The effects of inducing a cardiac arrest at stunning on brain function, bleeding efficiency and susceptibility to carcass bruising in sheep

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Introduction

In the conventional slaughtering methods used for sheep in Britain, the animals are stunned either by electricity or a captive bolt and then killed by sticking in the neck. Stunning has to be effective up to the time the animal dies to prevent it from perceiving the painful stimuli which normally occur during the slaughtering procedure.

This series of experiments examined the effects of inducing a cardiac arrest at stunning on brain function, to see whether this method produces a quicker kill and thus reduces the likelihood of the animal regaining consciousness (Experiment 1). The effectiveness of the head-to-back electrical stunning system in inducing a cardiac arrest plus epileptiform activity in the EEG was evaluated in Experiment 2, and some practical recommendations for applying this method are provided. In Experiment 3, the effect of inducing a cardiac arrest at stunning on bleeding efficiency and susceptibility to carcass bruising were compared with a stunning method which did not induce a cardiac arrest, to see whether a beating heart is essential for adequate bleeding and for bruise formation.

Materials and Methods

Experiment 1

Forty four sheep were implanted with electrocorticogram (ECoG) electrodes as described previously (Gregory and Wotton, 1982; 1983) for determining the time to loss of visual evoked responsiveness of the brain following exsanguination or cardiac arrest, and,during the whole procedure the animals were under halothane anaesthesia. Cardiac arrest was induced with an electric current applied at 20V 50 Hz for 4 sec through indwelling needle electrodes, and the effectiveness of the procedure was confirmed with an epicardiogram. A flashing light was used as the visual stimulus, and the evoked responses in the brain were recorded on magnetic tape for subsequent averaging (Gregory and Wotton, 1983).

Experiment 2

Ninety one sheep were used in this experiment, with at least thirty animals in each treatment. The treatments were:

1. Head-only 300V 50 Hz stunning for 3 sec, followed by sticking at 42 sec (± 3 SD) after the start of stunning (Head-only late stick treatment).
2. Head-only 300V 50 Hz stunning for 3 sec, followed by sticking at 10 sec (± 2 SD) after the start of stunning (Head-only quick stick treatment).
3. Head-to-back 300-400V 50 Hz stunning for 3 sec, followed by sticking at 43 sec (± 1 SD) after the start of stunning (Head-to-back late stick treatment).

The electrocardiogram (ECG) and electroencephalogram (EEG) responses were monitored to determine the proportion of sheep in each treatment which expressed ventricular fibrillation of the heart and epileptiform activity in the brain.

Experiment 3

Sixteen ewes (47 kg ± 9 SD) were anaesthetised with intravenous thiopentone and mechanically ventilated with air. The animals were suspended head-down from an overhead rail and subjected to bruising before and after stunning and sticking by firing a Cash Special pistol with a 3.8 cm diameter stainless steel percussion head at the end of its bolt onto the shorn skin overlying the longissimus dorsi muscle. A control bruise was administered at 35 sec before stunning (bruised control), and then at 15 and 30 sec after stunning. The animals were stuck at 35 sec after stunning, and further bruising was administered at 45, 60 and 70 sec after stunning.

All the sheep were electrically stunned with 300V for 3 sec using head-only tongs, but half the animals received, simultaneously with the stunning, a 50V 50 Hz current through the chest to fibrillate the heart. Cardiac fibrillation was confirmed with an ECG.

The rate of bleeding from the sticking wound was measured with a load cell balance. The severity of bruising was determined in two ways at 24h after slaughter. A five point subjective score was used on the cut surface of the L. dorsi muscle in the region of the insult, with 0 = no bruising and 4 = severe bruising. Secondly, total haem pigment concentration was measured in minced samples of muscle taken from the bruised site (Warriss, 1979). Unbruised control samples were also assayed for haem content for each carcass.

Results

Experiment 1

The time to loss of brain responsiveness to the flashing light was shortest in the sheep which had both carotid arteries plus jugular veins severed at sticking, and longest in those which had only their jugular veins cut (Table 1). The induction of a cardiac arrest took 14 sec longer than carotid artery sticking to induce brain failure.

Table 1. The effect of four different slaughtering methods on the rate of induction of loss of brain responsiveness.

