ELECTROENCEPHALOGRAPHIC STUDIES OF THE EFFICACY OF ELECTRICAL STUNNING OF SHEEP AND CALVES

D.K. BLACKMORE and J.C. NEWHOOK

Faculty of Veterinary Science, Massey University, Palmerston North, New Zealand.

INTRODUCTION

Any animal slaughtered for human consumption must be insensible throughout the various procedures involved.

Most methods of slaughter consist of two distinct procedures: stunning and exsanguination. In all methods, exsanguination is produced by severance of major blood vessels which results inevitably in permanent insensibility and death. However, there are a variety of different stunning methods designed to produce immediate insensibility, many of which only induce a period of temporary or reversible insensibility(Blackmore, 1979).

With the full implementation in New Zealand in 1977 of EEC requirements, electrical methods were widely adopted for stunning sheep and calves. Prior knowledge of this impending legislation stimulated the authors to investigate various aspects of the slaughter process in sheep and calves (Blackmore and Newhook, 1976; Blackmore 1979; Blackmore et al, 1979). This contribution summarises extensive electroencephalographic (EEG) studies of sheep and calves in an attempt to assess the onset and duration of insensibility induced by both electrical stunning and exsanguination.

MATERIALS AND METHODS

All experiments involved both sheep and calves, and EEG recordings were obtained from unstunned animals during exsanguination and from animals stunned by the application of electrodes either to the head only or to both the head and thoracic region of the back.

The animals consisted of 29 mature Cheviot cross and Romney sheep of mixed sexes and ages (two-tooth to full mouth), five Romney lambs seven days old, and 14 calves of mixed breeds and sexes between five and ten days of age.

The animals were slaughtered by either a transverse incision of all soft tissues ventral to the vertebral column or a lateral stab incision through the neck, caudal to the larynx and dorsal to the trachea and oesophagus (Blackmore and Newhook, 1976). Both techniques were designed to sever both common carotid arteries and external jugular veins.

Animals were stunned with a commercial stunner* which delivered a 50 cycle alternating current across the electrodes of approximately 0.7 amps at 150 volts. One stunner had two electrodes which were applied to the occipital region of the head, while the other had an additional third electrode which was placed on the back in the mid thoracic region. This exerted a concurrent direct effect on the heart which usually resulted in an immediate cessation of effective cardiac function.

The EEG recording techniques and interpretation of results were developed from a series of experiments which will be described elsewhere. Three hypodermic needles (1.25mm x 30mm) were used as electrodes. The two active electrodes were inserted through the skin to lie against the calvarium over the cerebrum 10-12mm on either side of the mid line. The reference electrode was inserted along the mid line, rostal to and equidistant from the active electrodes. The EEG obtained from these electrodes was a symmetrical, transhemispheric, bipolar derivation. Shielded cables from the electrodes led to differential amplifiers and thence to an oscilloscope with moving film camera and to a tape recorder. Verbal comments also were recorded on the latter.

As an EEG is a composite record of signals of various frequencies from a large area of the cerebral cortex, frequency analysis was inappropriate. Interpretation was therefore based on the amplitude and pattern of the fast wave signals from a transhemispheric, bipolar derivation. Based on preliminary findings from animals under a wide variety of states of arousal, lower and upper limits of 10μv and 35μv were chosen outside which it could be safely assumed that sensibility was not present.

Electrocardiography (ECG) was undertaken in all animals using subcutaneous needle electrodes inserted in the thoracic wall. Blood pressure was recorded in some sheep by means of a catheter in the femoral artery and a pressure transducer.

RESULTS

ONSET OF INSENSIBILITY DURING EXSANGUINATION

Table I summarises the times of onset of insensibility and an isoelectric trace in sheep, lambs and calves during exsanguination.

