Pain and its Control

In

Routine Husbandry Procedures

In

Sheep and Cattle

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## Contents

Routine Husbandry Procedures .................................................................................. 3
Castration ................................................................................................................... 3
Tail Docking ............................................................................................................... 3
Dehorning .................................................................................................................. 4
Mulesing .................................................................................................................... 4
Pizzle Dropping ......................................................................................................... 5
Identification ............................................................................................................ 5
Conclusion ................................................................................................................ 6

The Issue of Pain ........................................................................................................ 7
Pain, Stress, Distress and their measurement ............................................................. 9
Cortisol and the Hypothalamic-Pituitary-Adrenal Axis ............................................... 10
Behaviour .................................................................................................................. 12
Salivary cortisol and “free cortisol” ........................................................................... 13
β-endorphins ............................................................................................................. 14
Afferent activity (ascending nerve impulses) of the superior spermatic nerve ...... 14
Noxious mechanical thresholds ............................................................................... 14
Electroencephalogram ............................................................................................ 14
Observation of Inflammatory Lesions and Healing .................................................. 14
Acute Phase Proteins ............................................................................................... 15
Catecholamines ........................................................................................................ 15
Hands on and Hands off Measurements of Stress .................................................... 15

Comparison of techniques and analgesic regimes in husbandry procedures - Sheep .. 17
Non-surgical sterilisation ........................................................................................... 17
Surgical techniques .................................................................................................. 17
Castration .................................................................................................................. 17
Tailing ....................................................................................................................... 18
Research .................................................................................................................... 18
Mulesing .................................................................................................................... 27

Systemic Analgesics in Sheep .................................................................................. 28
Summary – Sheep ...................................................................................................... 30
Castration and Tailing ............................................................................................... 31
Castration .................................................................................................................. 33
Tailing ....................................................................................................................... 33
Conclusion ................................................................................................................ 36

Comparison of techniques and analgesic regimes in husbandry procedures - Cattle .......................................................................................................................... 37
Castration .................................................................................................................. 37
Chemical Castration ............................................................................................... 37
Non-Chemical Castration ....................................................................................... 38
Conclusion ................................................................................................................ 41
Disbudding and Dehorning ....................................................................................... 41
Research .................................................................................................................... 42
Summary .................................................................................................................... 48
Conclusion ................................................................................................................ 51
Branding ..................................................................................................................... 51
Conclusion ................................................................................................................ 53
Conclusion ................................................................................................................ 54
References ................................................................................................................ 57
Routine Husbandry Procedures

Domestic livestock (sheep, cattle, goats, pigs, and less common examples including deer and small camelids such as alpacas) are managed by farmers to maintain their health, welfare and productivity. This review will focus on some aspects of the management of sheep and cattle, since pigs are not kept for production in the ACT, and because sheep and cattle numbers far exceed those of the other species. While the husbandry of these other species may differ from that of sheep and cattle, the principles revealed by this review may be applicable to other species until specific research has been conducted. It should be noted that significant research has been conducted into the welfare (and other) aspects of the harvesting of velvet from deer, and that an industry accepted accreditation scheme enforcing the use of local and systemic analgesia (pain relief) is in place for this species.

This review is concerned with those aspects of the husbandry of livestock which include deliberate tissue damage, specifically:

- Castration, tail docking, mulesing, dehorning, “pizzle dropping” and identification of sheep (and goats)
- Castration, tail docking, dehorning and identification of cattle

Other procedures such as vaccination (where the discomfort of skin penetration is momentary, although there is stress associated with animal handling), shearing (including crutching, wigging etc) and foot paring, where tissue damage is accidental, will not be considered in this review.

Castration

Reasons for castration include:

- To avoid indiscriminate breeding and maintain genetic control of breeding stock
- To avoid risk of injury as a result of sexual related behaviours
- The belief that castration improves carcass conformation and quality and avoids carcass downgrading due to male “taint”
- To avoid the discount such carcasses attract at sale/slaughter
- To avoid other “disruptive behaviours” (broken fences, escaping stock etc)
- To fulfil legal requirements for example in relation to overseas export of live animals

Although there are niche markets for bull and ram meat, castration will remain essential across both the sheep and cattle industries for the foreseeable future. While ram lambs could be “turned off” before puberty and the associated taints develop, this relies upon rapid growth rates which are not reliable due to variable weather and climatic conditions in this area.

