Cranial Arterial Circulation and Ocular Pulsations in the Dog

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Abstract:
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The form of the ocular pulse in anesthetized dogs resembled an arterial pressure tracing. Obstructing the carotid artery reduced the amplitude of the pulse in the ipsilateral eye, but if collateral circulation through the basilar artery remained intact, the pulse soon returned to normal. Division of the basilar artery by itself temporarily increased the pulse amplitude in both eyes, probably reflecting increased collateral circulation through the carotid arteries. A 14% reduction in carotid blood flow or a 4% reduction in carotid blood pressure reduced the amplitude of the ocular pulse by 10% in dogs.

ADDITIONAL KEY WORDS
carotid occlusion collateral circulation experimental arterial occlusion

Circulation in the retinal artery has been studied by a variety of methods in patients with cerebrovascular insufficiency, but little attention has been paid to the pulsations of the eye itself. Only a few clinical studies have been reported (1-3), and we are aware of only one other study on the effects of division of a major cranial artery on ocular pulsations in animals (4). This report is based on a study in dogs in which circulation in the carotid and basilar artery was interrupted and the effects on ocular pulsation observed. Graded occlusion permitted flow and pressure in the carotid artery to be correlated with the amplitude of the ocular pulse.

Methods
Mongrel dogs were lightly anesthetized with sodium thiopental, intubated, and mechanically ventilated with a mixture of oxygen and methoxyflurane. Prior to recording ocular pulsations the animals were paralyzed with gallamine triethiodide and the respirator temporarily stopped to reduce motion artifacts in the recordings.

Pulsations of both eyes were measured simultaneously from hollow hemispherical aluminum cups held against the cornea by suction of 40 cm of water, as suggested by Galin (5, 6). The cups had an internal diameter of 7 mm, an external diameter of 8.5 mm, and a maximum depth of 5 mm. Plastic tubing with an internal diameter of 0.8 mm connected the cups to a pressure transducer which was in series in the suction line (fig. 1). Exchanging the cups between the two eyes minimized errors from inaccurate calibration of the transducers by permitting calculation of the mean ocular pulse pressure for an eye from the value obtained with each recording system. The pressure transducers were calibrated in mm Hg, and the ocular pulse pressure is reported as such in this paper. However, since cups attached to the outside of the globe do not directly measure changes in intraocular pressure, the values which we report are best taken as arbitrary units on an interval scale.

In addition to the amplitude of the pulsation, the time interval between the peak of the R wave in the electrocardiogram and the peak of ocular pressure was measured to gauge the length of time required to transmit the pulse wave from its origin at cardiac systole to its arrival in the eye.

In one group of nine dogs, the basilar artery was divided, and in a second group of seven dogs the right common carotid artery was excised, including the origin of its principal extracranial branches, namely, the superior thyroid, greater auricular, superficial temporal, facial, lingual, internal carotid, and internal maxillary arteries. Ocular pulsations were recorded at weekly intervals thereafter for as long as ten weeks. Three additional animals were observed up to 21 weeks after ligation of the basilar artery and removal of...
The hollow aluminum cup attached to the eye by a negative pressure of 40 mm Hg. A transducer in the suction line records pressure.

FIGURE 1

The extracranial portion of the right carotid artery in two stages.

In other animals one or both of the carotid arteries were exposed and connected to a probe to measure blood flow, a pneumatic collar to occlude the artery, and a catheter introduced through the thyroid artery to measure blood pressure. Flow and pressure in the carotid artery and ocular pulsations were recorded on an oscillograph. The pneumatic collar around the artery was gradually inflated until carotid blood flow fell to zero, and then the collar was slowly deflated, restoring the flow of blood. If a shift of the baseline for blood flow occurred during the experiment, the observations were discarded.

