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THE EFFECTS OF CAPTIVE BOLT STUNNING ON BRAIN FUNCTION IN CATTLE AND SHEEP

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INTRODUCTION The captive bolt is the principle method of pre-slaughter stunning used in cattle and, in Britain, is also used in about 10% of sheep. In sheep, this stunning method is not always successful since a survey of abattoirs found that 4% of animals were subjected to a second shot (Gregory & Wotton 1983a). Equivalent surveys have not been carried out in cattle.
This study examined the effects of captive bolt stunning on brain function in sheep and cattle in order to evaluate its effectiveness from a humanitarian standpoint. In sheep, two shooting positions, frontal and poll, were examined. In cattle, different bolt velocities were compared to determine whether an optimum velocity could be established. Brain function was assessed in terms of effects on cortical evoked responses. A stunning procedure which instantaneously and irreversably abolished evoked responses was considered a successful stun, whereas the presence of evoked responses during the post-stun period was considered to indicate recovery of brain function and therefore the potential for sensibility. Because some of the treatments employed in this work were potentially inadequate to produce an effective stun, experiments were for ethical reasons carried out in anaesthetised and mechanically ventilated animals.

MATERIALS AND METHODS Sheep experiments: Mature ewes and wethers of mixed breeding were employed. Anaesthesia was induced and maintained by mechanical ventilation with nitrous oxide, oxygen and between 1.5 and 1.8% halothane. Animals were suspended in a hammock throughout the experiment. Bipolar silver-silver chloride electrodes, 5mm in diameter and insulated down to their recording surfaces, were implanted onto the dura matter over the visual cortex and somatosensory cortex using bregma as an anatomical landmark and 1cm lateral to the midline. Where visual evoked responses (VERs) were recorded, the eyelids were sutured open and exposed to light flashes at a frequency of 2 flashes/sec. For somatosensory evoked responses (SERs), two stainless steel stimulating electrodes were threaded subcutaneously midway along the forelimb contralateral to the recording electrodes. The stimulation duration was 0.2msec and the stimulating voltage was adjusted until a pronounced cleat or leg twitch was evident. The procedures for recording the evoked responses were essentially as described by Gregory & Wotton (1983b). Animals were shot with a Short Cash Special pistol (Accles and Shelvoke) using a 1 grain cartridge (brown label, Cash). The frontal shot was positioned on the highest point of the cranium when the head was held horizontally, and the poll shot was positioned according to an imaginary line running between the base of the ears and aiming towards the throat. All shots were approximately 2cm lateral to the midline to avoid damage to the recording electrodes.

Cattle experiment: The animals used in these experiments were Hereford steers ranging in weight from 291 to 403kg, and mature Fresian cows ranging in weight from 455 to 735kg. Animals were tranquilised with 1ml/100kg I.M. Rompun(Xylazine) and sufficient intravenous sodium thiopentone (100mg/ml) to induce anaesthesia and permit intubation. Animals were supported in a prone position and anaesthesia was maintained by mechanical ventilation with halothane and oxygen-enriched air. The surgical, stimulating and recording procedures were similar to those described for sheep except that visual stimuli were presented at a rate of 1/sec. The captive bolt pistol employed was a Cash 9000 (Accles and Shelvoke). Different bolt velocities were achieved by the use of interchangable bolts with different size expantion chambers, combined with different size cartridges. The speed of each bolt was precalibrated by the manufacturer and the mean speed for each bolt was 39.6, 61, 79.2 and 100.9 m/sec with standard deviations of 2.7, 3.9, 3.5 and 4.6 respectively based on 6 readings per bolt. Animals were shot in the frontal position at the intersection of lines joining each eye to the contralateral ear but approximately 2cm lateral to the midline to avoid damaging the recording electrodes.
The evoked responses were averaged and quantified from their excursion distances as described by Gregory & Wotton (1983b). The spontanous electrocorticogram was analysed by integration using a Texas E&M GPA-10 capacitance discharge integrator with its negative input to earth. The post-stun changes in excursion distances and integrated activity was expressed as a percent change from the pre-stun, control levels

RESULTS Captive bolt stunning in sheep:

Captive bolt stunning in the frontal position was examined in 15 sheep; VERs were recorded in 8, and SERs in 7. Evoked responses were lost immediately in all animals. Excursion distances fell to less than 10% of control levels during the first 32sec of averaging. Since both VERs and SERs