Sticking method	No. of sheep	Time to loss of brain responsiveness (sec)*	± SE
Both carotid arteries + both jugular veins	20	14	1
One carotid artery + one jugular vein	8	70	7
No carotid arteries, both jugular veins	8	298	34
Electrically induced cardiac fibrillation	8	28	2

*Time to loss of brain responsiveness determined from the visually evoked responses

Experiment 2

Only one of the sheep subjected to head-only 300V electrical stunning developed fibrillation in the heart, and for the results shown in Table 2 this animal was removed from the experiment and replaced by another sheep. All the animals subjected to head-to-back stunning developed a cardiac arrest as determined from the ECG.

All the animals in this experiment showed epileptiform activity in the EEG, and this occurred when using the same current flow between the stunning electrodes in all 3 treatments. The duration of the epileptiform phase in the head-to-back late stick treatment was shorter than for the head-only late stick animals, suggesting that the induction of a cardiac arrest was quicker than stunning followed by exsanguination in inducing anoxia in the brain when the interval between stunning and sticking was as long as 40 sec.

Table 2. Comparison of head-only with head-to-back stunning on epileptiform activity in the brain and fibrillation of the heart.

	Head-only late stick	Head-only quick stick	Head-to-back late stick
No. of sheep	30	30	30
Stunning voltage (V)	300 ± 0*	300 ± 0	377 ± 39
Stunning current (amp)	1.00 ± 0.38	1.15 ± 0.53	1.01 ± 0.25
No. of sheep with an epileptiform EEG	30	30	30
No. of sheep with cardiac fibrillation	0	0	30
Duration of epileptiform phase in EEG (sec)	50 ± 20	21 ± 5	23 ± 8

* $\bar{x}$ ± SD

Experiment 3

The pigment content of the unbruised control samples was the same in each treatment (6.2 ± 0.5 v 6.1 ± 0.5 mg g^{-1} ± SE total haem concentration in non-cardiac arrest v cardiac arrest treatments). Inducing a cardiac arrest at stunning caused a prompt reduction in the development of a bruise, whereas in the non-cardiac arrest group the animals had to be stuck to reduce bruise formation (Fig. 1). In the non-cardiac arrest treatment 49% (± 13 SD) of the total blood was collected within 10 sec of sticking, this being the first interval at which no bruising was observed.

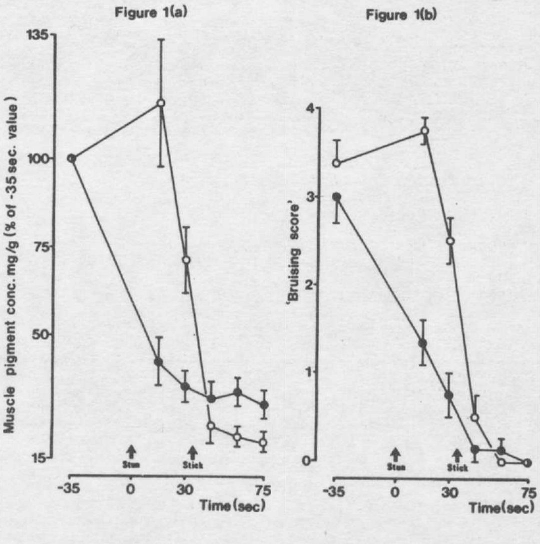

Figure 1. Effect of stunning, with and without inducing a cardiac arrest, and sticking on the haem pigment concentration and bruising scores in bruised L. dorsi muscle.

(Footnote): Closed circles, 8 sheep in which a cardiac arrest was induced at stunning. Open circles, 8 sheep in which there was no cardiac arrest at stunning. Vertical bars; ± SEM.

