RELATIONSHIP BETWEEN CORTICAL ELECTRICAL ACTIVITY AND MEAN ARTERIAL BLOOD PRESSURE DURING SLAUGHTER OF CALVES

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SUMMARY

Jugular blood flow was assumed to reflect cerebral blood perfusion in calves after head-only electrical stunning and throat cutting. In 10 of 12 animals the jugular flow was 3.6 ±1.4 ml/min/100 g brain tissue, or 4.8 ±1.9% of normal. In another experiment, electrocorticograms and measurements of mean arterial blood pressures were obtained from 10 calves during electrical stunning followed by either recovery from the stun, or slaughter. In six animals an isoelectric electrocorticogram was obtained at 34.5 ± 7.2 s after the throat-cut. During slaughter, the mean arterial blood pressure reached a maximum at 10 s after the start of the stun, declining to 120 mm Hg at 60 s. The inability of the cortex to function when the systemic blood pressure is still high is explained by a retrograde blood flow from the vertebral arteries, through the occipito-vertebral anastomosis, to the head end of the cut carotid arteries.

INTRODUCTION

The monitoring of spontaneous cortical electrical activity has been widely used as a means of assessing the functional state of the cerebral cortex (e.g. Baldwin and Bell 1963; Gross 1976; Blackmore and Newhook 1981, 1983; Devine et al. 1986a, 1986b). The relationship between cerebral blood flow and spontaneous cortical activity has also been extensively investigated. For example, Baldy-Moulinier and Ingvar (1968) and Freeman and Ingvar (1968) both described a high correlation between EEG frequency and cortical blood flow. Our observation that very little blood emanates from the head-end of the severed jugular veins during halal slaughter of cattle prompted experiments to examine aspects of cerebral blood flow, systemic blood pressure and cortical function during halal slaughter of calves.

MATERIALS AND METHODS

Blood collection

Twelve calves, less than four weeks old and of mixed breed, were head-only electrically stunned (50 Hz, 400 V open circuit, current limited to 1.0 A, 4 s duration) and their throats cut at approximately 10 s post-stun. Blood was collected in pre-weighed containers from the head-end of the cut jugulars. The operation was accurately timed, using a video camera with a built-in second timer. Subsequently, the brains were removed and weighed, as were the collection vessels containing the recovered blood. The blood flow was standardized to ml blood/min/100 g brain tissue and compared with the normal blood flow in calves reported by Gardiner (1980).

ECoG-MABP experiment

Electrocorticograms (ECoG) and mean arterial blood pressure (MABP) were obtained from 10 calves of mixed breed and less than three weeks old. Three custom-made chlorided silver electrodes were implanted in the skull in a line 2 cm to the side of, and parallel with, the midline. The electrodes were placed 2, 4 and 6 cm behind a line between the lateral corners of the eyes. After the inter-electrode impedance had been measured at 100 Hz with a Wayne-Kerr Automatic Precision Bridge, dental cement was applied to hold the electrodes in place. Movement of electrode tips with respect to the cerebral surface gave rise to artefacts in the recordings from some of the animals. Therefore, the procedure for anchoring the cortical electrodes was modified in the last three animals. For five calves, the skull was opened at the conclusion of the experiment to ascertain the electrode position. Only some of the electrodes had penetrated the dura mater, resting directly on the cortex; however, this difference had no apparent effect on the quality of the recording. The recorder used was a Mingograf EEG 10 with a time constant set at 0.03 s (5.30 Hz), 0.6 s (2.67 Hz) or 1.0 s (0.16 Hz), an upper frequency limit of 30 Hz, and a sensitivity of 100 or 200 V/cm.

For blood pressure recording, a 16 gauge vialon catheter was introduced into the caudal end of the abdominal aorta through the left femoral artery and connected to a Statham P23 physiological pressure transducer. After appropriate amplification, the signal was recorded on a Watenabe MC6600 multipen chart recorder, with a time marker provided by interconnection with the Mingograf.

