THE HUMANE SLAUGHTER OF ANIMALS: A REALISTIC GOAL!

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Summary

New techniques and concepts are described that define the neural events associated with effective humane electrical stunning and subsequent slaughter. Effective quality control must then be applied to ensure proper commercial application. Such quantitative scientific techniques could, and should, be applied to other methods of stunning and slaughter.

Introduction

Throughout human evolution, slaughter of animals has been a biological imperative. Stunning, introduced to protect those involved in slaughter, has been primarily used to control animal movement for desirable safety reasons. It is only relatively recently, with changes in societies priorities from purely biological obligations, that humaneness issues have become important. While most of us are divorced from direct predator role, we should not be completely removed from the moral issues of assuring welfare consideration during all phases of a meat producing animal's life.

Pre-slaughter head-only electrical stunning, is used in this review to demonstrate the approach taken to understand the scientific basis for determining humaneness in pre-slaughter stunning techniques. Head-only electrical stunning takes place with a passage of an electric current through the brain. The brain's electrical activity can be measured by electrodes placed on the scalp, i.e., electroencephalogram (EEG) (Figure 1.) or by electrodes placed on the surface of the cortex, i.e. electrocorticogram (ECoG). The pattern exhibited after stunning consists of an epileptic-like seizure (epileptiform activity) with large amplitude swings of a five-fold magnitude greater than non-stun levels. This electrical storm following a stun, predicates against the brain forming a *coherent mental construct of the external world* -- a condition necessary to form a model against which perception can occur. Captive bolt stunning typically results in immediate loss of recovery of evoked cortical potentials, although, interestingly, the EEG (or ECoG) can remain unchanged from the prestun state for many seconds (Daly *et al.*, 1988).

Slaughter without stunning

Slaughter without stunning involves severance of the main blood vessels, usually of the neck, and also severing nerves, trachea and oesophagus. Animal perceptions and levels of pain experienced during the subsequent period are unknown. The carotid arteries supply blood to the brain directly, and during exsanguination the brain's functional state will decline rapidly, although the role of the vertebral artery has not been definitively established. Theoretically in cattle, however, some blood under normal circumstances can reach the brain via the vertebral arteries following carotid severance (Daly *et al.*, 1988). This could be exacerbated by post-slaughter sealing of the carotid arteries (Baldwin, 1971). Issues of humaneness regarding the animal's perceptions, including pain, clearly arise.

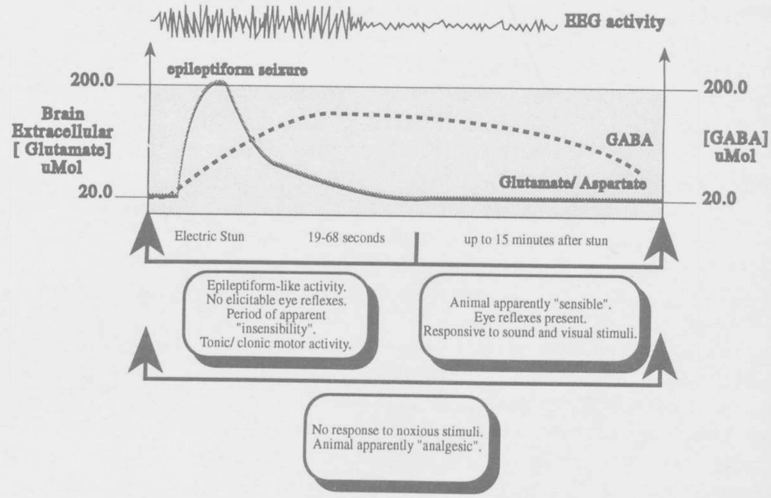

Figure 1. Neurotransmitter changes following head-only electrical stunning and the superimposed EEG trace typical of electrical stunning and durations of post-stun analgesia (not to scale).