(a) Adult sheep : In five of six sheep that were slaughtered without prior stunning, satisfactory bilateral severance of blood vessels was achieved. The EEG of these indicated that insensibility supervened after two to seven seconds and traces became isoelectric ('flat') after 20 to 50 s. In the sixth sheep, where the blood vessels were cut on one side of the neck only, an EEG of 18μv was recorded for 29s. During this time the animal also subjectively appeared to be aware of its surroundings. Results from twelve other sheep which were stunned by either electrical or percussive methods prior to exsanguination demonstrated similar times of onset of an isoelectric trace (23 - 59s).

* Thornton Engineering Group Ltd., Auckland.

(b) Lambs : In all five lambs, amplitudes dropped to below 10μv in 2 - 7s and became isoelectric within 10 - 25s.

(c) Calves : The results obtained from calves were markedly different from those from sheep and lambs. The mean time to estimated onset of insensibility in calves (66s) was fourteen times as long as that in sheep and lambs, and the mean time to an isoelectric EEG (242s) was ten times as long. However, the evidence provided by the traces from calves was less clear cut than that from sheep, and the possibility of even later brief episodes of sensibility cannot be excluded. In six of the eight calves, each reflex respiratory gasp was succeeded by a brief rise in EEG amplitude to a level compatible with sensibility, for more than 100s after the blood vessels had been severed.

DURATION OF INSENSIBILITY INDUCED BY STUNNING

Table II shows the duration of insensibility induced by both "head only" and "head to back" electrical stunners and the time of onset of an isoelectric trace in those animals in which concurrent cardiac dysfunction was induced by the "head to back" stunner. Sheep stunned by electrodes applied only to the head were insensible for a mean period of 33s after which they made a complete recovery. Sheep and calves stunned by electrodes applied to both head and back remained insensible until death supervened. It is interesting to note (see Table I) that the mean time at which the EEG became isoelectric in sheep which were stunned only (45s) was similar to that associated with exsanguination in both stunned sheep (42s) and unstunned sheep (34s). In calves with induced cardiac dysfunction, the mean time at which the EEG became isoelectric was 87s compared with a mean of 242s in unstunned animals during exsanguination.

It is interesting to note that the massive intracranial trauma in calves caused by a captive bolt stunner resulted in rapid cessation of any detectable EEG activity (see Table I).

DISCUSSION

Sheep stunned by application of electrodes to the head only, developed an average period of reversible insensibility of 33s. Further observations of sheep being stunned in a similar manner at abattoirs suggests that this is a rather conservative figure. Use of the stunner with concurrent automatic application of saline or warm water to increase electrical conductivity appears consistenly to induce 40-45s of insensibility in both sheep and calves. These subjective assessments of insensibility were made only when the electrically stunned animals showed the tonic and clonic muscle spasms described by Croft and Hume (1956) and gave no evidence of head raising for at least 45s when laid on the floor immediately after stunning.

An electrical stunner with both head and back electrodes was equally successful in producing immediate insensibility. It had the added advantage of causing cardiac dysfunction and thus ineffective circulation. Providing normal cardiac function does not recur, this insensibility is prolonged until death finally supervenes. ECG recordings indicated a variety of changes in cardiac function including fibrillation and patterns consistent with auricular/ventricular node block.

Further observations on several hundred sheep and calves stunned with a "head to back" stunner in abattoirs indicate that it is possible to achieve an effective stun and cardiac dysfunction in more than 99% of animals. It has also been shown that ausculation with a stethoscope is as effective as an ECG in detecting cardiac arrhythmias (Blackmore et al, 1979).

The studies on the onset of insensibility associated with exsanguination and subsequent hypoxia and anoxia of the brain revealed major differences between sheep and calves. In both adult sheep and lambs, insensibility occurred between two and seven seconds. This similarity suggests that the brain of the young lambs is no less sensitive to hypoxia than that of the adult sheep. It is therefore assumed that the results obtained from calves would be similar in older cattle. In calves, the onset of insensibility was prolonged for up to 84s and, as discussed earlier, periods of intermittent sensibility may have occurred in many cases for more than 100s.

