ELECTRICAL STUNNING IN CATTLE AND SHEEP: ELECTRODE PLACEMENT AND EFFECTIVENESS

K.V. Gilbert, C.J. Cook, C.E. Devine,
A. Tavener and H. Reed

SUMMARY

Our studies suggest that the placement of electrodes during electrical stunning is a critical variable in assuring the humaneness of the operation both with head-only and head-to-body stunning. A successful stun is dependent upon sufficient current passing through the brain. Electrode systems positioned caudal to the head do not always ensure this occurs.

Incorrect positioning of stun electrodes can induce a state that appears visibly similar to a correct stun, with animal paralysis present and cardiac fibrillation having occurred, but without an accompanying electroplectic fit. Such a procedure is not a humane operation.

An acceptable stun must employ electrode placement that ensures an adequate current flow through the brain, inducing an epileptiform-like state, as evidenced by an electroencephalogram (EEG). When combined with correct body electrode placement, animal movement control and cardiac fibrillation can also be assured.

INTRODUCTION

Electrical stunning, used prior to slaughtering, can assure animal welfare by preventing needless suffering during slaughter procedures. Stunning can involve passing a current through the brain only (i.e. head-only stunning), or passing a current through the brain via a contact on the head to a body contact such as the back (head-to-back) or brisket (head-to-brisket). This latter type of stunning system in addition to rendering the animal insensible, also abolishes movement and produces cardiac arrest.

Preslaughter electrical stunning, performed correctly, induces an epileptiform-like activity which is usually taken to assume the animal is unconcious and insensible to pain (Gregory, 1985; Bager et al., 1990). The production of epileptiform-like activity, following electrical stunning, is dependent upon the amount of current that passes through the brain, and possibly the area of the brain through which it passes.

Previous work (Cook et al., In Press) has shown that, in calves, the position of stunning electrodes is an important variable in assuring stunning efficacy. If head-only stunning is used, either positioning electrodes on either side of the head or positioning electrodes on the lateral aspects of the neck (an area approximating cervical vertebrae #2 to #5), an effective stun results with epileptiform-like activity being present on the EEG. This presumably results from the spread of the electric field producing adequate current flow through the brain. If however the current passes from the same neck region to an electrode on the brisket, cardiac fibrillation and animal rigidity (followed by flaccidity) occurs, but was shown not to be accompanied by epileptiform-like activity and as such is not a correct stun. In contrast, head-to-brisket stunning with an electrically-connected pair of electrodes on either side of the head, rather than on the neck, does produce a correct stun.

The purpose of the work presented in this paper was twofold: to determine current flow and resistance through the head and brain and, to study the effects of electrode positioning and configuration on the efficacy of stunning.

MATERIALS AND METHODS

Current and Resistance Measurements in the Head and Brain of Sheep

(a) *Resistance in Isolated Sheep Heads and Brains Postmortem*

Resistance measurements between a set of points on the sheep head and brain were performed using a high frequency bridge. The resistance determined using this device was checked against a simultaneous 50Hz current flowing during electrical stunning procedures. The sites included: eye to eye, ear to ear (both with the brain intact and in the pathway), bone to bone, brain to either brain, bone, eye, spinal cord or skin. To position electrodes in the brain, holes were trephinated through the bone and dura. The electrodes were constructed from stainless steel rods with an uninsulated surface area of 1.5 cm^2. With bone contact it was difficult to get the entire rod area exposed in contact, but a close approximation was achieved by drilling holes into the thickest part of the bone, inserting the rods and filling the lateral spaces with saline.

(b) *Current Flow*

Current flow between electrodes in the brain during electrical stunning was measured by stainless steel electrodes (as above) placed in the brain in trephinations drilled in the bone 1.5 cm apart laterally and 1.5 cm anterior to posterior orientated. The stunning electrodes were placed in one of four postitions: across the eyes perpendicular to the longitudinal axis of the skull, immediately behind the ears, immediately in front of the ears, or on either side of the nose. Normal stunning parameters (1.5A current limited, 400V open circuit, 50Hz and 4 seconds duration) were used and the current flow between electrode pairs placed either laterally or anterior-posteriorly was determined using resistance and voltage measurements.

