Responses of Isolated Dog Cerebral and Peripheral Arteries to Prostaglandins after Application of Aspirin and Polyphloretin Phosphate

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SUMMARY In helically cut strips of dog cerebral, coronary, mesenteric and femoral arteries, the contractile response to prostaglandin (PG) E\textsubscript{2} and F\textsubscript{2\alpha}, relative to contractions induced by 30 mM K\textsuperscript{+}, did not appreciably differ, whereas relaxations induced by PGE\textsubscript{1} relative to those induced by 10\textsuperscript{-4} M papaverine were significantly different; the least in cerebral arteries and the greatest in mesenteric arteries. The relaxation of human cerebral arteries in response to PGE\textsubscript{1}, was similar to that of dog cerebral arteries. Treatment for 60 min with polyphloretin phosphate (3 × 10\textsuperscript{-5} and 10\textsuperscript{-4} M) suppressed the contractile response to PGF\textsubscript{2\alpha} and E\textsubscript{2}, but did not alter the response to 25 mM K\textsuperscript{+}. The relaxing effect of PGE\textsubscript{1}, was not influenced. Aspirin (5 × 10\textsuperscript{-4} and 2 × 10\textsuperscript{-4} M) significantly potentiated the contractile response to PGF\textsubscript{2\alpha} and E\textsubscript{2}, but did not alter the relaxation induced by PGE\textsubscript{1}. In contrast, relaxations induced by serotonin were attenuated. It is concluded that dog cerebral, coronary, mesenteric and femoral arteries relaxed differently in response to PGE\textsubscript{1}. It appears that arterial responses to vasoconstricting PGs, but not to the vasodilating PG, are significantly attenuated by polyphloretin phosphate and potentiated by aspirin.

PROSTAGLANDINS (PGs) induce changes in systemic blood pressure, regional blood flow and tone of vascular smooth muscle. Alterations induced by a variety of PG derivatives differ markedly, and even the same PGs sometimes elicit opposite actions on vessels from various species. Different responses of cerebral vessels to PGE\textsubscript{1} and E\textsubscript{2} have been reported,\textsuperscript{1-4} however, it is generally agreed that PGF\textsubscript{2\alpha} causes constriction in cerebral vessels.

The ability of polyphloretin phosphate (PPP) to antagonize the effect of PGE\textsubscript{2} on intracellular pressure was first demonstrated by Beitch and Eakins.\textsuperscript{5} PPP does not antagonize all actions of PGs on uterine, tracheal and bronchial smooth muscles.\textsuperscript{6-10} Aspirin-like anti-inflammatory agents inhibit the biosynthesis of PGs in isolated tissues and whole animals,\textsuperscript{11,12} but the interaction between PGs and aspirin or indomethacin, related to responses of vascular smooth muscles, has not been clarified.

The present study was undertaken to compare the actions of PGE\textsubscript{1} and E\textsubscript{2} on isolated dog cerebral arteries with their actions on coronary, mesenteric and femoral arteries and to analyze the antagonistic action of PPP in these arteries. Alterations in the response of the arteries to PGs after aspirin and indomethacin application were also investigated.

Methods

Mongrel dogs of both sexes, weighing 7 to 15 kg, were anesthetized with intraperitoneal injections of sodium pentobarbital in a dose of 50 mg/kg and sacrificed by bleeding from common carotid arteries. The brain and heart were rapidly removed. Basilar and middle cerebral arteries (0.5 to 0.8 mm outside diameter) and ventral interventricular branches of the left coronary artery (0.6 to 0.9 mm) were isolated. Distal portions of the mesenteric (0.5 to 0.8 mm) and femoral arteries (0.5 to 0.8 mm) were also removed. The arteries were helically cut into strips, the length being approximately 20 mm. The specimen was vertically fixed between hooks in a muscle bath containing nutrient solution, which was maintained at 37 ± 0.5°C and aerated with a mixture of 95% O\textsubscript{2} and 5% CO\textsubscript{2}. Hooks anchoring the upper end of the strips were connected to the lever of a force-displacement transducer (Nihonkoden Kogyo Co., Tokyo, Japan). The resting tension was adjusted to 1.5 g, which was determined to be optimal for obtaining maximum contraction.\textsuperscript{13,14} Composition of the nutrient solution was (mM): Na\textsuperscript{+}, 162.1; K\textsuperscript{+}, 5.4; Ca\textsuperscript{++}, 2.2; Mg\textsuperscript{++}, 1.0; Cl\textsuperscript{−}, 159.0; HCO\textsubscript{3}−, 14.9 and dextrose, 5.6. The pH of the solution was 7.2 to 7.3. Osmotic adjustment was not made when K\textsuperscript{+} (up to 30 mM) was added to the bathing media. Before the start of experiments, all preparations were allowed to equilibrate for 90 to 120 min in the control media during which time the fluids were replaced every 15 to 20 min.

