

**A SCIENTIFIC COMMENT ON THE WELFARE OF SHEEP
SLAUGHTERED WITHOUT STUNNING**

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**ANIMAL WELFARE
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Biographical Sketches

Australian Contributors

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Associate Professor Andrew D Fisher *BVSc PhD* is a veterinarian and scientist at the Faculty of Veterinary Science, The University of Melbourne and conducts his research within the Animal Welfare Science Centre. He has had a 17-year research career studying animal health and welfare, particularly of sheep and cattle. He is recognised for his research on painful husbandry procedures and analgesia, as well as livestock transport. He is a member of the Australian College of Veterinary Scientists through examination in animal welfare, and is a member of the writing group for sheep welfare standards and guidelines under the Australian Animal Welfare Strategy.

New Zealand Contributors

Professor David J Mellor *BSc(Hons) PhD HonAssocRCVS ONZM* is an animal welfare scientist, applied physiologist and bioethicist who is Co-Director of the Animal Welfare Science and Bioethics Centre and a Distinguished Scientist in the Institute of Food, Nutrition and Human Health at Massey University. Throughout his 42-year research career he has used fundamental science to solve practical, clinical and animal welfare problems in farm livestock. He is an international authority on the causes and prevention of death and ill-thrift in newborn animals, the assessment and alleviation of pain caused by husbandry procedures, the scientific and ethical assessment of slaughter, and the science and regulatory management of animal welfare. He was a member of the international *Ad Hoc* Group that drafted the OIE Global Guidelines for the Slaughter of Animals for Human Consumption (2005).

Associate Professor Craig B Johnson *BVSc PhD DVA DipECVA MRCA MRCVS* is a veterinarian and neurophysiologist based at The Institute of Veterinary, Animal and Biomedical Sciences Massey University, and is an Associate of the Animal Welfare Science and Bioethics Centre at that University. He has extensive clinical and research experience in the areas of veterinary anaesthesia and comparative analgesia acquired over the past 20 years. He is particularly recognised for the development of the minimal anaesthesia model and its application to the study of a number of painful husbandry procedures including castration in lambs and slaughter without stunning in cattle. Regarding his work in the latter area, he was recently awarded the UK Humane Slaughter Association's 2009 prize for significant advances in the humane slaughter of farmed livestock.

Executive Summary

This review, utilizing the current literature, provides a scientific comment and the associated rationale on the welfare of sheep slaughtered without stunning. The supporting scientific evidence is derived from specific studies of sheep and other ruminant livestock. Where appropriate, reference is also made to findings in other mammals, and for general knowledge about the direct experience of pain, reference is made to human studies and clinical practice.

Pain is an inherently subjective experience. While humans can report pain, only indirect indices of pain are available for use in animals. Furthermore, many of the traditional behavioural and physiological indices that have been used to study pain are also measures of non-painful stressors. For example, measures such as heart rate, hormone response and behaviour are not specific to pain. However, neurophysiological tools are now widely used in humans to assess pain in both research and clinical settings. Studies in human volunteers and in patients experiencing pain have demonstrated that in contrast to the more traditional physiological measures, electroencephalographic (EEG) variables correlate well with subjective evaluations of pain, indicating the value of quantitative EEG analysis as an indicator of the degree of pain perceived by humans. These neurophysiological tools have also been applied and demonstrated in animal studies in search of a monitor of adequacy of anaesthesia and to assess the efficacy of analgesic agents.

Human beings overwhelmingly report pain associated with major cutting injuries to tissues and it is widely accepted in science that farm animals and other mammals also experience pain due to such injuries. Furthermore, the overwhelming international scientific opinion has long been that neck cut slaughter of conscious animals would cause pain. A recent series of studies in calves at Massey University demonstrated that the act of slaughter by ventral-neck incision is likely to be perceived as painful in the period between the incision and the onset of insensibility. In view of the lack of difference between cattle and sheep with respect to functional anatomy of the neck, neurophysiology of peripheral nerves, brain centres and pain experience, and control of acute pain, it is proposed that, as in cattle, non-stunned sheep would experience pain during the period between the neck cut and the onset of insensibility after slaughter.