Electrode Positioning Studies in Sheep

Twelve lambs, bodyweights 25 to 40 kg, were used in these studies. A hand held head-to-back stunner was used to deliver the stun current as above. The distance between the head electrodes and body electrodes was kept constant at 35 cm and the head electrodes were moved progressively further caudal in placement with respect to the head in each individual animal. At selected positions a stun current was passesd between the electrodes placed on each side of the head, i.e. a head-only stun and the effect of the stun was examined. The animals were instrumented with needle electrodes (Bager et al., 1990; Cook et al., 1991) to record both the electroencephalogram (EEG) and the electrocardiogram (ECG). These were recorded for 5-10 minutes prior to the stun and for up to 10 minutes after the stun. The analysis of these records provided evidence of epileptiform-like seizure activity and cardiac fibrillation. Pupillary, corneal, eyelash, and limb reflexes were also tested immediately prior to and immediately after the stun. Head-to-back stunning was performed in 11 animals with the head electrodes positioned at one of the following positions: (a) 3 cm rostral to the ear midline, (b) 3 cm caudal to the ear midline (an area approximating the cervical vertebrae #1 to #2), (c) 6.5 cm caudal to the ear midline (approximately cervical vertebrae #3 to #6), (d) 10 cm caudal to the ear midline (approximating cervical vertebrae #5 to thoracic vertebrae #1) and (e) 15 cm caudal to the ear midline (approximating cervical vertebrae #7 to thoracic vertebrae #3). In five of the animals head-only stunning was performed prior to head-to-back stunning at the same head electrode positions as above. Complete recovery of the EEG, ECG and reflexes was required before the head-to-back stun was subsequently performed. One of the animals received a head-only stun and was allowed complete recovery.

RESULTS

Current and Resistance Measurement Experiments

(a) The maximum resistance measured was approximately 800 ohms and was between two bone sites. The minimum resistance was 600 ohms measured between two brain sites. Outside of this range there was no appreciable difference in resistance seen with changing electrode positions. This data is summarised in Figure 1.

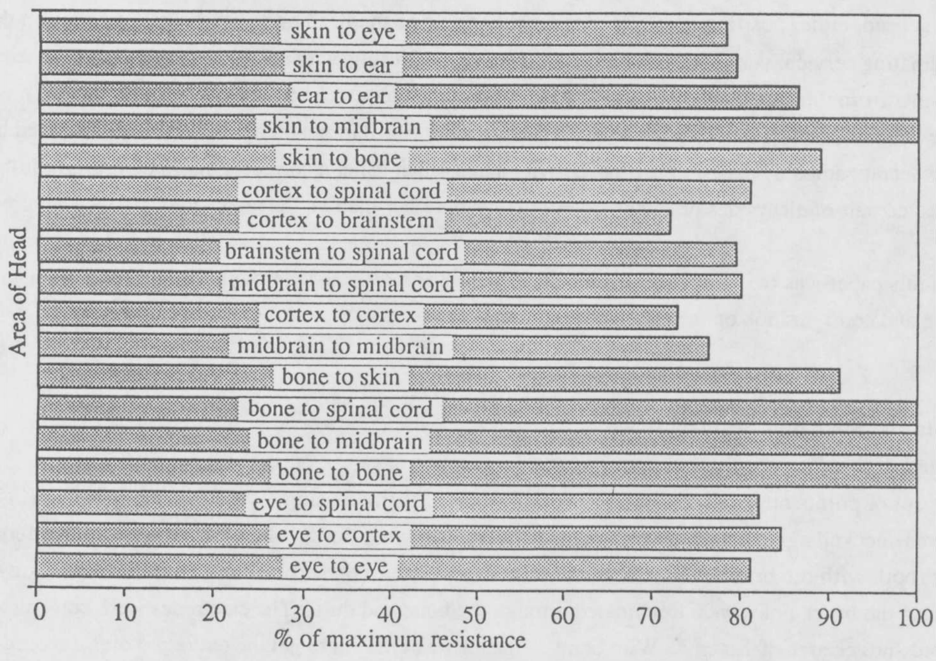

Figure 1. Resistance measurements through different areas of the head and brain of freshly slaughtered sheep. The resistance is shown as a percentage of the maximum recorded (maximum 800 ohms) resistance at any of the different recording sites.

(b) Current flow in the brain was greatest when the recording electrodes were in line with the stunning electrodes. Movement of stunning electrode position anteriorly (onto the nose) or posteriorly (behind the ears) reduced the apparent current flow in the brain as compared to the positions over the eyes and in front of the ears. The recorded current flow in the paired recording electrodes positioned perpendicular to the stunning electrodes, was dramatically less than seen with parallel electrodes. Figure 2 presents this data.