Seven human cerebral arteries (4 intracranial internal carotid and 3 basilar) were obtained during autopsy from 4 humans, 50-, 61-, 65- and 81-year-old males, within 8 hours after death. The causes of death were lung cancer, peritoneal carcinomatosis, and urinary bladder cancer. Human arteries were cut into helical strips, which were fixed at a resting tension of 2 g in the bathing media, as described above.

Isometric contractions and relaxations were recorded on an ink-writing oscillograph (Sanei Sokki Co., Tokyo, Japan). The contractile response to 30 mM K\textsuperscript{+} was first obtained. PGs and serotonin were added directly to the bathing media in cumulative concentrations, and relaxations relative to those induced by 30 mM K\textsuperscript{+} are presented. Arterial strips were contracted with either PGF\textsubscript{2\alpha} or K\textsuperscript{+} before the addition of PGE\textsubscript{1}. Relaxations induced by 10\textsuperscript{-4} M papaverine were taken as 100% and relaxations induced by PGE\textsubscript{1}, relative to papaverine-induced relaxations are...
presented. Preparations were exposed for 60 min to PPP or for 20 min to other blocking agents, before the dose-response curve of PGs was obtained. Results shown in the text and figures represent mean values ± standard errors of the means. Statistical analyses were made using the Student’s t-test. Drugs used were PGA₂, A₂, E₂, and F₂a (Ono Co., Osaka, Japan), serotonin creatinine sulfate, acetyl salicylic acid (aspirin), indomethacin, sodium polyphloretin phosphate (PPP), chlorpheniramine maleate, phenotolamine mesylate, methysergide bimaleate, dl-propranolol hydrochloride, atropine sulfate, cimetidine, aminophylline and papaverine hydrochloride.

**Results**

Responses of Different Arteries to PGs

In helically cut strips of dog cerebral, coronary, mesenteric and femoral arteries, the addition of PGF₂α in concentrations ranging from 10⁻⁷ to 10⁻⁴ M caused a dose-related contraction (fig. 1, left). Further increase in the concentration above 5 × 10⁻⁵ M relaxed the arterial strips by 20 to 35%, as compared with the maximum contraction induced at 10⁻⁵ M. The dose-response curve found for cerebral arteries was almost identical with the curves from other arteries. In 4 out of 16 cerebral, 3 out of 16 coronary and 2 out of 14 mesenteric arteries, slight and transient relaxation was observed in response to 2 × 10⁻⁸ and 10⁻⁷ M PGF₂α. In the remaining preparations, even though contracted with serotonin or K⁺, no relaxation was obtained.

The addition of PGE₂ (2 × 10⁻⁸ to 10⁻⁴ M) also elicited dose-dependent contractions; the maximum contraction was attained at 10⁻⁴ M (fig. 1, right). Dose-response relationships in cerebral, coronary, mesenteric and femoral arteries were similar, although the highest concentration of PGE₂ (10⁻⁴ M) produced greater contractions in femoral than in cerebral arteries (P < 0.02).

In 2 human cerebral arteries, PGF₂α and E₂ produced a dose-related contraction. PGA₂, and A₂ (10⁻⁷ to 10⁻⁴ M) caused contractions in isolated dog cerebral, coronary and mesenteric arteries. Maximum contraction of cerebral arteries induced by 10⁻⁴ M PGA₂, A₂, F₂α, and E₂, relative to those induced by 30 mM K⁺, averaged 53.1 ± 5.6% (N = 16), 56.0 ± 8.1% (N = 13), 60.8 ± 6.1% (N = 16) and 73.4 ± 8.4% (N = 14), respectively.

The addition of PGE₁ failed to contract cerebral (N = 2), coronary (N = 5), mesenteric (N = 2) and femoral arteries (N = 2). PGE₁ (2 × 10⁻⁸ to 10⁻⁴ M) relaxed arteries contracted with PGF₂α in a dose-dependent manner (fig. 2, left). Different responses of a basilar arterial strip to PGF₂α, E₁, and E₂ are demonstrated in figure 3. At 10⁻⁴ M PGE₁ caused slight contractions in 6 out of 13 mesenteric arteries.