However, the precise assessment of the point after slaughter at which non-stunned animals become insensible to pain has been and remains a major methodological challenge. A review of the literature on this issue indicates no unequivocal estimate of the interval to insensibility. The shortest estimate based on loss of ability to stand is 2-4 seconds and the longest estimate based on time to onset of clonic convulsions is 68-158 sec. The estimates based on EEG measurements all fall between these two extremes, that is from 2-8 seconds in duration up to 8-20 seconds in duration..

Taken together, these review findings indicate that because the slaughter of sheep by ventral-neck cutting without prior stunning is likely to cause pain, slaughter of sheep without stunning poses a risk to animal welfare in the period between the time of the neck cut and the time of loss of awareness. The duration of this period of risk is not currently known with certainty. It is at least 2-8 seconds in duration, but may be 8-20 seconds in duration.

Introduction and Scope of the Review

This review has been prepared in response to a request from Peter Bailey, Executive Director, Biosecurity Victoria, Department of Primary Industries, for a scientific comment from the Animal Welfare Science Centre, a joint centre of The University of Melbourne, Monash University, the Victorian Department of Primary Industries and The Ohio State University on the welfare of sheep slaughtered by neck cut without stunning. This paper, utilizing the current literature, provides a scientific comment and associated rationale on the welfare of sheep slaughtered without stunning. Scientists at Massey University, New Zealand, have long-established international standing for their research excellence on pain in farm animals and more recently for their research on pain in animals undergoing slaughter. Therefore, in order to benefit from this world-class expertise during this project, two members of the Animal Welfare Science Centre, Professor Paul Hemsworth and Associate Professor Andrew Fisher, collaborated with Professor David Mellor and Associate Professor Craig Johnston of the Animal Welfare Science and Bioethics Centre (AWSBC) at Massey University.

This review focuses on the welfare of sheep at slaughter. Supporting scientific evidence is derived from specific studies of sheep and other ruminant livestock. Where appropriate reference is also made to findings in other mammals. Reference to non-mammalian vertebrates has been specifically excluded. For general knowledge about the direct experience of pain, reference is made to human studies and clinical practice.

1. Pain assessment in relation to neck cut slaughter

“Pain is an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage” (Merskey, 1979).

1.1 Pain and its assessment

Pain is an inherently subjective experience. While humans can report pain, only indirect indices of pain are available for use in animals (Gregory, 2004; Mellor et al., 2008). Many of these are also measures of non-painful stressors (e.g. Mellor et al., 2000, Appendix 1; Gregory, 2004), yet some have been useful indicators of pain in closely controlled experimental circumstances where their limitations were recognised (Table 1). Those used most often have been indices of physiological stress responses and pain-related behavioural responses (Lester et al., 1996; Peers et al., 2002; Gregory, 2004, Mellor et al., 2008).

Neurophysiological tools are now widely used in humans to assess pain in both research and clinical settings (e.g. Apkarian et al., 2005). They have also been applied to animals in search of a monitor of adequacy of anaesthesia and also to assess the efficacy of analgesic agents (Table 1 from Murrell and Johnson, 2006; Appendix 2). The value of neurophysiological tools in assessing pain and its alleviation in farm animals has been demonstrated (Gibson et al., 2007, Appendix 3; Johnson et al., 2009).

Table 1: Some physiological and behavioural indices of distress responses to noxious stimuli in ruminants and other species [Originally from Mellor et al. (2000), subsequently supported by Gregory (2004) and Mellor et al. (2008)].

