Electroencephalography, blood oxygen levels and sensibility of electrically stunned cattle.

DEVINE, C.E., GILBERT, K.V., TAVENER, A., GRAAFHUIS, A.E. and REED, H.
Meat Industry Research Institute, P.O. Box 617, Hamilton, New Zealand

To use electrical stunning effectively for routine slaughter of cattle, it is necessary to understand the effects of the stun on duration of insensibility, inhibition of breathing, control of movement and humaneness of slaughter. Head only stunning which does not stop the heart is appropriate for certain markets, but its humaneness has been questioned for calves and cattle because bilateral severance of the carotids does not appear to produce immediate and permanent insensibility [defined as being when the electroencephalogram (EEG) pattern is above 35 μV or falls below 10 μV][4]. If cattle can recover from the stun before exsanguination brings about permanent insensibility then the process may not be humane. However these concerns arose from experiments not using electrical stunning and the many changes in blood flow, breathing inhibition and EEG, have not been fully examined for both head only and head-to-back stunning. The present series of experiments were designed to investigate some of the effects of electrical stunning on the state of insensibility.

METHODS

EEG Recordings

Calves (ranging from 2 days to 6 weeks) and adult cattle (ranging from 8 months to 2 years) were used for experimentation. The methods of implanting stainless steel screws in adult cattle (n=12) and methods of head-only electrical stunning were as previously described[1,3]. For calves (n=35), stainless steel syringe needles were sutured and glued in place and the animals were head-only stunned as previously described[1,2].

Electro-immobilization commencing between 10-20 s post stun was applied to calves and adult cattle through electrodes attached to the nose and anus (80 V peak, 14.3 Hz, 5 ms duration square wave pulses) for 15-30 s.

Fast Fourier transforms (FFT) of the EEG waveforms of 4 calves were made using a Proteus microcomputer for data capture and a VAX 11-750 computer for subsequent analysis and plotting. The process enabled a resolution of <1 μV in 200 μV with 1024 data points for 2 s of data.

Blood Oxygen Recording

Oxygen free samples of blood were obtained from the carotid arteries of head-only stunned adult cattle (n=35) after throat severance and at intervals throughout the bleed. Similar samples of blood were obtained from the carotid arteries and jugular veins from head-to-back stunned cattle before bleeding (n=4).

For anaesthetized calves (n=14) blood was obtained throughout the stunning procedures from catheters in the jugular veins and carotid arteries. Some samples were also obtained from the wound of non anaesthetized calves.

The oxygen levels were determined with a Radiometer pHA934 meter and were expressed as mm Hg and converted to percentage saturation from experimentally obtained curves. Video recordings were made of all experiments with the timer display in the camera activated at the commencement of stunning.

RESULTS

Adult Cattle

After electrical head-only stunning of two adult cattle, the forelegs and hind legs were tucked underneath the animal and then extended to become walking or paddling movements that became more violent before subsiding at about 40 s. Violent anoxic kicking occurring later. Breathing was inhibited for at least 20 s after the stun. The immediate post stun EEG showed high amplitude peaks corresponding to the tonic phase of an electroplectic fit. The EEG amplitude became larger, with a periodicity of approximately 1 Hz, which then decreased at 50 s and 73 s post stun for each animal to become less than 10 μV. Following 30 s of electro-immobilization the EEG amplitude of the remaining cattle was at, or less, than 10-12 μV at 50 s post stun and the animal movements were abolished.

In adult cattle which were head-to-back stunned, the legs extended and the walking or paddling movements were almost abolished, the heart went into fibrillation and breathing was inhibited for 20-25 s. The animals showed almost no movement and electro-immobilization was needed only to reduce the later anoxic movements.

The levels of oxygen in arterial blood from the cut carotids of head-only stunned cattle was initially 96 mm Hg (100% saturation) and rapidly decreased to approximately 40 mm Hg (range 16-66 mm Hg) after approximately 60 s corresonding to oxygen saturation of 70%. In head-to-back stunned cattle (n=3) arterial blood was initially 96 mm Hg (100% saturation) and fell to 65-86 mm Hg (93-95% saturation) at 120-180 s. The amount of blood flowing when the vessels were cut was extremely small due to cardiac fibrillation, but not negligible. The venous blood was 20-26 mm Hg (25-35% saturation) at 120-180 s.

Calves

When calves recovered sensibility after head-only stunning, the sequence of events was as follows; the forelegs tucked under the animal and paddling and walking movements developed from 8-10 s post stun. The EEG showed a pronounced amplitude increase of the electroplectic fit which lasted until 33.4±6.54 (n=15) and continued into a depressed phase before increasing again. The high amplitude EEG waveforms at 60 s were much greater than those of a prestunned calf even though the calf was recovering at this time. Even when the calf was able to walk, the EEG was greater in value (up to 10 min in some animals) than that recorded before stunning. If the throat was cut severing the carotids and jugulars, the electroplectic fit stage was reduced in duration to 23.0±4.3 (n=12) and the amplitude continued to fall, reaching 10 μV at periods ranging from 50-79 s.