![Figure 1](http://stroke.ahajournals.org/)

**Figure 1.** Dose-response curves of PGF₂α and E₂ for isolated dog cerebral, coronary, mesenteric and femoral arterial strips. Contraction induced by 30 mM K⁺ was taken as 100%; mean absolute values in cerebral, coronary, mesenteric and femoral arteries were 978 ± 139 mg (N = 16), 1486 ± 123 mg (N = 16), 2174 ± 228 mg (N = 14) and 1246 ± 158 mg (N = 6), respectively (left figure), and those were 872 ± 139 mg (N = 14), 1512 ± 123 mg (N = 13), 1850 ± 237 mg (N = 12) and 1368 ± 225 mg (N = 5), respectively (right figure). Vertical bars represent standard errors of means. Figures in parentheses indicate the number of preparations used.
An increase in the concentration to $5 \times 10^{-6}$ M caused additional contractions in mesenteric and slight contractions in the other arteries.

The relaxation induced by PGE$_1$ was significantly greater in mesenteric than in cerebral arteries. The relaxing effect on cerebral arteries did not differ in basilar and middle cerebral arteries. The average relaxations induced by $5 \times 10^{-4}$, $2 \times 10^{-4}$ and $10^{-4}$ M PGE$_1$ were $15.9 \pm 4.1$, $41.1 \pm 4.6$ and $56.7 \pm 4.9\%$, respectively (N = 18), in basilar arteries, and $12.9 \pm 7.5$, $51.1 \pm 5.4$ and $61.1 \pm 5.8\%$, respectively (N = 8), in middle cerebral arteries. Similar dose-dependent relaxations were observed in human cerebral arteries contracted with PGF$_{2\alpha}$ (fig. 2). In 7 out of 24 cerebral and 11 out of 23 coronary arteries, slight but significant contractions were produced at low concentrations ($2 \times 10^{-4}$ and $10^{-4}$ M) of PGE$_1$. In contrast, such contractions were not observed in mesenteric and femoral arteries.

Relaxation in response to PGE$_1$ was also found in coronary arteries contracted with K$^+$ (10 to 15 mM).

**Figure 2.** Dose-response curves of PGE$_1$ for isolated dog cerebral, coronary, mesenteric and femoral arteries and human cerebral arteries. Left figure: preparations were contracted with PGF$_{2\alpha}$, $5 \times 10^{-5}$ to $3 \times 10^{-4}$ M. Right figure: coronary arterial strips were contracted with either K$^+$ (10 to 17 mM) or PGF$_{2\alpha}$. Relaxation induced by $10^{-4}$ M papaverine was taken as 100%. Mean absolute values in cerebral, cerebral (human), coronary, mesenteric and femoral arteries were $672 \pm 86$ mg (N = 24), $1753 \pm 299$ mg (N = 7), $840 \pm 72$ mg (N = 23), $602 \pm 87$ mg (N = 13) and $702 \pm 79$ mg (N = 8), respectively (left figure), and those in coronary arterial strips contracted with PGF$_{2\alpha}$ and K$^+$ were $840 \pm 72$ mg (N = 23) and $771 \pm 217$ mg (N = 8), respectively (right figure).

**Figure 3.** Comparison of dose-related responses to PGF$_{2\alpha}$, E$_1$, and E$_2$ of a dog cerebral arterial strip. Concentrations from 1 to 5: $2 \times 10^{-4}$, $10^{-4}$, $5 \times 10^{-5}$, $2 \times 10^{-5}$ and $10^{-5}$ M, respectively. Before the addition of PGE$_1$, the strip was contracted with $10^{-4}$ M PGF$_{2\alpha}$; the horizontal line just left of the bottom tracing represents the level prior to the addition of PGF$_{2\alpha}$. PA: papaverine.
However, in the $K^+$-contracted arteries, contractions seen at low concentrations of PGE$_2$ were greater and relaxations at high concentrations were significantly less, as compared with those in PGF$_{2\alpha}$-contracted arteries (fig. 2, right). Similar results were observed in 3 cerebral and 2 mesenteric arteries.