Tail Docking

Tail docking of sheep is performed to reduce fleece soiling (of the tail and breech[perineum]) and hence fly strike. Tail docking is essential for all replacement sheep (i.e. those which will remain in the flock for a number of years – rams and ewes for breeding and wethers for wool). Experiments in Victoria have shown that although tail docking is not absolutely essential to maintain the health and welfare of prime lambs in all production zones, rates of fly strike and of chemical usage are likely to be higher. The impact of flies may be minimised in seasons where rapid growth and early turn off are possible, but this is neither practical nor predictable. Tail docking of sheep will continue for the foreseeable future.

Tail docking of dairy cattle is common in some areas (New Zealand, Victoria, and Tasmania), but rare in other States. Docking is banned in Denmark, Germany and the United Kingdom but
common in Ireland and the USA. Tail docking of dairy cattle has been performed to improve milking shed and udder hygiene, cow health and workplace health and safety, importantly because of the belief that this procedure would reduce the spread of Leptospirosis (Weil’s disease) in dairy farmers. Existing scientific evidence does not support claims that tail docking of dairy cows reduces the prevalence of mastitis, improves the clinical health of cows, reduces the soiling of teats and udders, reduces bacterial contamination of milk or reduces the incidence of leptospirosis in staff, and there are moves to enforce a ban on tail docking of cattle. Neuromas (a tangled mass of disorganised axons (nerve fibres) which may grow where a nerve is severed, and which may cause pain) have been found in the tail stumps of cows slaughtered at more than 3 years of age which had been docked with a knife at 12-18 months of age. Hyperalgesia and phantom pain may occur in livestock, as they do in people. However, other welfare problems may occur due to reduced ability to swat flies and perhaps through loss of a social or mood signaler. Finally, there is only one dairy farm in the ACT, which does not practice tail docking, so this procedure will not be considered further.

**Dehorning**

Dehorning, or horn trimming, is performed in sheep relatively rarely, because many breeds and classes of sheep are naturally polled (born without horns) or are sent for slaughter at such an early age that horns do not pose a risk to other animals or handlers. Some older sheep (especially rams) have their horns tipped or trimmed to avoid self-damage (growing into the face) or damage to other sheep e.g. when fighting or in yards. This procedure is usually performed with a saw or bolt cutters (or equivalent) and does not involve sensitive tissue. Some (perhaps 10% of) wethers whose horns begin to grow toward their heads (commonly at 2-3 years of age) may have the outer shell of the horn stripped off with a sharp twisting movement. This only needs to be performed once.

Dehorning of cattle is commonly performed in breeds which are not naturally polled to improve safety for stock handlers, to reduce injuries to other animals and carcass damage in animals en route to slaughter, and as a requirement for cattle entering feed lots. The extent of dehorning, and indeed the proportion of polled versus horned cattle in the ACT is not known. This could be explored through a survey of rural lessees.

**Mulesing**

Mulesing of sheep is a technique where strips of wool-bearing skin are removed around the anus and tail of sheep to induce scar tissue which is not wool bearing. The intention is to minimise moisture and faecal contamination of perineal wool, in order to prevent fly strike. Other measures to prevent fly strike include parasite control to prevent scouring, crutching (shearing of wool from the perineal area), selection of sheep with fewer “wrinkles”, application of insecticides to sheep, blowfly control (e.g. release of sterilised male flies) and, of course, tail docking. Mulesing has been shown to dramatically reduce the incidence of breech strike in otherwise well managed sheep flocks. Blowfly strike is acknowledged as a major welfare problem for sheep (causing pain, illness, death and stress of treatment) and “the most important problem confronting the wool and sheep-meat industries in Australia today”.

There are a number of techniques for mulesing. The so-called “radical” mules procedure can no longer be justified on welfare grounds, and should be abandoned for the “modified” technique or one of its variants. Consideration could be given to banning the radical mules operation to improve the husbandry of sheep.
The mules operation is typically performed at lamb marking (1-7 weeks of age), without anaesthesia or analgesia. Even the most strident advocates of mulesing agree that is a painful procedure, but one which is well justified in reducing later suffering and death. Like all husbandry procedures, the pain and stress of the procedure are inversely proportional to the skill, experience and care of the operator, and in NSW about 60% are done by contractors, who are likely to be much more experienced than stock owners. There is a mulesing accreditation scheme managed by the Livestock Contractors Association of NSW, but accreditation is not compulsory.