Mathematical analysis of EEG and ECoG traces

It is difficult to fully assess the animal's level of consciousness, feelings of pain, confusion or awareness from the gross examination of the EEG. Analysis of the various frequency components of an EEG or ECoG using fast Fourier transform (FFT) (Bager *et al.,* 1989) can give some indication as to the state of the brain requiring analysis. The preponderance of low frequency, high amplitude activity, suggesting unconsciousness, is characteristic of anoxia (Prior, 1973), and after throat cutting without prior stunning, this state is that achieved between eight seconds for sheep and up to 85 seconds for cattle (Newhook and Blackmore, 1982). In the case of electrical stunning slaughter the analysis of the EEG indicates that there is never a stage at which the animal regains consciousness (Bager *et al.,* 1992).

Measurement of brain neurotransmitters and changes during stunning

An innovative approach to measure the changes in brain function is to evaluate the state of the brain with regard to neurotransmitter functional shifts during slaughter and to develop a nonanthropomorphic approach to quantitate humane issues using microdialysis probes implanted in the brain (Kendrick, 1989). The microdialysis probes, which can be placed in intimate contact with a particular brain area, work on a principle of osmotic equilibration across a dialysate membrane. The probes can pick up changes in the brain's environment such as a release of neurotransmitters. Measurement of these neurotransmitter shifts over time has shown profound changes following electrical stunning. Combining the changes in the neurotransmitters with studies using pharmacological receptor agonists and antagonists for the various neurotransmitters has allowed us to understand the contribution of these neurotransmitters to states of consciousness and contributions to the EEG signal (Cook *et al.,* 1992). The epileptic-like seizure that follows a head-only stun is mediated by three neurotransmitters: glutamate, aspartate and permissively, glycine. These neurotransmitters make important contributions to brain arousal states and, at levels attained by electrical stunning, result in an overexcitation of the brain. These increases occur to a lesser, but still more important extent, in animals slaughtered without stunning and this situation eventually contributes to the ischaemic-related loss of consciousness during death. Another neurotransmitter, γ-amino-4-butyric acid (GARA), is also released following electrical stunning and indices an analgesic state that lasts for up to 15 minutes in animals that are allowed to recover from a stun. Experimentally, this results in post-stun recovery analgesia, where the animal has recovered consciousness with sensory awareness but, with an apparent absence of pain perception.

Pharmacological experiments show that with extremely high levels of glutamate and aspartate receptor blockade, it is possible to deliver the stun current to the head and not induce a seizure, leaving the animal completely conscious (Cook *et al.*, 1992). In this state, the animal still exhibits the post-stun analgesia which is effective almost immediately following the delivery of the electrical current. If, however, the GABA receptors are blocked pharmacologically, then this post-stun analgesia is reduced and eventually abolished in a dose-dependent manner. Furthermore, the duration of the seizure is found to be extended.

Synergistic action of stunning and slaughter

When animals are slaughtered by severance of the carotid arteries and jugular vein, there is a typical time profile of approximately eight seconds for sheep and up to 85 seconds for cattle, to loss of consciousness (Newhook and Blackmore, 1982). The period of unconsciousness following a four second head-only stun lasts for approximately 45 seconds. Theoretically, in cattle this could leave a further 40 second period in which consciousness and presumably pain or distress could be perceived by the animal until ischemia-related unconsciousness ensued. Animals with a combined head-only stun followed by throat cutting go directly from the epileptic seizure state to one of loss of consciousness without a recovery period (Sager *et al.*, 1992).This suggests that both head-only stunning and throat cutting are acting in some synergistic manner on mechanisms affecting loss of consciousness. In other ischemic models (Shimada *et al.*, 1989), glutamate and aspartate appear to be involved in both loss of consciousness and in irreversible ischemic brain cell death. In animals that receive a throat cut alone, glutamate and aspartate neurotransmitter levels increase and continue to rise in response to the ischemic anoxic stimulus. The initial action is one of behaviourial arousal alerting the animal to a metabolic dysfunction. However, it appears that the glutamate and aspartate neurotransmitters are a two-edged sword such that concentrations following a throat cut reach a level at which they produce overexcitation, loss of consciousness, occasionally seizures and eventual cell death. Electrical head-only stunning results in a very rapid increase in glutamate and aspartate to levels at which overexcitation and seizures occur. When a throat cut follows, a further stimulus is applied to the glutamate and aspartate system and levels continue to rise. As they are already at a high magnitude, the time to irreversible loss of consciousness dramatically shortens (Figure 2). If we pharmacologically block the glutamate and aspartate receptors prior to a throat cut, then we can prolong the period of consciousness considerably, as shown by EEG's and animal behaviour (Cook *et al.*, in preparation). This synergistic combination, provides humaneness in slaughter.