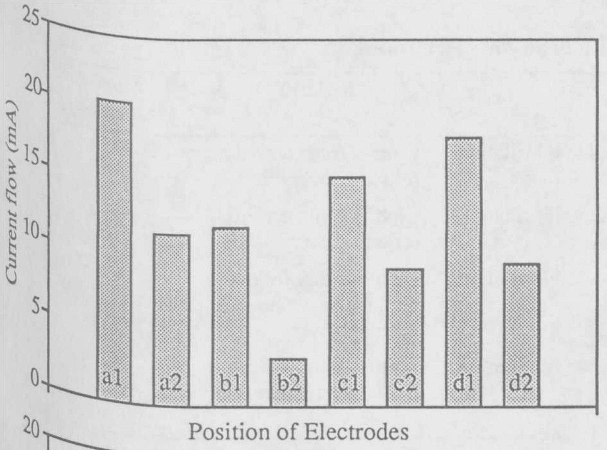

Figure 2. Current flow (mA) measured by pairs of electrodes oriented either parallel or perpendicular to the applied stun voltage. The current was recorded from the electrodes in the mid brain placed as follows:

a1: Parallel to stunning electrodes placed across the eyes.
a2: Perpendicular to stun electrodes placed as above.
b1: Parallel to stunning electrodes placed across the nose.
b2: Perpendicular to stun electrodes placed as above.
c1: Parallel to stunning electrodes placed behind the ears.
c2: Perpendicular to stun electrodes placed as above.
d1: Parallel to stunning electrodes placed in front of the ears.
d2: Perpendicular to stun electrodes placed as above.

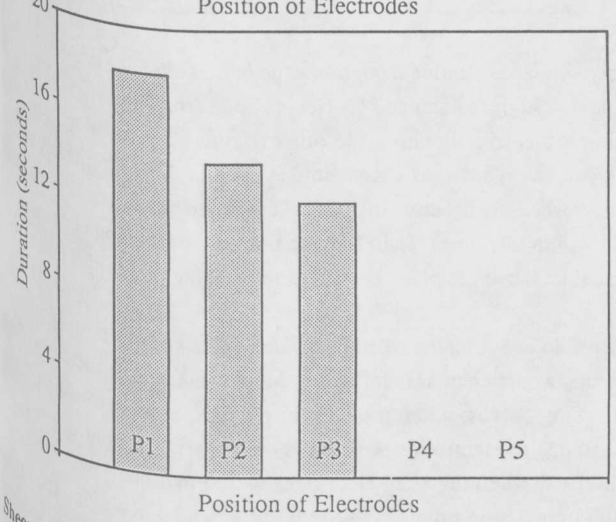

Figure 3. Duration of epileptiform-like activity (recorded by the EEG) following electrical stunning (head-to-body) with different electrode positions.
Duration of epileptiform-like activity shown in seconds for head electrodes positioned as follows:

P1: 3cm rostral to the ear midline, back electrodes 35cm caudal to this.
P2: 3cm caudal to the ear midline, back electrodes 35cm caudal to this.
P3: 6.5cm caudal to the ear midline, back electrodes 35cm caudal to this.
P4: 10cm caudal to the ear midline, back electrodes 35cm caudal to this.
P5: 15cm caudal to the ear midline, back electrodes 35cm caudal to this.

In P4 and P5 no epileptiform-like activity was observed.

Sheep Electrode Positioning Experiments

Head-to-body stunning, with head electrodes positioned 3 cm rostral or 3 or 6.5 cm caudal to the ear midline, elicited epileptiform-like activity and cardiac fibrillation. To qualify as epileptiform-like activity an arbitary criterion of the EEG amplitude being 5 times or greater than that seen prestun was used. The more rostral the position the greater the amplitude and duration of the epileptiform-like activity. With head electrodes positioned at 10 and 15 cm caudal to the ear midline epileptiform-like activity was not seen but cardiac fibrillation occurred. Using the head electrodes, only, at 3 cm and 6.5 cm caudal to the ear midline produced epileptiform activity without fibrillation. At the 10 and 15 cm caudal position using the head-only electrodes produced a limb rigidity and apparent paralysis but no evidence of epileptiform activity nor fibrillation. Data from these experiments are summarised in Tables 1 and 2 and Figure 3.

Table 1. EEG, ECG and Reflex Characteristics in sheep stunned head-to-back.

Position of Stun Electrodes	*EEG*	*ECG*	*Reflexes*	*Stun Acceptability*
3 cm Rostral to Ear Midline	Epileptiform-like activity present	Cardiac Fibrillation	Limb rigidity followed by flaccidity.	+
3 cm Caudal to Ear Midline	Epileptiform-like activity present	Cardiac Fibrillation	Limb rigidity followed by flaccidity	+
6.5 cm Caudal to Ear Midline	Epileptiform-like activity present	Cardiac Fibrillation	Limb rigidity followed by flaccidity	+
10 cm Caudal to Ear Midline	Epileptiform-like activity occasionally present (variable)	Cardiac Fibrillation	Limb rigidity followed by flaccidity	?
15 cm Caudal to Ear Midline	No epileptiform-like activity seen	Cardiac Fibrillation	Limb rigidity followed by flaccidity	–

Table 2. EEG, ECG and Reflex Characteristics in sheep stunned with head-only electrodes.