Modification by PPP of Response to PGs

Contractile responses in cerebral arterial strips to PGF$_{2\alpha}$ and E$_2$ were unaffected by $10^{-6}$ M phentolamine, $10^{-6}$ M methysergide and $10^{-6}$ M chlorpheniramine. Relaxation induced by PGE$_2$ was not affected by $10^{-6}$ M propranolol, $10^{-6}$ M atropine, $10^{-6}$ M cimetidine and $2 \times 10^{-5}$ aminophylline.

Treatment for 60 min with PPP ($3 \times 10^{-5}$ and $10^{-4}$ g/ml) attenuated the contractile response of cerebral arterial strips to PGF$_{2\alpha}$ and E$_2$ (fig. 4). Similar attenuation was observed in mesenteric arteries (fig. 5). The attenuation with PGE$_2$ was greater than that for PGF$_{2\alpha}$. The inhibition was reversed only partially by repeated washing of the preparations. PPP in a concentration of $3 \times 10^{-5}$ g/ml did not alter the contractile response of cerebral arteries to $25$ mM $K^+$ but at $10^{-4}$ g/ml significantly attenuated the response (fig. 6).

Contraction induced by low concentrations of PGE$_2$ ($2 \times 10^{-4}$ and $10^{-5}$ M) in coronary arteries, contracted with $K^+$, was unaffected by PPP ($10^{-4}$ g/ml). Relaxation induced by PGE$_2$ in coronary and mesenteric arterial strips in concentrations ranging from $2 \times 10^{-4}$ to $2 \times 10^{-4}$ M was not affected by PPP, while the response to $10^{-5}$ M PGE$_2$ was potentiated (fig. 7).

Modification by Aspirin of Response to PGs

Contractile responses of cerebral arteries to PGF$_{2\alpha}$ and E$_2$ were significantly potentiated by treatment for 20 min with aspirin ($5 \times 10^{-5}$ and $2 \times 10^{-4}$ M). This potentiation was reversed by repeated replacement of aspirin-added solutions with control fluids (fig. 8). Similar potentiation was observed in mesenteric arterial strips treated with aspirin. Contractions at $2 \times 10^{-4}$ and $10^{-5}$ M PGF$_{2\alpha}$ were $61.2 \pm 10.7\%$ and $100\%$ ($1823 \pm 213$ mg, $N = 6$), respectively, in control preparations, and $106.7 \pm 17.4\%$ and $149.8 \pm 20.0\%$, respectively, in aspirin ($2 \times 10^{-4}$ M)-treated preparations. Indomethacin ($10^{-6}$ M) was also effective in potentiating the response to PGF$_{2\alpha}$ and E$_2$. Treatment with aspirin in concentrations of $5 \times 10^{-5}$ and $2 \times 10^{-4}$ failed to alter significantly the contractile response of cerebral arteries to $25$ mM $K^+$, but attenuated the response to serotonin in a dose-dependent manner (fig. 9).

Treatment with $2 \times 10^{-4}$ M aspirin did not influence the relaxing effect of PGE$_2$ in cerebral and mesenteric arterial strips contracted with PGF$_{2\alpha}$ (fig. 10) or with $K^+$.

Discussion

The addition of PGF$_{2\alpha}$ and E$_2$ caused a dose-related contraction of isolated dog basilar and middle
MESENTERIC ART.

- Control (8)
- PPP 3x10^{-5} g/ml (8)
- After wash (4)

CEREBRAL ART.

- Control (6)
- PPP 3x10^{-5} g/ml (6)

**Figure 5.** Inhibition by PPP of the contractile response of mesenteric arterial strips to PGF_2\alpha and E_2. Contractions induced by 10^{-5} M PGF_2\alpha (left figure) or 10^{-6} M PGE_2 (right figure) in control media were taken as 100%; mean absolute values with PGF_2\alpha and E_2 were 1636 ± 221 mg (N = 8) and 1417 ± 349 mg (N = 6), respectively.

**Figure 6.** Modification by PPP of the contractile response of dog cerebral arterial strips to 25 mM K^+. The absolute contraction induced by 25 mM K^+ in control media averaged 880 ± 190 mg (N = 6).

