6-keto-PGF₁₀ was not changed. The selective increase in TxB₂ may indicate that cellular elements which produce TxA₂, e.g., platelets, macrophages, and neutrophils, are activated. The lack of increase in PGE₂ immediately after reperfusion might be the result of inhibition of PGE-isomerase by the high arachidonic acid (AA) concentration in the tissue at this time. 26 On consumption of much of the AA, PGE-isomerase activity is resumed, leading to PGE₂ generation as seen 30 minutes after reperfusion. Since PGE₂ has constrictor effects on rabbit CNS microvessels, 13 elevated PGE₂ levels may propagate the initial vasoconstriction produced by TxA₂. The imbalance in the TxA₂: PGI₂ ratio could favor platelet aggregation and vasoconstriction, thus leading to further ischemic damage. 3 This possibility is supported by studies showing that supplementing PGI₂ together with blocking TxA₂ formation protects CNS tissue from acute ischemic insults. 27,28

At 4 hours after reperfusion, the levels of the PGs and TxB₂ were virtually normal; at that time substantial recovery of neurologic motor functions were also observed. Eighteen hours after the ischemic insult most rabbits had decreased hindlimb function. Analysis of TxB₂ in hopping vs. nonhopping rabbits showed higher TxB₂ levels in the nonhopping rabbits. Also, it appears that rabbits with spinal cord TxB₂ levels of > 500 pg/mg protein had major neurologic deficits. Other studies have reported that carotid infusion of a TxA₂-generating system (platelet suspensions) reduced cerebral blood flow and precipitated a stroke-like condition in rabbits. 29

Since AA metabolites are produced de novo, these data suggest that PG levels may represent the function-
ischemia\textsuperscript{36} and the increase in 5-HETE (a 5-lipoxygenase metabolite) during reperfusion after spinal cord ischemia in rabbits.\textsuperscript{37}

During the 18–24 hour period, we observed an increase in the number of necrotic neurons, which may be responsible for the increased fluid accumulation due to osmotic differences between the blood and tissue.\textsuperscript{38} However, the increase in tissue water may also increase tissue pressure, resulting in a concomitant decrease in local microcirculatory blood flow. Interestingly, the number of necrotic neurons increased over time, from the intermediate to intermediate–dorsal to VH regions of the spinal cord. This agrees with studies in which normal spinal cord blood flow was reported to be highest in the intermediate gray region with progressively lower values in the intermediate–dorsal to the VH and may reflect the sensitivity of neurons in

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{figure6.png}
\caption{A. Tissue edema measured as specific gravity in different regions of the rabbit spinal cord subjected to 25 minutes of aortic occlusion. Tissue water content temporarily increased in ventral horn, dorsal white, and ventral white but returned to normal levels by 4 hours. At 18 hours, tissue water content was significantly increased in the ventral horn followed by significant increases in all regions by 24 hours after reperfusion. (\textit{p}<0.05, **p<0.01, ANOVA followed by Dunnett's test). B. Composite graph of edema (Figure 6A) and neurologic score (Figure 1B) during the 24-hour reperfusion period. The pattern of tissue edema changes in each region of the spinal cord followed the pattern of neurologic changes. Neurologic score as median values.}
\end{figure}

\begin{figure}[h]
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\includegraphics[width=0.4\textwidth]{figure7.png}
\caption{A. The major histopathologic changes after 25 minutes of aortic occlusion in rabbits were neuronal necrosis and vacuolation of the neuropil (edema formation) in the lumbar spinal cord. Lesions at 24 hours in the dorsal and ventral horns and intermediate gray matter. Hematoxylin and eosin stain, bar = 300 \textmu m. B. Neuronal necrosis indicated by arrows. Micrograph of the intermediate gray matter after 24 hours of reperfusion. CC, central canal; hematoxylin and eosin stain, bar = 50 \textmu m. C. Vacuolation of the neuropil indicated by arrows, necrotic neurons indicated by arrowheads. Micrograph of the ventral gray matter after 24 hours of reperfusion. Hematoxylin and eosin stain, bar = 50 \textmu m.}
\end{figure}
these regions to blood flow changes. The histopathologic changes observed in this model during the first 24 hours after ischemia are reported here for the first time. Several rabbits were also followed to 7 days, and the histopathologic changes such as neuronal necrosis, edema, etc., were similar to those reported by DeGirolami and Zivin.

In summary: This study describes a model with continuous deterioration of motor function during reperfusion after an initial ischemic insult. This deterioration is associated with increased tissue edema and increased formation of TxA₂. However, the relations of the increased TxA₂ to tissue edema, histopathologic changes, and late functional deficits need further investigation.

Acknowledgments

We wish to thank Ms. Debbie Anderson and Ms. Sharon Nagle for their skillful technical assistance. We also thank Ms. Leslie S. Watts and Mrs. Laura L. Garza for preparing this manuscript.

Table 4. Neurologic and Histopathologic Scores Observed in Rabbit Spinal Cord After 25 Minutes of Ischemia

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<thead>
<tr>
<th>Neurologic after reperfusion</th>
<th>Pathologic after reperfusion</th>
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<td>4 hrs</td>
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Hindlimb motor function and histopathology scores based on ordinal scoring methods (see "Materials and Methods"). Association between scores was highly significant by Spearman's rank correlation test ($r_s = 0.642, p < 0.01, n = 23$).

References

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**Key Words** • prostaglandins • thromboxane • stroke • edema • rabbits
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