Table 1. Amount of jugular blood collected from calves after head-only stunning and gash-cutting.

Animal	Blood collected (g)	ml blood/ min/100 g brain[a]	% of normal[b]
1	17.5	3.2	4.3
2	16.8	3.6	4.9
3	16.6	3.7	5.0
4	79.4	29.1	39.3[c]
5	13.9	2.9	3.9
6	13.1	3.8	5.1
7	24.3	4.9	6.6
8	18.3	6.6	8.9
9	8.2	2.7	3.6
10	44.8	16.3	22.0[c]
11	6.5	2.4	3.2
12	5.2	1.8	2.4

a Specific gravity of blood given as 1.052.

b Normal cerebral blood flow is defined as 74 ml/min/100 g brain weight (Gardiner, 1980).

c Body ends of carotid arteries occluded.

Table 2. Parameters of cortical electrical activity during stun-recovery and stun-slaughter of young calves.

Animal*	Stun-recovery,	Stun-slaughter		
	Duration of fit (s)	Time of throat-cut (s post-stun)	Duration of fit (s)	Onset of isoelectric (s post-stun)
1		10**	35	35
2	34	12	22	42
3	22	9	25	ND
5	28	11	24	43
6		10	24	56
7	30		ND	ND
8	41	11	30	ND
9		11	31	49
10	24	9	22	42

* No ECoG recording was obtained from animal no. 4.

** Recut at 20 s as the carotids were not severed by first cut.

ND Not able to be determined.

The experiments were done on the day after surgery. The animals were placed in a polypropylene net, to isolate them from ground, and electrically stunned, using the same parameters as in the blood-collection experiment. Six animals were stunned, then allowed to recover and rest for 20 minutes. These animals, plus four more, were then stunned and slaughtered by a transverse section of the throat at the level of the larynx. The ECoG and MABP were recorded throughout the experiment, except that the ECoG recorder was isolated electrically during the application of the stun (4 s) to protect it.

RESULTS AND DISCUSSION

The results from the blood collection experiment are summarized in Table 1. The quantities collected from animals no. 4 and 10 were markedly higher than from the rest of the animals. It was observed at the end of the experiment that the body ends of the severed carotids had formed large clots in these two animals. The increased rate of flow, however, was evident right from the start of the collection, indicating that some factor other than clotting (for example, arterial spasm) was responsible for the increased blood perfusion, and that clotting may be secondary to this. The quantity of jugular blood collected (mean ±SD, n = 12) was 6.8 ±8.0 ml/min/100 g brain tissue, or 9.1 ±10.9 % of the normal value reported by Gardiner (1980). When the two animals with high flow are excluded from the calculation, the mean jugular flow was 3.6 ±1.4 ml/min/100 g brain tissue, or 4.8 ±1.9% of normal. The two animals with the increased blood flow did not show any subjective signs of recovering sensibility during exsanguination.

In calves, a transverse section of throat as performed in this experiment will sever the common carotid arteries just caudal to where the occipito-vertebral anastomoses are given off from these vessels. The rate of flow of a liquid along two alternative pathways is inversely proportional to the flow resistance in the two pathways, and Baldwin (1971) suggested that after carotid severance the altered pressure gradients will cause most of the flow from the vertebral arteries to pass through the anastomoses to the rostral open ends of the carotid arteries. A retrograde arterial flow was evident during blood collection as a rapid and often pulsating flow from the head end of the severed carotids.

In cattle with the vascular system intact, some of the cerebral venous blood can drain through routes other than the jugular veins. We have assumed that the pressure gradients in the venous system of the head and cranial neck during slaughter caused most of the cerebral venous drainage to occur through the jugulars and that jugular flow therefore reflects cerebral blood perfusion. If this assumption is correct, the results indicate that the basi-occipital plexus, which constitutes a direct connection between the vertebral artery and the carotid rete in cattle, does not assure that the cerebral blood flow is maintained after carotid severance.