Cerebral arteries, while PGE_1 elicited relaxations. Similar results with PGE_1 and E_2 were observed in isolated dog coronary and mesenteric arteries. It has been demonstrated that cerebral vessels are constricted by PGF_2\alpha when applied intraarterially, intravenously or topically to basilar and pial arteries. However, there is conflicting evidence concerning the cerebrovascular effect of PGE_1 and E_2. PGE_2 injected intraarterially or intravenously causes cerebral vasodilatation in dogs and cats but when applied topically causes vasoconstriction in cats. Yamamoto et al. have demonstrated that PGE_1 decreases cerebral blood flow in dogs, but Steiner et al. and Nakano et al. found the opposite in humans and dogs. Allen et al. have shown a PGE_2-induced contraction of isolated cerebral arterial segments from humans and dogs, while the present study demonstrated marked relaxation of dog as well as human cerebral arteries in response to PGE_1. Such an inconsistency in the response of cerebral vessels to PGE_1 is not believed to be due to species difference but possibly to the ability of PGE_1 to induce both contraction and relaxation. In approximately one-third of the cerebral arterial preparations, PGE_1 in low concentrations induced slight but significant contractions. At the highest concentration used (10^{-5} M), contractile
**Figure 7.** Modification by PPP of the relaxation of coronary and mesenteric arterial strips induced by PGE$_1$. Preparations were contracted with K$^+$ (10 to 17 mM). Relaxation induced by $10^{-4}$ M papaverine was taken as 100%; mean absolute values in control and PPP-treated preparations were 983 ± 195 mg ($N = 4$) and 1283 ± 217 mg ($N = 4$), respectively, in coronary arteries, and 661 ± 67 mg ($N = 7$) and 983 ± 119 mg ($N = 7$), respectively, in mesenteric arteries.

**Figure 8.** Potentiation by aspirin of the contractile response of dog cerebral arterial strips to PGF$_{2\alpha}$ and E$_2$. Contractions induced by $10^{-5}$ M PGF$_{2\alpha}$ (left figure) or $10^{-4}$ M PGE$_1$ (right figure) in control media were taken as 100%; mean absolute values with PGF$_{2\alpha}$ and E$_2$ were 1191 ± 279 mg ($N = 7$) and 871 ± 254 mg ($N = 6$), respectively. Preparations were exposed for 20 min to aspirin before the addition of PGF$_{2\alpha}$ and E$_2$. 
responses appear to be masked by marked relaxation, since treatment with PPP potentiated the relaxation.

The dose-response curve of PGF$_{2\alpha}$ and E$_{2}$ in dog cerebral arteries is similar to the curves for coronary, mesenteric and femoral arteries. Similar dose-related contractions have been demonstrated by Strong and Bohr$^{18}$ with isolated dog peripheral arteries. In contrast, PGE$_{1}$-induced relaxation relative to that induced by papaverine differed in different arteries. Relaxation of dog as well as human cerebral arteries by PGE$_{1}$ was less than for dog mesenteric arteries. It seems unlikely that the lower degrees of relaxation are associated with the ability of PGE$_{1}$ to contract cerebral arteries to a greater extent, since the relaxing effect of PGE$_{1}$ ($5 \times 10^{-9}$ to $2 \times 10^{-6}$ M) was not significantly influenced by treatment with aspirin or PPP. These were demonstrated in the present study to potentiate or attenuate the response to vasoconstricting PGs, respectively. Further, the difference in PGE$_{1}$-induced relaxation is not due to the relative unresponsiveness of cerebral arterial strips to vasodilating agents, since NaNO$_{2}$, adenosine and papaverine cause
Cerebroarterial relaxation to a similar or even greater extent than those of peripheral arteries. 19, 20

Contractile responses to PGE_{2a} and E_{2} were not reduced by phentolamine, methysergide and chlorpheniramine, suggesting that alpha-adrenergic, serotoninergic and histaminergic H_{3} mechanisms are not involved. These results are consistent with those of Strong and Bohr. 21 Relaxation induced by PGE_{2} was not attenuated by propranolol, atropine, cinetidine and aminophylline, suggesting that beta-adrenergic, cholinergic, histaminergic H_{3} and adenosine-related mechanisms are not involved. PPP suppressed the response to PGF_{2α} and E_{2} in a dose-dependent manner, while this antagonist failed to alter the contractile effect of K^{+}. Specific antagonism of PPP to actions of PGF_{2α} and E_{2} has been demonstrated in isolated rabbit intestine, guinea pig, rat, rabbit and monkey uterus. 22, 23 and human bronchus. 10 However, the response of human umbilical cord to PGE_{2} is not necessarily the same, because a PG derivative, 7-oxa-13-prostynoic acid, in concentrations sufficient to reduce the response to PGE_{2} fails to alter the response to PGF_{2α}. 24 On the other hand, relaxations induced by PGE_{2} were not influenced by PPP, except the relaxation at 10^{-9} M, which was potentiated, possibly due to an attenuation of the contractile response. It may be concluded that responses to vasoconstricting PGs (PGF_{2α}, E_{2} and E_{2} except for the contraction induced by low concentrations of PGE_{2}) are specifically antagonized by PPP but the response to vasodilating PGs is not influenced.