These differences are probably due to differences in the contribution of blood to the brain made by the vertebral arteries in sheep and cattle (Baldwin and Bell, 1963). In both species, the blood supply to the brain reaches the arterial circle via the rostral rete. In the sheep, the common carotid arteries are the sole source of blood to the rostral rete whereas, in the bovine, the vertebral arteries also supply the rete and thus make a significant contribution of blood to the brain.

The slaughter process is unlikely to sever the vertebral arteries since they arise from the subclavian arteries and run cranially in close association with the vertebral column. In sheep, this is of little consequence as the vertebral arteries provide no supply to the brain. However, in calves, even when the bicarotid trunk is severed, there is still some blood supply to the brain, via the vertebral arteries, so long as an effective cardiac output is extant. ECG recordings from unstunned slaughtered sheep and calves showed a diminishing but normal pattern for at least five and often more than ten minutes.

The results obtained from the one sheep which was inadvertently slaughtered by unilateral severance of the carotid and jugular vessels are important. The onset of insensibility was prolonged to 29s. Thus, if this animal had been stunned by a method which induced a temporary insensibility of 40s and was not actually slaughtered for more than 10s after stunning, which is a common occurrence in an abattoir, the animal would have regained sensibility while being bled.

Similarly, these results clearly indicate that any method of stunning which induces only temporary insensibility would be inhumane if used for calves. Many animals might be sensible for periods of more than 60s while being bled. This statement has been corroborated by subjective observations in abattoirs, similar to those discussed in relation to sheep.

Subjective assessment of insensibility in calves is difficult as animals which the EEG clearly indicates are

insensible still show many reflex movements including respiratory gasps, vocalisation, eye movements and violent struggling. Such reflexes, even in insensible animals, can be the cause of concern for both veterinarians and slaughtermen. It can be difficult to persuade such people, especially the latter group, that the process is not cruel.

It is believed that this work has demonstrated three particularly important factors related to electrical stunning of sheep and calves by application of an electrical current to the head only. First, the stunning of calves by such a method is an inhumane practice. Secondly, if such a technique is used on sheep the bleeding process must be initiated within 20 seconds and, thirdly, it is imperative that bilateral severance of the common carotid arteries is achieved.

It would therefore appear that the use of an electrical stunner which also causes cardiac dysfunction is the most reliable method for both sheep and calves, especially if there is a delay between stunning and bleeding. Although the lack of an effective circulation may reduce the rate of bleeding, preliminary observations suggest that this has little effect on the final total amount of blood obtained from the carcase.

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TABLE I : EEG RECORDINGS OF ANIMALS SLAUGHTERED BY BILATERAL SEVERANCE OF CAROTID AND JUGULAR VESSELS

Stunning Procedure	Animals Number	Animals Type	Onset of insensibility (s) Range	Onset of insensibility (s) Mean	Onset of isoelectric trace (s) Range	Onset of isoelectric trace (s) Mean
None	5	sheep	2 - 7	5	20 - 50	34
None	5	lambs	2 - 7	4	10 - 25	17
None	8	calves	34 - 85	66*	132 - 336	242
Electrical: head only	6	sheep	Immediate		23 - 59	42
Concussive	6	sheep	Immediate		23 - 59	43
Captive bolt	2	calves	Immediate		10 - 14	12

* Six of these animals may have periodically regained sensibility for more than 100s.

TABLE II : ECG RECORDINGS OF ANIMALS ONLY ELECTRICALLY STUNNED

Stunning Procedure	Animals Number	Animals Type	Duration of insensibility (s) Range	Duration of insensibility (s) Mean	Onset of isoelectric trace (s) Range	Onset of isoelectric trace (s) Mean
Head only	7	sheep	16 - 40	33	Recovery	
Head & back	4	sheep	Permanent		40 - 51	45
Head & back	4	calves	Permanent		40 -135	87