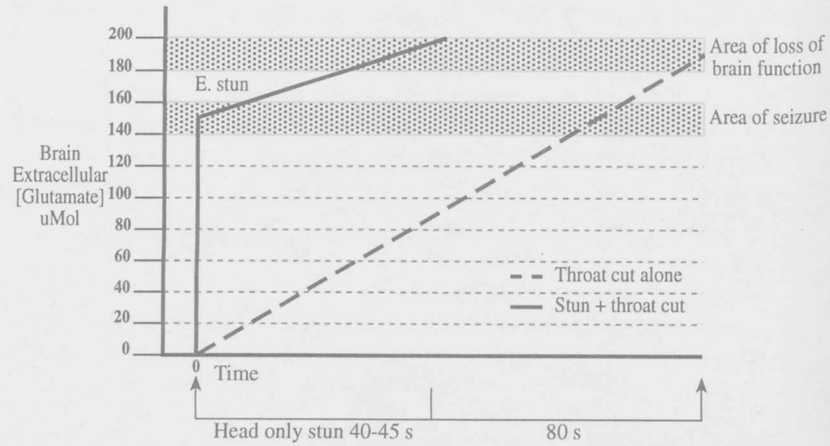

Figure 2. Schematic diagram showing the relationships of the rises in glutamate and aspartate and associated phases of seizure and unconsciousness during a throat cut alone and electrical stunning followed by throat cut in cattle. Sheep have a reduced time to unconsciousness and are not considered in this figure.

Quality assurance of head-only stunning: current levels and electrode placement

In order for electrical stunning to be effective and reproducible, adequate current must pass through the brain, which must be determined for each species. The position of the electrodes has been examined by Gilbert *et al.* (1991), who showed that when electrodes are placed too far (10cm) caudal to the brain (in sheep), the animal appeared stunned but in fact it was only paralysis, with no loss of consciousness, masquerading as a stun. As the current duration decreases, from 4 seconds down to 0.2 seconds, the animals were found to be stunned, as evidenced by the epileptiform fit, but the duration of this fit decreases. This is attributed to reduced glutamate and aspartate secretion when short duration stuns are used (Cook *et al.*, 1993). As stun durations increase, post stun movements decrease, although long stuns seem to result in some unusual physiological features that need further examination.

Implications for other stunning systems

In captive bolt stunning, the dispersal of the kinetic energy or the bolt in the brain results in failure of brain function. In particular, the energy absorbed during the impact of the bolt with the skull, produces the concussion which results in unconsciousness. However, in a manner equivalent to electrical stunning, the minimum requirements to produce insensibility and appropriate quality assurance need to be defined. The minimum kinetic energy (equivalent to current magnitude in electrical stunning) and appropriate shooting accuracy (equivalent to electrode positioning) are at present not as well defined as in the penetrative variety (Daly, 1987), although this stunning method also suffers from a lack of adequate characterisation of the minimum requirements to consistently produce an effective stun. It has been suggested that percussion stunning (Daly, personal commmunication) requires greater care in its use compared with the penetrative version for two reasons:

- firstly, there is a need for greater accuracy, as hitting weaker areas of the skull produce large depressed fractures, which absorb the energy of the bolt rather than transmit it to the brain; and

- secondly, the short travel distance of the percussion head means that even minimal pretriggering of the gun before the head is in contact with the head can severely impair performance. If percussion stunning is used to stun, rather than kill the animal as in religious slaughter, there is more uncertainty of humaneness especially with low impact energy.

The humaneness of carbon dioxide stunning has still not been satisfactorily determined by scientific research. It is clear that the high amplitude low frequency activity of the EEG precedes the convulsive activity in pigs (Forsslid, 1992), but the effect on the animals during the induction period is unclear and it produces a period of breathlessness which at the least is unpleasant (Gregory *et al.,* 1990). While this method may be humane and some scientific evidence does support this (Forsslid, 1992), there is too little so that this process needs addressing by more direct methods of brain function assessment.

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