Aspirin and indomethacin, PG synthesis inhibitors, in concentrations sufficient to inhibit responses of isolated cerebral arteries to bradykinin 25 potentiated the contractile response to PGF_{2α} and E_{2} but did not influence the relaxing effect of PGE_{2}. Treatment with these concentrations of aspirin failed to alter the contraction induced by K^{+} but attenuated the contractile effect of serotonin. These findings indicate that aspirin and indomethacin specifically potentiate the action of vasoconstricting PGs but not the action of vasodilating PGE_{2}. It has been postulated that probenecid, indomethacin and aspirin interfere with the active transport of PGs across cell membranes of kidney slices. 26, 27 where PGs are metabolized. 28 The potentiation by aspirin as well as indomethacin may be associated with an interference with the metabolism of PGs in arterial smooth muscle cells. Whether the metabolism and the interference by these agents with the metabolism in arteries are observed only with PGF_{2α} and E_{2} but not with PGE_{2} remains to be determined. Further, 15-hydroxyprostaglandin dehydrogenase, which inactivates PGs including E_{2}, 29 is inhibited by aspirin and indomethacin. 30 However, the potentiation of contractile responses to PGF_{2α} and E_{2} may not be related to the inhibition of the enzyme, since the response to PGE_{2} was unaffected.

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References

Cerebral Arterial Lesions Resulting from Inflammatory Emboli

Robert A. Foote, M.D., Thomas J. Reagan, M.D., and Burton A. Sandok, M.D.

SUMMARY In order to study the effects of septic embolism on the brain, silicone rubber emboli of various types were injected into the carotid arteries of 35 dogs. Pathologic and angiographic studies were performed to assess the resultant arterial and parenchymal lesions.

Pure silicone rubber emboli (14 dogs) produced occasional intra-arterial thrombosis but no arteritis. Sterile and bacterially contaminated emboli containing a lead-chromate pigment (similar to those used in previous studies of septic embolism) (11 dogs) and pure silicone rubber emboli with transversely oriented canals (10 dogs), after brief placement in a bacterial suspension, were associated with intense inflammatory arteritis. This was accompanied by focal meningeitis, subarachnoid hemorrhage, thrombosis, and cerebritis of the underlying cortex. The findings resembled those found in mycotic aneurysm. Aneurysmal dilatation was observed in one postmortem angiogram.

In previous models of mycotic aneurysm, the inflammation attributed to bacterial contamination was probably due to the lead-chromate pigment used.

INJECTION of artificial emboli into the cerebral circulation has often been utilized as a means of producing experimental cerebral infarction. Emboli used have included autologous blood clots,1 steel ball bearings,2 psyllium seeds, pigmented silicone rubber compounds with and without a coating of bacteria,3,4 barium-impregnated silicone spheres,5 and others. These studies usually have reported examinations of the resultant parenchymal lesions but little attention has been given to examination of the arterial lesions produced by the emboli. Molinari and associates,6 in their report describing experimentally produced aneurysms, noted possibilities of arteritis secondary to the pigment. Prostaglandin analogues and by some inhibitors of organic ion transport. J Pharmacol Exp Ther 198: 481-488, 1976

Molinari's technique, were premedicated with intravenous injections of pentobarbital (32 mg/kg of body weight) and, similarly to Molinari's technique, were anesthetized with intravenous injections of pentobarbital (32 mg/kg of body weight) and, similarly to Molinari's technique, were premedicated with intramuscular injections of 10,000 μg each of procaine and benzathine penicillin G. Under sterile conditions, a longitudinal incision was made in the anterolateral portion of the neck and the common carotid and internal carotid arteries were identified. The internal carotid artery was ligated at its origin and a 16-gauge catheter was introduced into it via a transverse arteriotomy. An embolus was then flushed through the catheter with approximately 5 ml of sterile normal saline solution, after which the artery was ligated distally and the catheter was removed.

Emboli were of 3 types: microfil emboli, solid elastic emboli, and canulated Silastic emboli (fig. 1). These emboli were produced as follows:
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