Chemical alternatives to surgical mulesing have been developed, and formulations containing phenol\textsuperscript{xii}, a complex of the polyanionic glycosaminoglycans in skin with a cationic compound\textsuperscript{xii} and quaternary ammonium compounds\textsuperscript{xiii} have been shown to be effective, as has irradiation\textsuperscript{xiv}. However, these methods have either been impractical, or not found favour with farmers.

A recent press release heralds a major advance in this area from the CSIRO\textsuperscript{xv}. In conjunction with Virbac Australia Pty Ltd, a new “Breech Strike Prevention Technology” has been developed. After close clipping, a “natural compound” is painted onto areas of the breech which are to be rendered wool free. Metabolism in the skin makes the compound photo-active, when light of a limited wavelength is applied for several minutes, some skin organelles are destroyed, including hair follicles. The technique is apparently not constrained by age, but would probably not be done at lamb marking time to avoid castration and tail docking wounds and blood. Because of the artificial (filtered) light source, it would probably be performed indoors, using a cradle or bail for restraint. The product is at least 5 years from commercial release.\textsuperscript{xvi}

It is generally accepted that mulesing will continue as a routine component of the husbandry of replacement sheep in the ACT for the near future. The welfare of sheep could be improved by encouraging the training and accreditation of operators for performing the mules operation, and by legislating that only accredited operators be allowed to perform the procedure.\textsuperscript{xvii}

Mulesing will be further mentioned in passing in discussion of pain control for other husbandry procedures.

**Pizzle Dropping**

“Pizzle dropping” of sheep, a technique intended to reduce the incidence of “pizzle rot” (infection and fly strike of the prepuce) has been abandoned due to lack of efficacy.\textsuperscript{xviii}

**Identification**

Identification of livestock is both a practical and legal requirement. Identification establishes ownership, fulfils requirements for “trace back” by animal health authorities (for example, for drug residue testing) and enables individual animal identification for breeding and other management purposes. Methods used include:

- Branding of cattle (almost exclusively hot iron rather than freeze branding)
- Horn branding of sheep (rare)
- Ear tags
- Ear notching
- Tail tags

Hot iron branding is performed less commonly than previously, partly due to the reduced value of hides when marked with brands, but is still considered necessary by many ACT rural lessees, especially those in more isolated areas, as protection against cattle theft. Although clearly a
painful procedure, there appears to have been little research into the alleviation of pain from this procedure.

Ear tags are commonly applied in cattle (and to a lesser extent, sheep), usually at “marking time”. Sheep are routinely “ear notched” for property identification (and commonly age), and this is currently a legal requirement (section 22 of the ACT *Stock Act 1991*) associated with foot rot control. Ear tagging and notching are quick procedures and I am unaware of research into welfare aspects of these procedures, so they will not be discussed further, except in passing.

Tail tagging of cattle is routinely performed for all animals for sale, is a legal requirement, and is not a surgical procedure. It will not be further discussed.

**Conclusion**

Castration of all sheep and cattle, mulesing and tail docking of all replacement sheep, and dehorning of a percentage of cattle will continue as routine husbandry procedures for the foreseeable future. This review will consider techniques for optimising the welfare of animals undergoing these procedures.
The Issue of Pain

It can be argued, and is generally accepted, that most or all of the husbandry procedures routinely performed upon livestock animals are necessary, not just for ease and convenience of the stock handler, nor just for productivity, but also for the health and long term welfare of the animal itself. Farmers would not have continued to perform these procedures, sometimes at risk to themselves, unless there was a clear and observable benefit, and scientists would not, in the last century, have continued to conduct research about these procedures (for example, tail length in lambs). While increasing production can push an animal beyond the limits of acceptable welfare, when an animal is taken out of its “natural state”, animal production improves as animal welfare improves. xix

But do these procedures cause pain? Can animals experience pain, and if they do, is it the same as the way we experience it? Pain was defined by the International Society for the Study of Pain as “an unpleasant sensory or emotional experience associated with actual or potential tissue damage”. There is a purely physiological component (nociception), and a psychological component (the experience of pain). Another definition is “an aversive sensory experience that elicits protective motor actions, results in learned avoidance, and may modify species-specific traits of behaviour, including social behaviour”. xx