Results

The contour of the pulsations resembled an arterial pulse and included a notch on the diastolic slope of the curve (fig. 2). The mean ocular pulse pressure in the dogs prior to any surgery was 0.64 mm Hg (SD 0.23), and the peak pulse pressure was delayed 0.25 second (SD 0.04) after the T wave of the electrocardiogram. In response to dividing the basilar artery, the ocular pulse pressure rose to 1.03 mm Hg (P < 0.02), and the pulse arrived in the eyes 0.05 second late (P < 0.01). These changes lasted only a week, after which the ocular pulse pressure decreased to below control values (0.55 mm Hg; P < 0.02) and the delay in arrival of the ocular pulse disappeared. Excision of one carotid artery and the origin of its principal branches decreased the ocular pulse pressure to 0.49 mm Hg in the ipsilateral eye and increased pulse pressure to 0.82 mm Hg in the contralateral eye. Neither of these changes was significantly different from the control values, but the differences in pressure between the two eyes was highly significant (P < 0.01). The reduced pressure in the ipsilateral eye lasted for a week after occlusion of the carotid artery, and by the second week any difference between the two eyes was statistically insignificant. However, if dogs were deprived of

FIGURE 2

Ocular pulsations in a normal, anesthetized dog. Amplitude is 1 mm Hg, and the peak pulse pressure is delayed 0.28 second after the QRS complex.
CRANIAL ARTERIAL CIRCULATION

FIGURE 3

The relationship between ocular pulse pressure and blood flow in the ipsilateral carotid artery. Each point represents the mean of several trials in a single animal. A total of eight animals were employed.

collateral blood flow in the basilar artery prior to occluding one carotid artery, the difference between the pulse pressure of the two eyes remained significant for many weeks.

Figure 3 shows the effect of reducing the flow of blood in the carotid artery on the pulse amplitude in the ipsilateral eye expressed in the per cent change from control values. The data are based on studies in eight animals and show that a 10% reduction in blood flow reduced ocular pulsations by 8%.

The correlation between pressure in the carotid artery and ocular pulse amplitude in four dogs is shown in figure 4. In this plot the per cent reduction in pressure in the ipsilateral carotid artery and eye was calculated from simultaneously measured pressures in the contralateral artery and eye. A decrease in blood pressure of 10% reduced the ocular pulse amplitude by about 22%.

Discussion

The observation that the choroid has 37 times the blood volume as the retina suggests that the choroid is primarily responsible for the ocular pulse, rather than the retinal arteries (7). Oculosphygmography reflects change in the shape of the globe as the eye pulsates and thereby differs from ophthalmodynamometry, which estimates pressure in the retinal artery. Since both the retina and the choroid depend on a blood supply from the carotid artery, carotid insufficiency can be expected to have similar effects on both tests.

Oculosphygmography should not be confused with suction ophthalmodynamometry, as recently described by Galin et al. (5). In their technique enough negative pressure is applied to the suction cup to distort the globe and block the flow of blood in the retinal arteries. In the present study gentle suction was employed, which held the cups in place and allowed ocular pulse to be transmitted to the recording apparatus.

In the dog carotid ligation immediately dampens the amplitude of the ocular pulse and lengthens the time necessary to transmit the pulse to the eye from the heart. The dog's excellent collateral circulation soon compensates for insufficiency of a single carotid artery and returns the ocular pulse to normal. In order for carotid ligation to dampen ocular pulsations permanently, the rich supply of blood provided by the basilar artery must also be interrupted. The relationship between the rate of blood flow and pressure in the carotid artery and the ocular pulse amplitude appears linear in the dog and does not vary greatly between animals.

The effects of carotid ligation no doubt
vary with the species. The immediate result in the rabbit is a fall in ocular pulse pressure, as it is in the dog, but the chronic effects are unknown (4).

Acute obstruction of the carotid artery in man has been shown to reduce the pressure in the ipsilateral retinal artery, and collateral circulation is often inadequate to return the pressure to normal, even after a prolonged interval of time. This effect is probably due to the fact that the carotid arteries supply nine-tenths of the total cerebral blood flow in man (8), whereas in the dog the basilar arterial flow at least equals that in the carotid arteries.

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