<u>Physiological Indices</u>	<u>Behavioural Indices</u>
<i>Blood hormone concentrations</i>	<i>Vocalisation</i>
adrenaline	whimpers, howls, growls
noradrenaline	screams, grunts, moans,
	squeaks, squeals, chirps,
	silent.
corticotropin releasing factor	
adrenocorticotrophic hormone	
glucocorticoids (e.g. cortisol)	
	<i>Posture</i>
prolactin concentrations	cowers, crouches, huddled,
	hiding, lying (legs extended,
	all or some legs tucked in),
<i>Blood metabolite concentrations</i>	standing (on all or not all legs,
glucose	rigid, head against wall,
lactic acid	drooping).
free fatty acids	
β -hydroxybutyrate	<i>Locomotion</i>
	reluctant to move, awkward,
<i>Other variables</i>	shuffles, staggers, falls, stands
heart rate	up /lies down repeatedly,
breathing (rate and depth)	circles, escape/avoidance
packed cell volume	movements, pacing, restless,
sweat production	writhing.
muscle tremor	
body temperature	<i>Temperament</i>
	withdrawn, depressed,
plasma α -acid glycoprotein levels	quiet, docile, miserable,
blood leukocyte levels	agitated, anxious, frightened,
cellular immune responses	terrified, aggressive.
humoral immune responses	

Human beings overwhelmingly report pain associated with major cutting injuries to tissues (Gregory, 2004). It is widely accepted that farm animals and other mammals also experience pain due to such injuries (Gregory, 2004; Mellor et al., 2008).

The scientific basis of this is as follows:

- *Functional anatomy*: an extensive cut through tissues transects skin, muscle, arteries, veins, sensory nerves (including nerves transmitting information about pain), other nerves and connective tissue. These soft tissues are sensitive to pain (Loeser et al., 2001; Gregory, 2004).
- *Neurophysiology of peripheral nerves*: cutting most of these tissues and the nerves themselves will cause a barrage of impulses to travel to the brain leading to the experience of acute pain (Gregory, 2004).
- *Pain sensitisation*: chemical chain reactions instigated by products of cell damage activate pain pathways in the period following tissue damage (Gregory, 2004).
- *Brain centres and pain experience*: the results of imaging and electrophysiological studies indicate that specific areas of the brain including the primary somatosensory, anterior cingulate and pre-frontal cortices are active during an acute pain experience (Gregory, 2004; Apkarian et al., 2005).
- *Control of acute pain*: these pathways can be manipulated to reduce pain in several ways using a variety of pharmacological approaches including nerve blockade (local anesthetics) and specific pain-relieving drugs (analgesics) (Mellor et al., 2008).

1.2 Neck cut slaughter and pain assessment

The overwhelming international scientific opinion has long been that neck cut slaughter of conscious animals would cause significant pain (e.g. NAWAC, 2001; FAWC, 2003; EFSA, 2004).

The scientific basis of this is as follows (Gregory, 2004):

- *Functional anatomy of the neck*: The neck cut is very extensive and transects skin, muscle, trachea, oesophagus, carotid arteries, jugular veins, other blood vessels, sensory nerves (including nerves transmitting information about pain), other nerves and connective tissue. These soft tissues are sensitive to pain.

- *Neurophysiology of peripheral nerves*: cutting the tissues and the nerves of the neck will cause a barrage of impulses to travel to the brain leading to the experience of acute pain.
- *Pain sensitisation*: will not occur due to the neck cut per se – the chemical chain reactions associated with this occur over a longer time course than is relevant to the events following slaughter (Woolf and Chong, 1993).
- *Brain centres and pain experience*: nerve conduction velocities ensure that activation of brain centres following major cutting injury occurs within milliseconds. Therefore, the potential experience of pain is directly relevant to the events following the neck cut.
- *Control of acute pain*: stunning abolishes the experience of pain caused by the neck cut. Effective methods currently include percussive and electrical stunning (Gregory, 1998).

Nevertheless, few if any direct studies of pain following neck cut slaughter were undertaken until recently. This is primarily because most of the indices available are not suitable for this purpose for several reasons:

- They are not specific to pain (e.g. heart rate, hormone responses, behaviour)
- The time course is too short for a meaningful response to be expressed (e.g. hormone responses, behavioural aversion)
- Features in the process of slaughter inherently confound the measure (e.g. heart rate, blood pressure)
- Features in the process of slaughter prevent expression of the measure (e.g. vocalisation, physical withdrawal responses).