In mammals, and possibly in other vertebrates, the receptors, nerves, transmitters, and spinal pathways are the same as in humans. xxxi So are the physiologic mechanisms such as autonomic responses, neuro-endocrinological changes, and altered Electro-Encephalo-Graphic (EEG) responses. Behavioural responses are similar – animals avoid noxious stimuli that are painful to human beings. Threshold measures (e.g. temperature, skin pressure) are comparable for aversive behaviours (withdrawal, avoidance). xxxii

The perception of pain, or at least the unpleasant aspects of pain, is likely to occur in the pre-frontal cortex, at least in humans. Most animal species have relatively small areas of pre-frontal cortex, and this has been used to argue that their perception of pain may be less than ours. xxxiii However, the size of the pre-frontal cortex may not be a determinant of the experience of pain, or other areas of the brain may fulfil this role in other species. There is no reason to suppose that the perception of pain evolved as a wholly new sensory phenomenon in humans. xxxiv
It is generally assumed that if a procedure is painful in human beings, then it must also be painful in animals. xxv xxvi While it is “unclear what form animal experiences take and unlikely that their experience is as complex as those of humans under similar circumstances, intact awake animals are capable of sensory experiences, which (given the opportunity), they avoid and which modify their biochemistry, physiology and behaviour in species-specific ways which can be related to those seen in humans experiencing pain”. xxvii

Just as we accept that there are individual differences in the response to pain, some of which are associated with age, gender, and health status (Flecknell PA 2000 1-8), there are also differences between species and between breeds. An animal’s response to pain can be a determinant of its survival. Amongst prey animals, the behaviour in response to pain, which is most likely to help them to survive, is the behaviour which does not attract the attention of predators. This applies to cattle, sheep, goats and other wild herbivores which appear more stoical and do not overtly demonstrate that they are in pain. Predators on the other hand, can afford to demonstrate pain, as can be more readily seen in dogs and cats. A third group are those animals which live in a well developed social structure, where clear demonstration of pain, often vocally, will bring others to defend or help the injured individual – this may happen in pigs, monkeys and possibly elephants and dolphins. Humans, which are both predators and social animals, may be a very poor example of a typical animal response to pain. Consequently, to judge the pain animals experience by the way humans behave will seriously underestimate their suffering in most cases. xxi

But is the fact that animals suffer pain important? “Pain may have a certain protective role in minimizing tissue damage. Animals learn many things about their environment though pain, and acute pain frequently serves to change behaviour and prevent further tissue damage. However, pain may also serve as a stimulus for destructive behaviour. ….Pain and suffering are associated with maladaptive physiologic responses and maladaptive behaviours. …there are no beneficial effects of unrelieved pain in animals….” xxv

To simply regard pain as an unacceptable state because of its detrimental effects on the animal (and its production) ignores the ethical component. “As soon as one has admitted that animals can be hurt in ways which matter to them, or even admitted that animals are entitled to humane care and treatment, or that unnecessary animal suffering is wrong, one has implicitly but inescapably presupposed that animals are in the moral arena, that it makes sense to talk about them in the moral tone of voice, that one can be morally wrong in how one uses or treats animals, none of which we could say of chairs or wheelbarrows”. xxvii It is the view of the author that allowing an animal to suffer avoidable pain is morally wrong and is repugnant to most in Australian society. This review explores evidence for pain associated with routine husbandry procedures, and considers ways to minimise the pain (and stress) of such procedures.
Pain, Stress, Distress and their measurement

In order to determine whether a procedure causes pain, it is necessary to select certain parameters to observe which reveal an animal’s response to pain. Further, if different procedures are to be compared for their “degree of painfulness”, these parameters must be observable, repeatable, recordable, and gradable – that is, we need some objective measures of “painfulness”. And especially if we are to recommend that certain procedures or techniques be either used or abandoned, it is necessary to be able to prove that there is a benefit to the animal, in reduction of pain, associated with the recommended procedure.