Position of Stun Electrodes	*EEG*	*ECG*	*Reflexes*	*Stun Acceptability*
3 cm Rostal to Ear Midline	Epileptiform-like activity present	No Cardiac Fibrillation	Clonic/Tonic activity reflex recovery	+
3 cm Caudal to Ear Midline	Epileptiform-like activity present	No Cardiac Fibrillation	Clonic/Tonic activity reflex recovery	+
6.5 cm Caudal to Ear Midline	Epileptiform-like activity present	No Cardiac Fibrillation	Limb rigidity followed by flaccidity then reflex recovery	+
10 cm Caudal to Ear Midline	No Epileptiform-like activity present	No Cardiac Fibrillation	Limb rigidity followed by flaccidity then reflex recovery	–

DISCUSSION

The resistance between any two points over the head was remarkably similar exhibiting an upper value of 800 ohms. Such a similarity is surprising as it would be expected that bone, for example, would have a high resistance. However, bone from freshly slaughtered animals contains blood and other ionic constituents effectively making it electrically similar to other tissues. The similarities of the resistance measurements is also a consequence of the fact that the brain can be regarded as a weak ionic solution. This effectively means that the whole head (skin, bone and brain) participates in conductance between electrodes. In effect the voltage generated between two stunning electrodes can be regarded as the generator of an electrical field within the brain. Therefore the further the stunning electrodes are away from the brain the lesser the effect, and recording electrodes perpendicular to the plane between the stunning electrodes will record only a small voltage difference.

Preslaughter electrical stunning is required to render an animal insensible to subsequent slaughter procedures such as throat cutting or heart stoppage. With head-to-body stunning it is of critical importance that a sufficient amount of current passes through the brain of the animal inducing epileptiform-like activity. In previous experiments using calves, when the current passed between the neck, (with electrodes positioned in an area approximating cervical vertebrae #2 to #5) to electrodes positioned on the brisket, stunning was not achieved (Cook et al., In Press) and in sheep a similar failing was observed when the head electrodes were positioned over the lower cervical/higher thoracic regions. Thus in both animal species caudal electrode positions producing a head-only stun (shown by epileptiform-like activity) can occur but the same caudal electrode positions cannot produce a stun when combined with a body electrode.

The foci of the electric field will obviously differ depending upon the electrode position and the addition of a body electrode presumably shifts the electric field down the body causing insufficient current to flow through the brain. Positioning electrodes at other body positions may be equally ineffective at eliciting a true stun with epileptiform-like activity, an example being a neck-to-hoof electrode system. In systems where the minimal required current flow through the brain is not met but where current does flow through the spinal cord and body, classic physical signs of a stun may be present, including loss of limb reflexes and paralysis, although true loss of consciousness cannot be assured. Without other interventions the animal will lose consciousness and die from cardiac insufficiency, due to fibrillation and resultant cardiac failure, and the humane criterion of humane slaughtering will not have been met. Stunning systems that involve a flow of current through the brain to the body, such as anterior head-to-brisket or nose-to-brisket, will be effective provided the stun parameters ensure adequate current flow.

Limb rigidity, apparent temporary paralysis, followed by a limb flaccidity was seen following neck-to-body stunning and in the animals where the positioning of the electrodes was too caudal, with respect to the head, to elicit epileptiform like activity. This feature of post electrical stunning thus appears to involve changes induced in the spinal cord by current flow. Movement control in animals during slaughtering is probably dependent upon good spinal current conduction and the temporal-spatial nature of the current delivered.

CONCLUSIONS

For preslaughter electrical stunning to be humane adequate current must flow through the brain, eliciting a loss of consciousness and hence insensibility to pain. This need can be fulfilled by suitable electrode placement combined with suitable stun parameters. Combining such placement with a body position that allows good spinal conduction of a suitable temporal nature will also provide excellent movement control.

REFERENCES

(1) Gregory, N.G. (1985) Preslaughter electrical stunning of pigs. Pig News and Information, 6(4), 407-413. Commonwealth Agricultural Bureaux, London.

(2) Bager, F., Shaw, F., Tavener, A., Loeffen, M., Devine, C. (1990) Comparison of EEG and ECoG in detecting cerebrocortical activity during slaughter of calves. Meat Sci. 27, 211-225.

(3) Cook, C.J., Devine, C.E., Gilbert, K.V., Tavener, A. and Day, A.M. (1991) Electroencephalograms and electrocardiograms in young bulls following upper cervical vertebrae to brisket stunning. N.Z. Vet Journal (In Press).