The shortest period of electro-immobilization that consistently shortened the duration before the EEG amplitude reached 10 μV, was 16 s. Post stun movement was progressively reduced with an increasing duration of electro-immobilization.

The analysis of the EEG waveforms by FFT's showed that there was a difference between unstunned calves which died by exsanguination alone and those that died by exsanguination following an electric stun. With the electrically stunned calves, there was a frequency component between 15-40 Hz which persisted until the EEG fell below 10 µV. Examination of the EEG of calves which were stunned and recovered showed that these high amplitude components persisted even when normal sensibility was maintained.

The levels of carotid blood oxygen in anaesthetized calves were similar to that for unanaesthetized animals but lower than for adult cattle. The comparison is however useful. The blood from the jugular vein before stunning was 35-40 mm Hg (80-87% saturation) and that from the carotid artery 57-66 mm Hg (94-96% saturation). After head-only electrical stunning followed by throat cutting, the blood virtually ceased to flow after 10 s and from the small amounts of blood obtained, the pO_2 at this time was 16-36 mm Hg (35-83% saturation). For blood obtained later (60-180 s), the pO_2 was approximately 13 mm Hg but the blood remaining in the cannulas contributed to this. The pO_2 of carotid blood rapidly fell to values of 31-40 mm Hg (76-87% saturation) at 50-65 s. For two anaesthetized calves which were head-only electrically stunned but the throat was not cut, there was a transient fall in arterial and venous pO_2 to 42 mm Hg and 22 mm Hg respectively (88% and 54% saturation). In the case of venous blood obtained after head-to-back stunning, which resulted in cardiac fibrillation, the pO_2 was 24-28 mm Hg (59-67% saturation) and the arterial blood was 38-54 mm Hg (85-94% saturation) at 20-60 s post stun.

DISCUSSION

The high amplitude phase of EEGs recorded during the electroplectic fit was reduced in duration for those calves which had their carotid arteries severed, suggesting that the metabolism required to maintain the electroplectic fit could not be sustained with the limited blood flow that occurred. It was expected that some blood would flow from the jugular veins of calves via the intact vertebral arteries even when the carotids were severed, but this apparently was not so. As both the jugulars and carotids on one side were cannulated it is likely that the flow was modified but some transfer of blood would have occurred at the circle of Willis. However even in adult cattle we could not satisfactorily obtain samples of venous blood from the cut jugular veins. There was blood emerging from the cephalic end of the cut carotid of adult cattle (approximately 10% of carotid flow, unpublished observations) which suggests that most of the vertebral artery blood was diverted rather than perfusing the brain.

It is clear that the limited amounts of blood perfusing the brain after a stun and throat cut reduced the duration of the electroplectic fit. The low oxygen levels of the arterial blood may be sufficient in an intact animal with a normal circulation to ensure sensibility, but are unlikely to do so during slaughter procedures. Such changes after the throat cut, coupled with an elevated EEG due to the stun suggest that EEG data alone cannot be used to indicate sensibility. In reviewing the criteria of sensibility, we believe that insensibility can be presumed to continue from stun initiation, through the throat cut until the EEG falls below 10 µV, provided that there is no resurgence of activity and the EEG amplitude continues to decrease. By this criteria, calves which are electrically stunned and rapidly exsanuinated remained permanently and irreversibly insensible.

The prolonged high amplitude EEG's following the electroplectic fit seem to be a consequence of the stun itself and not a response to the slaughter process as the FFT analysis shows that such changes persist even when normal sensibility is regained in an animal allowed to recover.

An interesting and unexpected effect is that some blood flows after a head-to-back stun in calves even though fibrillation of the heart prevents a major flow. The blood also has a relatively large amount of oxygen, probably due to the slow emptying of the heart, aorta, and lungs. Once the movement reducing effects of the stun have worn off, the subsequent reflex movements that may occur could be a consequence of this relatively high oxygenated blood shifting to the brain by hydrostatic pressure changes upon hoisting.

REFERENCES

1. Devine, C.E., Gilbert, K.V., Tavener, A. & Day, A. (1985). NZ Vet. J. 33, 47.
2. Devine, C.E. Tavener, A., Graafhuis, A.E. & Gilbert, K.V. (1986). NZ Vet. J. (accepted for publication).
3. Devine, C.E., Gilbert, K.V., Tavener, A. & Day, A. (1986). NZ Vet. J. (accepted for publication).
4. Newhook, J.C. & Blackmore, D.K. (1982a). Meat Sci. 6, 221.