It is not possible to directly measure “pain”. Even amongst humans, it is very difficult to compare levels of pain – is your experience of pain greater or lesser than mine? This has been partly overcome by the development of “pain scales”. Such scales integrate objective (heart and respiratory rates, blood pressure) and subjective (spoken descriptions in people, behavioural changes in animals), and such scales have been explored and developed for dogs, and have been used in studying the pain of castration in lambs.

In reality, these “pain scales” are not measuring pain, but rather indicators of stress and distress. Stress is a physiological response, indirectly measurable by various objective parameters including hormone levels, by which the body attempts to resume homeostasis (return to “normal”). These changes are induced by a “stressor,” such as excessive environmental or psychological pressures or human intervention. Technically, it is not correct to speak of stress as the external effector, although even Medical Dictionaries may use this more common parlance.

Distress refers to the emotional content of noxious experiences that elicit physiological stress responses in animals, whether that noxiousness is predominantly emotional (fear), physical (vigorous exercise) or a combination of both (pain). Pain-induced distress is used to indicate the interacting emotional and physical facets of the noxious experience.

Stress is a complex issue. There is no one best biological variable by which to measure it. While there is no one non-specific stress response which characterises all types of stressors, many very different stressors can result in very similar stress responses. Inter-animal variability in response can confound assessment of stress, and there has been difficulty in establishing a correlation between stress measures and a meaningful impact on an animal’s well being. Moberg points out that the end point of a measure of stress should be a biological response that has a meaningful impact on the animal’s well being. He defines a sequence from the stimulus (stressor), perception of stressor, organisation of biological defence, biological response (behavioural, autonomic, neuro-endocrine), change in biological function, pre-pathological state, to development of pathology. He considers that only the last two are meaningful as measures of stress or distress, but concedes that it is illogical and inhumane to allow animals to enter a pathological state in order to assess a stressful situation. Therefore, he proposes that investigators use the pre-pathological state as the end point for such experiments. Unfortunately, it does not appear that any researcher has moved beyond the physiological markers below in investigating pain and distress in husbandry procedures. Moberg’s suggestions for pre-pathological indicators – immune suppression and altered reproductive function - are open to investigation, but are perhaps less likely to be altered by short term stressors such as those discussed here.
Many physiological and behavioural indices may be measured in the assessment of stress and distress in animals, including:

**Physiological indices**
- Blood hormones – nor-adrenaline, adrenaline, corticotropin releasing factor (CRF), adrenocorticotropic hormone (ACTH), gluco-corticoids (e.g. cortisol in mammals, corticosterone in birds and reptiles), prolactin, oxytocin
- Blood metabolite concentrations – glucose, lactic acid, free fatty acids, β-hydroxybutyrate
- Other variables – heart rate, breathing (rate and depth), packed cell volume, sweat production, muscle tremor, body temperature, plasma α-acid glycoprotein levels, blood leucocyte levels, cellular immune responses, humoral immune responses

**Behavioural indices**
- Vocalisation – whimpers, howls, growls, screams, grunts, moans, squeaks, squeals, chirps, silence
- Posture – cowers, crouches, huddled, hiding, lying (legs extended, all or some legs tucked in), standing (on all or not on all legs, rigid, head against wall, drooping)
- Locomotion – reluctant to move, awkward, shuffles, staggers, falls stands up/lies down repeatedly, circles, escapes/avoidance movements, pacing, restless, writhing
- Temperament – withdrawn, depressed, quiet, docile, miserable, agitated, anxious, frightened, terrified, aggressive

**Cortisol and the Hypothalamic-Pituitary-Adrenal Axis**
One of the most commonly used markers for “stress” is the measurement of blood cortico-steroid levels. The cortico-steroid (gluco-corticoid) hormones (mainly cortisol in mammals) are released from the cortex of the adrenal gland after stimulation from the hypothalamus and pituitary gland, and initiate protracted metabolic and anti-inflammatory responses. Almost by definition, cortico-steroids are considered as “stress hormones”. Moberg argues that because these hormones evolved to help an animal cope with stressors, they cannot be taken as measures of change in the animal’s well being. Rushen pointed out that Cortisol levels rise in association with coitus and with expectation of the delivery of food, and with voluntary exercise in human subjects, situations we would not associate with stress or distress. In response, Barnett argues that the sort of pathological and pre-pathological states considered useful by Moberg (loss in body protein, reduced reproductive performance, sustained increase in metabolic rate, suppression of the immune system) are seen in animals where there is a compromise in welfare, and “are a consequence of a sustained elevation of corticosteroids, that is, a chronic stress response”.