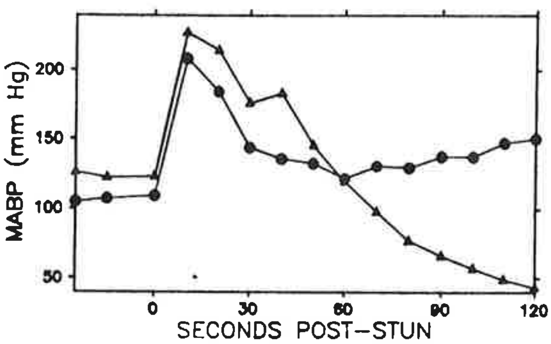

Figure 1. Mean arterial blood pressure in calves during stun-recovery (●) and stun-slaughter (▲).

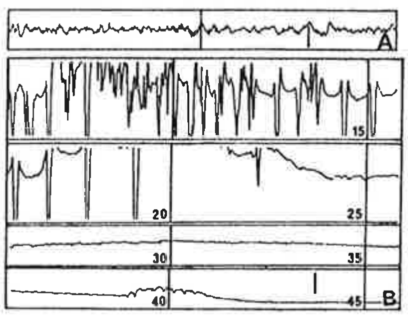

Figure 2. Animal No. 10. ECoG activity pre-stun (A) and during stun-slaughter (B). Numbers represent s post-stun. Scalebars: 350 µV. Time constant 1.0 s.

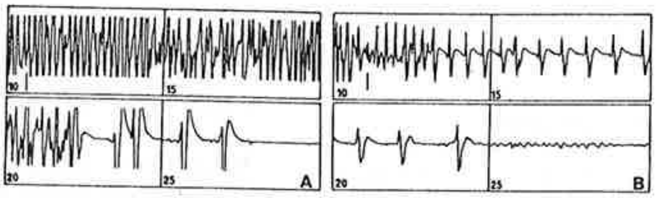

Figure 3. Animal No. 5. ECoG trace of electroplectic fit during stun-recovery (A) and stun-slaughter (B). Numbers represent s post-stun. Scale bars: 175 μV. Time constant 0.03 s.

The MABP behaved similarly during the first 30 s post-stun, whether the calves were allowed to recover after the stun or had their throats cut at 10 s (Fig. 1). The MABP increased to a maximum at 10 s after the start of the stun and declined again over the following 20 s. When animals were allowed to recover, there was then a considerable fluctuation in pressure during recovery.

The MABP was still slightly elevated when the animals were re-stunned after 20 min. During exsanguination there was a small, transient increase in MABP from 30 to 40 s post-stun, followed by a steady decline to 120 mm Hg at 60 s and 43 mm Hg at 120 s after the start of the stun.

The ECoG recordings are summarized in Table 2 and an example of a trace is given in Fig. 2.

In contrast to the electroplectic fit during stun-recovery, that observed during stun-slaughter was characterized by a progressive slowing of the high- amplitude spikes, starting 4-6 s after the throat cut was made (Figs.3A and B). It is hypothesized that this slowing is caused by failure of the cerebral blood flow.

The onset of an isoelectric trace was determined with certainty for six animals and occurred at 34.5 ± 7.2 s from the time of the throat-cut (44.5 s from the start of the stun). The time to isoelectric could not be determined with certainty in animals no. 3 and 7 because of artefacts associated with electrode movement, and in calf no. 8 because an electrode connection was faulty. In all animals, the cortical activity recorded between the end of the electroplectic fit and the isoelectric trace was characterized by moderate amplitudes, predominance of low frequencies, and almost complete absence of high frequencies. Based on these extreme changes to the ECoG, we consider that these animals did not regain sensibility during exsanguination.

CONCLUSIONS

The amounts of jugular blood that were collected indicate that cerebral blood perfusion is very severely impaired after gash-cutting. Cortical dysfunction occurred at a time when the MABP was sufficiently high to maintain cerebral circulation. We regard these findings as indirect evidence of a retrograde flow of blood from the vertebral arteries, through the occipito-vertebral anastomosis, to the open cephalic ends of the severed carotids.

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