Title
Cerebral circulation: Response to visual deprivation

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Reversible responses of the cerebral circulation to visual deprivation

Cerebral blood circulation has long been thought to be of paramount importance for brain development[9,12]. How does this blood flow exert its influence? The high requirement of cerebral tissue for glucose and oxygen suggests that the rate at which these nutrients are supplied to the brain may affect subsequent development.

Previous work from our laboratory using newly hatched chicks has shown that as early as 1 h after monocular eyelid suturing, significant deficiencies in the circulation through contralateral brain regions can be observed[5]. The present study reports on the reversibility of this impaired cerebral blood flow in both newly hatched and older birds.

The advantages of this system are: (1) The complete decussation of the avian optic tract in conjunction with the absence of major interhemispheric commissures reduces interactions between the two halves of the brain[7]. (2) Metabolic deficits caused by monocular visual deprivation are largely confined to regions contralateral to the sutured eye[4,8]. (3) The avian brain is symmetrical with no left or right dominance[6]. (4) Regions of the brain that are primarily or secondarily innervated by the sutured eye can be compared to the corresponding unimpaired regions in the same animal. Thus, differences observed between paired experimental and control regions cannot be attributed to systemic hormonal variations (which should affect both regions equally) and thus must be directly caused by the experimental procedure. (5) By the use of paired regions within a single animal rather than paired individual animals, small differences can readily be distinguished.

[4-^{125}I]Iodoantipyrine has been shown to be rapidly diffusible within body tissues[2]. In addition iodoantipyrine reaches a stable level in the brain of rats within 6 sec after injection and maintains this level for over 1 min[1,10]. It can therefore be used to estimate the relative distribution of cardiac output to paired regions of the brain[5].

After various periods of monocular eyelid suture, groups of 8–16 New Hampshire chicks were injected intracardially with 0.1 ml saline containing 19–38 μCi of [4-^{125}I]iodoantipyrine. Ten sec after this injection the birds were decapitated and individual cerebral hemispheres and optic lobes dissected out on ice. These regions were then rapidly weighed and placed in glass scintillation vials. NCS tissue solubilizer (obtained from the Amersham–Searle Corp., Arlington Heights, Ill.) was added and the tissues dissolved over several hours at 70 °C. After cooling, 10 ml of scintillation solution consisting of toluene containing 0.5% 2-phenyl-(5-biphenyl-2-yl)-1-oxa-3,4--diazole and 0.01% 1,4-bis-(5-phenyloxazol-2-yl) benzene was mixed into each sample and radioactivity assayed.

Probability of these internally paired sets of data was calculated by one-tailed t-test with differences where $P < 0.05$ taken as significant.

In experiments using chicks which had been monocularly sutured 1 day after hatching, optic lobes contralateral to the sutured eye exhibited a significantly reduced rate of blood flow relative to the ipsilateral lobes at all times studied (Fig. 1a). However, within 1 h after suture removal, any significant difference between visual and deprived lobes was lost (Fig. 1a).

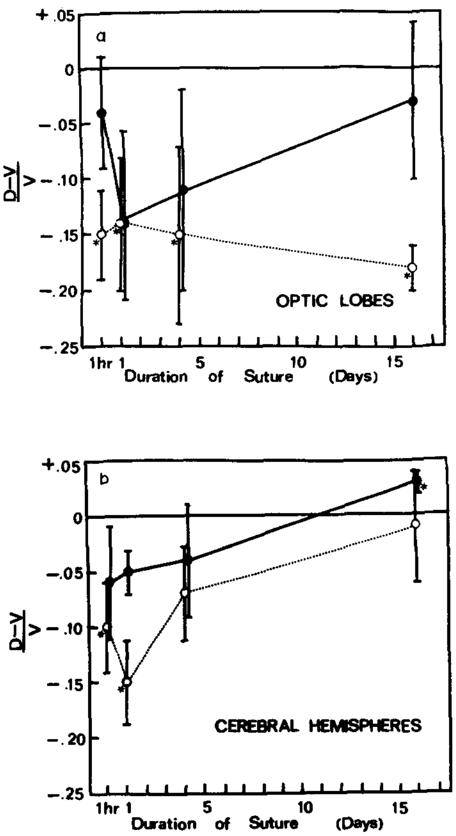

Fig. 1. Reversibility of cerebral blood flow deficits incurred during visual deprivation. Day old chicks were monocularly sutured and blood perfusion rates within (a) optic lobes and (b) cerebral hemispheres, estimated at various times (○——○). This was also assayed in chicks whose sutures had been removed for the hour preceding assay (●——●). V = counts/min/mg tissue of region contralateral to sutured eye (visual side). D = counts/min/mg of region ipsilateral to sutured eye (deprived side). Vertical bars indicate standard error of the mean. * $P < 0.05$.

In cerebral hemispheres a significant difference in blood flow between visual and deprived regions was also observed within 1 h after suturing. Unlike the observations in the optic lobes this effect was not maintained beyond 1 day (Fig. 1b). Again, within 1 h after suture removal an increase in blood flow to the previously deprived hemispheres could be observed. After 16 days of suture this 1 h reversal resulted in a significantly *greater* blood flow to the previously deprived cerebral hemispheres, relative to corresponding visual regions (Fig. 1b).

Parallel studies using more mature chicks sutured at 15 days after hatching also revealed a differential in blood flow between visual and deprived cerebral regions which developed within 1 h after suturing (Table I). This differential was maintained in both cerebral hemispheres and optic lobes for 2 days. Within 1 h of suture removal, however, this effect was lost. In the case of cerebral hemispheres in birds sutured for

TABLE I

CEREBRAL BLOOD FLOW DURING AND AFTER VISUAL DEPRIVATION

15-day-old chicks were monocularly sutured and the velocity of regional blood flow determined 1 h and 2 days after suturing, or 1 h after suture removal. V, D, as in Fig. 1. Standard errors of the mean follow each value. * $P < 0.05$.

	Continuous suture	*Unsutured for 1 h*
Optic lobes		
1 h suture	—0.14 ± 0.03*	+0.04 ± 0.05
2 day suture	—0.23 ± 0.03*	+0.07 ± 0.04
Cerebral hemispheres		
1 h suture	—0.11 ± 0.04*	+0.01 ± 0.03
2 day suture	—0.16 ± 0.07*	+0.06 ± 0.02*

2 days, a significant reversal in blood flow differences was found following suture removal (Table I).

Sokoloff has reported increased blood flow in the visual cortex of the cat occurring in response to retinal illumination[11]. Our data show that loss of patterned visual input reversibly reduces cerebral circulation within the primary visual area (visual lobe) and the secondarily innervated associative area (cerebral cortex). Rapid reversal, even over-compensation of blood flow deficits, suggests that there are no differences in the capillary bed development of visual and deprived sides of the brain.

Relative maturity of the animal does not reduce either the attainment or reversal of blood flow differences, indicating that the control of cerebral circulation remains plastic and rapidly responsive. However, impaired brain development following monocular suture previously reported[3] could result from chronically decreased blood flow during crucial growth periods. Cerebral blood flow may be a means by which sensory input modulates brain development.

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