In a review published in 1990, the Australians Barnett and Hemsworth suggest that the threshold for the adrenocortical system may be higher than for behavioural systems, that is, that behavioural evidence of a response to a treatment may be seen in the absence of a cortisol response, if the level of distress is less. They point out that while the stress response is an adaptive response, it has a cost including the development of ulcers, hypertension, arteriosclerosis and immune suppression (all seen in the pig).

They also suggest a level at which cortisol responses may indicate detrimental consequences – when there is a rise in free cortico-steroids of > 40%, at least for housing and handling (human-animal interaction) situations.

Recent research has also confirmed significant interactions between the endocrine, immune and central nervous systems. Cortisol is released from the cortex of the adrenal gland due to a surge in blood levels of Adreno-Cortico-Trophic Hormone (ACTH). This hormone is released from
the pituitary gland in response to raised levels of the neuro-peptide Corticotropin releasing hormone (CRH) from the hypothalamus. CRH also acts as a neuro-transmitter, playing a key role in the activation of endocrine, physiological, neuro-chemical and behavioural responses. It activates the sympathetic system resulting in raised levels of catecholamines, blood pressure and heart rate. It also acts in areas of the brain critical for cognitive function and emotion. Thus, blood cortisol may in part reflect activation of all of these components of a stress response. Stress, acting through CRH and other cytokines from the immune system, may cause animals to learn faster, and the resulting behavioural changes may be adaptive to maintaining or restoring immune system homeostasis.\textsuperscript{31}

Blood cortisol levels have been shown to rise in response to a wide range of husbandry and clinical procedures – see Table 1. This does not mean that cortisol is a measure of pain, but has been used to indicate the overall noxiousness of the experience, including both physical and emotional components. If two groups of animals are treated identically, except that one group acts as a “control” for a group who experience a surgical husbandry procedure (such as castration), and cortisol levels are found to rise higher in all the treated animals than in the control animals, then it would be foolish to presume that the cortisol rise indicated anything other than stress or distress.

It is important to note that the cortisol response is relatively slow and that catecholamines (adrenaline, nor-adrenaline) may be more useful in assessing the early stages of the distress response.\textsuperscript{xxiv}

Table 1 – Noxious, unpleasant or challenging experiences known to stimulate the hypothalamic-pituitary-adrenocortical system

<table>
<thead>
<tr>
<th>Physical Injuries</th>
<th>Emotional challenges</th>
<th>Physiological challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branding</td>
<td>Anticipating/remembering challenge</td>
<td>Extreme cold or heat</td>
</tr>
<tr>
<td>Cautery (hot-iron)</td>
<td>Anxiety/fear</td>
<td>Hypotension</td>
</tr>
<tr>
<td>Cryo-cautery (freezing)</td>
<td>Anticipating/remembering challenge</td>
<td>Hypoxaemia</td>
</tr>
<tr>
<td>Burns</td>
<td>Electro-immobilisation</td>
<td>Vigorous exercise</td>
</tr>
<tr>
<td>Castration</td>
<td>Strange environments/isolation</td>
<td>Metabolic disease</td>
</tr>
<tr>
<td>Cutting (knife)</td>
<td>Unusual handling/restraint</td>
<td>Pregnancy toxoaemia</td>
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<tr>
<td>Constriction (rings)</td>
<td>Shearing</td>
<td></td>
</tr>
<tr>
<td>Clamp (burdizzo)</td>
<td>Mustering/yarding/barking dogs</td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>Transport, loading and unloading</td>
<td></td>
</tr>
<tr>
<td>Disbudding, cautery (hot iron)</td>
<td>Predator-prey interactions</td>
<td></td>
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<tr>
<td>Dehorning, cutting (amputation)</td>
<td>Social dominance expression</td>
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<tr>
<td>Mulesing, cutting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tailing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cutting (knife)</td>
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</tr>
<tr>
<td>Constriction (rings)</td>
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<td></td>
</tr>
<tr>
<td>Cautery (docking iron)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tooth grinding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical injuries, post-anaesthetic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other physical injuries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Some disease states</td>
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</tbody>
</table>