TABLE 1. EFFECTS OF DIFFERENT BOLT VELOCITIES ON BRAIN FUNCTION IN CATTLE

Bolt velocity (m/sec)	No. of cattle	Mean live weight (kg) ± S.D.	Incidence of VER post-shooting (%)	Incidence of VER during the first 8 sec post-shooting (%)	Mean time to recovery of VER (sec) ± S.E.
40	6	445.6 ±153.4	66.7[a] n=4	50.0[a] n=3	14.0 ± 12.1
60	66	452.3 ±126.2	66.7[a] n=4	66.7[a] n=4	0 -
80	14	461.6 ±123.0	35.7[a] n=5	14.3[b] n=2	69.6 ± 39.6
100	13	441.7 ±152.5	61.5[a] n=8	23.0[b] n=3	43.0 ± 31.5

Different superscripts denote statistically significant differences at the 5% level when comparing low velocity (40 and 60 m/sec) with high velocity (80 and 100 m/sec)

were absent when responses were averaged over the first 4 sec following stunning, the loss of evoked responses was considered to be instantaneous. Evoked activity did not reappear in any of the animals for the duration of the experiment (5min). In general, spontaneous cortical activity fell following shooting, but there was considerable variation between individual animals. Four sheep maintained more than 50% of their prestun levels throughout the experiment, whereas spontaneous activity in the remainder fell to less than 10% in a mean time of 76sec (S.E ± 15sec).
The effects of shooting in the poll position was examined in 8 sheep using VERs only. Responses were abolished in all animals during the first 32 seconds following shooting. Responses were also absent when averaging was performed during the first 4sec following shooting. However, in 5 animals, VERs gradually returned. By averaging consecutive 8sec periods post-shooting, the mean time to recovery of VERs was found to be 49.6sec (S.E. ± 16.7sec). Also, spontaneous activity remained high in most animals following this treatment, and became isoelectric in only 2 animals.

Captive bolt stunning in cattle:

Effective stunning was again determined by the presence of VERs during a 5 min period following shooting and, where relevant, recovery of VERs was determined by averaging over consecutive 8sec periods. The proportion of animals with VERs present at some point during the post-stun period did not change significantly when bolt velocity was increased. Thus, at 40, 60, 80 and 100m/sec, the incidence of VERs being present following shooting was, respectively, 66.7 (n=4/6), 66.7 (n=4/6), 35.7 (n=5/14) and 61.5% (n=8/13). The mean of live weights of animals in each group did not vary significantly.
However, bolt velocity did influence the time needed for recovery of VERs following shooting. At the two lowest bolt velocities (40 and 60m/sec), VERs were present, although attenuated, during the first 8 sec following shooting in all but one animal. The bolt velocity most effective at producing immediate loss of VERs was at 80m/sec since only 2 animals had surviving VERs following shooting and the mean time for recovery of responses in this group was 69.6 sec (S.E. ± 39.6sec). The 100 m/sec bolt velocity proved to be less effective since VERs survived the shooting process in 5 animals and the mean time to recovery of VERs in this group was 43 sec (S.E. ± 31.5sec).

DISCUSSION From a humanitarian standpoint, it is essential that a stunning method should produce instantaneous insensibility and that this state should be maintained until death occurs by exsanguination. Unfortunately, an unequivocal method of assertaining objectively an insensible state in an animal is a difficult proposition. One method is to diagnose insensibility by the presence of high amplitude, low frequency electrical activity from the cortex. By these criteria, captive bolt stunning has been reported to be effective when used in the frontal position in sheep (Lambooy

1982) and calves (Lambooy & Spanjaard 1981).

An alternative approach is the use of cortical evoked resposes. This technique has proved useful in providing an index of brain damage following concussion in experimental animals (Ommaya & Genarelli 1974; Shaw & Cant 1984), as well as for diagnostic purposes in comatose patients (Jorgensen 1974; Rappaport et al 1977). Loss of evoked responses is associated with severe insult to the central nervous system, while recovery of cortical evoked potentials reflects return of neural function and therefore the potential for consciousness or sensibility. In the context of captive bolt stunning, the period when evoked responses are absent will therefore represent the period when insensibility can confidently be assumed to exist.

The present results on the effects of captive bolt stunning in the frontal position in sheep confirm the results of Lambooy (1982). However, the rapid recovery of VERs in sheep shot in the poll position suggests that the duration of the stun is more limited when this shooting position is employed. Furthermore, the time to recovery of VERs is within the stun to stick interval reported to occur in some abattoirs (Gregory & Wotton 1983a), which emphasises the need for prompt sticking when this stunning method is used.

VERs were also found following shooting in cattle. At low bolt velocities (40 and 60 m/sec), VERs were merely attenuated immediately following shooting and it must therefore be concluded that these velocities are not sufficient to adequately stun cattle. Nevertheless, even at high velocities, considerable variation existed with respect to the extent of brain damage and further research will be required to clarify the reasons for this variability. This study does however point out the high incidence of recovery of brain function in cattle and therefore the need for minimizing the stun to stick interval.

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