Accordingly, the focus of most studies was on determining the period of sensibility that followed the neck cut in the belief that pain would occur until insensibility supervened (Newhook and Blackmore, 1982; Gregory and Wotton, 1984, 1988; Devine et al., 1986; Tidswell et al., 1987). These studies will be considered in more detail below (Section 2).

It should be recognised that although the majority scientific view was that the neck cut causes pain (NAWAC, 2001; FAWC, 2003; EFSA, 2004), an alternative view was held by others who claimed that significant pain may be avoided with the use of an extremely sharp knife with a swift, clean incision followed by a free bleed-out (e.g. Grandin, 1994; Levinger, 1995; Rosen, 2004).

1.3 ***New evidence on pain and the neck cut***

1.3.1 *Non-slaughter research*

Recent electroencephalographic (EEG) studies, which involved use of a new 'minimal anaesthesia' model (Murrell and Johnson, 2006), have provided fresh insights into the perception of pain by animals.

The principal rationale for this approach is as follows (Johnson, 2008). The EEG gives a direct indication of the activity of the cerebral cortex (Silva, 2004). Functional imaging techniques developed in the last decade have demonstrated that certain cortical structures, in particular the anterior cingulate gyrus, play a central role in pain perception (Apkarian et al., 2005). Studies in human volunteers and in patients experiencing pain have demonstrated that in contrast to the more classical physiological measures, EEG variables correlate well with subjective evaluations of pain (Chen et al., 1989). These findings indicate the value of quantitative EEG analysis as an indicator of the degree of pain perceived by an animal, as opposed to the magnitude of the noxious stimulus applied to the animal.

Quantitative EEG analysis has now been used as an indicator of the experience of pain in nine mammalian species, namely humans, horses, sheep, pigs, rats, red deer, wallabies, cattle and dogs (Chen et al., 1989; Murrell et al., 2003; Johnson et al., 2005; Haga & Ranheim 2005; Murrell & Johnson, 2006; Johnson et al., 2005 b; Diesch et al., 2005; Gibson et al., 2007). The animals studied were lightly anaesthetised. Although anaesthesia blunts these EEG responses, researchers have developed the technique of 'minimal anaesthesia' (Murrell & Johnson, 2006). The animals are anaesthetised and so cannot experience pain, but their cerebral cortices respond in the same way as when they are conscious.

1.3.2 *Calf slaughter studies*

In a recent series of studies in calves, Gibson et al. (2009a-d, Appendix 4), investigated the potential for slaughter by ventral-neck incision to be perceived as painful in the interval between the incision and subsequent loss of awareness. The impact of ventral-neck incision alone is reported in the first paper (Gibson et al. 2009a): *the incision was associated with significant noxious sensory input that would have been likely to be perceived as pain in conscious animals*. The question of whether this noxious sensory input was due primarily to the cutting of neck tissues or to interruption of blood flow to and from the brain is addressed in the second paper (Gibson et al. 2009b): *the predominant noxious stimulus was*

transection of neck tissue. The third paper reports on the impact of non-penetrative captive-bolt stunning on the features of the EEG, which were assessed quantitatively for the first time (Gibson et al. 2009c): *the vast majority of animals were rendered insensible before data were able to be collected from about 3 seconds after stunning.* The fourth paper assesses the extent to which applying a non-penetrative captive bolt stun 5 seconds after the ventral-neck incision ameliorated the noxious sensory input caused by the incision (Gibson et al. 2009d): *the stun prevented the subsequent development of responses in the EEG to noxious sensory input in most of the animals.*

This new information demonstrates clearly for the first time that the act of slaughter by ventral-neck incision is likely to be perceived as painful in the period between the incision and the onset of insensibility. The effects of captive-bolt stunning in producing rapid insensibility and ameliorating changes in the EEG associated with neck incision have also been clearly demonstrated. Taken together, these papers (Gibson *et al.*, 2009a-d) provide the most comprehensive electrophysiological picture to date of the events surrounding slaughter by neck incision, and provide further support for the value of stunning in preventing pain in animals subjected to this procedure.