Figure 2

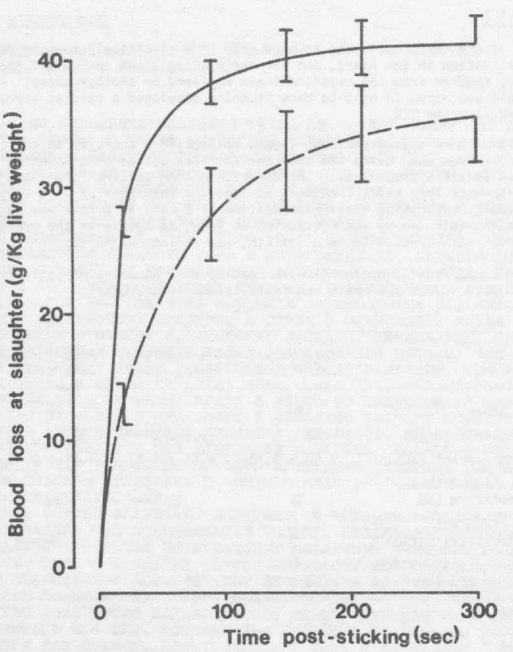

Figure 2. Effect of cardiac arrest at stunning on the weight of blood collected at exsanguination.

(Footnote): Broken line, 8 sheep in which a cardiac arrest was induced at stunning. Continuous line, 8 sheep in which there was no cardiac arrest at stunning. Vertical bars; ± SEM.

The rate of blood flow from the sticking wound was slower in the cardiac arrest group (Fig. 2).

Discussion

In a survey of slaughtering procedures at 40 sheep abattoirs in Britain, it was found that on average the time between stunning and sticking was 23 sec (Gregory and Wotton, 1984). In Experiment 1 of this study the time between sticking and loss of brain responsiveness was 14 sec, and so, on average the time between stunning and loss of brain responsiveness would be 37 sec. It was estimated from the combined survey and experimental results that the time to loss of brain responsiveness following stunning which encompassed 99% of the sheep population was 96 sec, and this represents the required duration of anaesthesia in the slaughterhouse situation. This estimate, however, is based on the assumption that all sheep have both their carotid arteries and jugular veins severed at sticking, but is clear that this is not always the case. In one study, it was observed that between 4 and 47% of the sheep in a New Zealand abattoir had only one carotid artery severed at sticking, and the exact incidence depended on the slaughterman who was doing the job (Blackmore and Petersen, 1981). Severing only one carotid artery would increase the time to loss of brain responsiveness five-fold and the required duration of anaesthesia would correspondingly rise.

The problems associated with late and incomplete sticking in some abattoirs can be approached in one of two ways. Either, greater emphasis should be placed in correcting these mistakes, or, an alternative method which provides a more prompt kill should be sought. Inducing a cardiac arrest at stunning is such an alternative, as it was found to reduce the time to loss of brain responsiveness to 28 sec. This was 9 sec shorter than the average time to loss of brain responsiveness in the commercial situation, and for 99% of the sheep population it was found to be 51 sec quicker. Inducing a cardiac arrest at stunning should therefore be a quicker method of killing a sheep both on average and in the worst situations, and so it would reduce the likelihood of resumption of consciousness following stunning. A stunning method which simultaneously induced a cardiac arrest would also do away with the humanitarian problems of incomplete sticking, as this procedure becomes superfluous as a means of arresting brain function.

The next question to be answered is, how can a cardiac arrest be induced at stunning? In Experiment 2 the head-to-back stunner was evaluated in sheep, and this system was found to be effective in inducing epileptiform activity in the brain and a cardiac arrest when applied at 400V 50 Hz for 3 sec. Applying a comparable current (about 1 amp) across the head of the animal induced a cardiac arrest in only one out of 61 sheep. A cardiac arrest was associated with a slower and less complete loss of blood from the sticking wound (Experiment 3), but in a separate study in pigs, no such effect was observed (Warriss and Wotton, 1981). A seemingly important factor with respect to meat hygiene is the amount of residual blood in the muscle, and it is relevant to note that inducing a cardiac arrest at stunning caused no difference in the amount of blood retained in muscle in pigs, sheep and poultry (Warriss and Wotton, 1981; Chrystall, Devine and Newton, 1980/81; Griffiths, 1983). An added advantage of using a stunning method which also induces a cardiac arrest is that it would reduce the susceptibility of the carcass to bruising (Experiment 3). Experience with this method has also shown that it was associated with less carcass kicking and reduced blood splash in the meat (Kirton, Frazerhurst, Woods and Chrystall, 1980/81).

In summary, it is concluded that a stunning method which simultaneously induces a cardiac arrest would have certain humanitarian and commercial advantages over the conventional electrical stunning methods which depend on the sticking procedure for killing the animal.

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