1.3.3 *Relevance to slaughter of sheep*

In view of the lack of difference between cattle and sheep with respect to functional anatomy of the neck, neurophysiology of peripheral nerves, brain centres and pain experience, and control of acute pain, it is anticipated that, as in cattle, non-stunned sheep would experience pain during the period between the neck cut and the onset of insensibility after slaughter.

All of the above information indicates that neck cut slaughter in non-stunned sheep will cause pain.

2. Assessment of the interval between the neck cut and insensibility

The purpose of the neck cut is to kill the animal. It severs major blood vessels supplying and draining the brain and this causes a catastrophic decrease in cerebral blood flow and eventually brain death. In non-stunned animals it is the lack of oxygen due this loss of blood flow to the brain that causes the onset of insensibility (Mellor and Littin, 2004). The interval between the neck cut and the onset of insensibility determines the period during which pain may be experienced after the neck cut.

Definitions of terms used in this context are often imprecise. For the purposes of this review, the following terms will be used.

- *Awareness* means the capacity to experience sensations, including unpleasant sensations such as pain.
- *Insensibility* means a complete inability to experience any sensations, including unpleasant sensations such as pain.

Insensibility represents a complete absence of awareness.

Over the years various attempts have been made to assess the interval between the neck cut and the onset of insensibility in non-stunned animals including ruminants.

2.1 Methodological approaches: strengths and limitations

The precise assessment of the point after slaughter at which non-stunned animals become insensible to pain has been and remains a major methodological challenge. Although attempts have been made using changes in different features of brain electrical activity and behavioural changes, there remain interpretational limitations with these. As noted by Tidwell et al. (1987), “*There are no definitive methods for determining the exact time of onset of insensibility during the slaughter process ...*”, and this is still true today.

2.1.1 EEG

EEG morphology

The EEG changes gradually from a normal pattern to an isoelectric pattern following the neck cut. A number of researchers have attempted to categorise the intermediate stages in this progression and have speculated about which stages indicate awareness and which insensibility. Nangaroni and Kennett (1964) used unspecified morphological changes to determine insensibility. Newhook and Blackmore (1982) identified three categories: active EEG, transitional EEG and isoelectric EEG. They considered that active EEG reflected awareness and that transitional and isoelectric EEG patterns indicated insensibility. Subsequent researchers have used categorisations based on those of Newhook and Blackmore (1982).

Evoked responses

Evoked responses are EEG patterns recorded in response to a rapidly repeating stimulus which may be visual, auditory, tactile or painful. They

can be difficult to interpret because mathematical amalgamation of multiple responses is often necessary to detect them against background EEG activity (Murrell & Johnson, 2006). In addition, the response to a repeated uniform stimulus can decrease over time in a stable preparation (Gibson, 2009). Finally, evoked responses change in different ways with different neurological manipulations. For example, they can be recorded under very deep anaesthesia with some agents (e.g. thiopentone, propofol), but are abolished under light anaesthesia with others (e.g. halothone) (Huatori et al., 2004; Gibson, 2009). Gregory and Wotton (1984) recorded visual evoked responses following neck cut slaughter of anaesthetised sheep.

2.1.2 Behaviour

Behaviour has been used as an indicator of the onset of insensibility, but interpretation of each behavioural index may be equivocal unless supported by other information (Blackmore, 1984).

Collapse

Collapse occurs when a freely standing animal falls to the ground. This is the earliest indication of approaching insensibility after the neck cut (Blackmore, 1984; Grandin, 1994).

Loss of righting reflex

This occurs when a recumbent animal that attempts to regain its feet ceases to do so. It has been suggested that this may indicate the loss of sensibility (Blackmore, 1984).

Clonic convulsions

Clonic convulsions are due to advanced brain oxygen shortage and loss of function (Blackmore, 1984; Grandin, 1994). Some researchers have used the time from the neck cut to the onset of such convulsions as an unequivocal indicator of definite insensibility which would have begun earlier.

2.2 Quantitative estimates of the interval to insensibility

There have been several investigations of the interval to insensibility following neck cut slaughter based on analysis of the EEG. The findings of these studies are summarised in Table 2.

A single study reports behavioural changes in three lambs and two ewes. These results are summarised in Table 3.

Table 2: Summary of previous studies in sheep on interval to insensibility following neck cut

Reference	Number of sheep	EEG criterion used to determine insensibility	Time after incision
Nangeroni & Kennett 1964	Unknown	Normal EEG Short period of high potential discharge before cessation of EEG	For 3.5-5 sec Began at 12-15 sec
Newhook & Blackmore 1982	10	Amplitude below 10 μ V	By 2-7 sec
Devine et al 1986	10	Amplitude below 10 μ V	By 8-22 sec 13.6 \pm 7.4 sec (SD)
Tidswell et al 1987	1 - neck cut	Amplitude below 10 μ V Isoelectric	By 7 sec By 48 sec
	1 - decapitation	Amplitude below 10 μ V Isoelectric	By 8 sec By 20 s
Gregory & Wotton 1984	20	Loss of visually evoked responses	At 14 sec(mean) By 22 sec (95% upper confidence limit)

Table 3: Summary of behaviour following neck cut in five sheep

Behaviour	Mean \pm se (sec)	Range (sec)
Loss of ability to stand	3 \pm 0.4	2 - 4
Loss of apparently coordinated attempts to rise	9 \pm 0.6	8 - 11
Pupil dilation	80 \pm 11.1	56 - 114
Onset of clonic convulsions	119 \pm 17.5	68 - 158

Data from Blackmore (1984)

These studies contained no unequivocal estimate of the interval to insensibility. The shortest estimate is based on loss of ability to stand at 2-4 seconds and the longest estimate is based on time to onset of clonic convulsions at 68-158 sec (Blackmore, 1984). The estimates based on EEG measurements all fall between these two extremes.

3. Conclusions – Welfare Risk

The research reviewed above represents an incomplete picture of the events surrounding slaughter by ventral-neck incision in sheep, but there is sufficient information to allow a number of conclusions to be drawn confidently and also a number of others by inference from studies carried out in other species of mammal, particularly in cattle. The following section will list these conclusions and inferences prior to providing a final analysis of the welfare risk of slaughter by ventral-neck cutting without prior stunning in sheep.

Conclusions about the neck cut and pain

Slaughter by ventral-neck cut without prior stunning in cattle has recently been demonstrated to be painful in the period between the time of the incision and the time of loss of awareness. There are currently no direct data that demonstrate this in sheep, but the physiological similarities between sheep and cattle indicate that neck cut slaughter in non-stunned sheep will cause pain.

Conclusions about the time to insensibility

As noted by Tidswell and colleagues in 1987, *“There are no definitive methods for determining the exact time of onset of insensibility during the slaughter process ...”* This remains true today. Thus, the precise assessment of the point after slaughter at which the animal becomes insensible to pain has been and remains a fundamental challenge in understanding the duration of sensibility in non-stunned animals at slaughter.

It is clear that slaughter by neck cut does not render sheep immediately insensible. Sheep may remain aware for at least 2-8 seconds following the cutting of major blood vessels of the neck. Depending on the interpretation of different behavioural and EEG measures as indicators of insensibility, the duration of this awareness may normally be in the order of 8-20 seconds. It might possibly be as long as 68–158 seconds, but this is not likely to be the case.

Overall conclusions

Taken together the conclusions above indicate that because the slaughter of sheep by ventral-neck cutting without prior stunning is likely to cause pain, slaughter of sheep without stunning poses a risk to animal welfare in the period between the time of the neck cut and the time of loss of awareness. The duration of this period of risk is not currently known with certainty. It is at least 2-8 seconds in duration, but may be 8-20 seconds in duration.

Appendices

Copies of published papers included in the appendices are not for reproduction or dissemination, and are provided specifically for reference only by those who will use this report.

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