Recording and graphing repeated blood cortisol levels against time, enables comparison of the speed of change, the magnitude and duration of the cortisol rise, between different groups of animals undergoing different treatments. There is no single numerical factor which defines
distress response. Mellor and co-workers have developed and used the “integrated cortisol response” (the area under the cortisol curve that lies above the pre-treatment concentration) as a useful parameter for comparative purposes, but have identified potential shortcomings if used alone.\textsuperscript{xix}

“Cortisol has been used extensively to assess distress because its response magnitude as indicated by peak height, response duration and/or integrated response, usually accords with the predicted noxiousness of different procedures”.\textsuperscript{xix} Some treatments may not induce a response greater than the “control group”, illustrating the strong emotional component of the cortisol response to “mock treatments”, and in other cases several, differing, treatments may all record a similar, maximal, cortisol response. In these cases, it is likely that that either the most painful factor predominates, or that there is a “ceiling effect”. This may lead to an underestimation of the noxiousness of more invasive treatments.

Loss of control and “helplessness” have been identified as major stimulators of the stress response \textsuperscript{xxv}, and the emotional content of the distress experienced by animals undergoing husbandry procedures is an important, though little recognised, consideration for those interested in improving their welfare and well being. Dantzer \textit{et al} stressed the importance of assessing these physiological indicators in conjunction with behaviour to assess mental experience.\textsuperscript{xxv} There is also a strong interaction between behaviour and hormonal responses. While it has also been shown that hormones can affect behaviour, the specific behaviour in which the subject engages is critical to the quality and intensity of hormonal responses.\textsuperscript{xl} For example, lambs which were isolated and restrained for 6 hours (binding all four legs with adhesive tape and isolation from tactile and visual contact with other lambs) demonstrated elevated blood cortisol levels for the duration of restraint. Values rapidly returned to normal, and this period of stress did not affect cell-mediated immune function in these lambs.\textsuperscript{xli}

\textbf{Behaviour}

While behaviour can and should be used to assess an animal’s psychological well-being or “mental state”\textsuperscript{xlii, xliv} as an important indicator of welfare, behaviour can also be used for monitoring pain-induced distress. Behavioural responses to pain may achieve four purposes:

- Automatic protective responses (e.g. withdrawal)
- Those that minimise pain and assist healing (e.g. lying still)
- Those designed to elicit help or stop further pain being inflicted (e.g. vocalisation, posturing)
- Those that induce learning or modify the animal’s behaviour to avoid recurrence of the experience

The behaviour may be presumed to indicate pain if it is seen in treated but not control animals, and if treated animals do not manifest the behaviour if pre-treated with effective local anaesthetics. Different treatments may induce different, treatment-specific behaviours, preventing a direct comparison of the noxiousness of treatments by behaviour alone. In these cases, physiological indicators are useful to compare levels of noxiousness (pain). Behaviour may be used to identify different features of the pain-induced distress response, through response magnitude and duration, but there are difficulties.\textsuperscript{xix}

When different treatments elicit unique behavioural responses this probably occurs because the sensations experienced by the animals are not the same, because different tissues are damaged, or the same tissues are damaged in different ways. Comparison should always be made between similar animals (age, sex, genotype, management) under similar conditions.\textsuperscript{xlv}
Components of behaviour must be very carefully observed, assessed and recorded. The abnormal behaviour may occur in “normal” individuals, but at a reduced frequency or magnitude compared to treated individuals. Similar but different behaviour patterns must be differentiated, and the observer must be looking for subtle effects.

Certain trends have been consistently found in behavioural observations of the (presumed) pain response to castration and tailing in lambs. xlvi xlvii

- An increase in restlessness generally indicates an increase in pain (for rubber ring methods) (however, it is not reliable to compare levels of pain between treatment groups by comparing the level of restlessness, and it should be noted that restlessness develops into a period of pain-induced immobile lateral lying)
- Lateral recumbency generally indicates more pain than ventral recumbency
- Extension, rather than flexion of the hind limb generally indicates more pain
- More abnormality of standing and or walking including ataxia, swaying and falling indicates more pain
- Standing still or lying still may reduce pain and at any particular time a lamb is considered to be suffering less pain when standing still than when moving abnormally (however, it is also possible that the character and intensity of pain could immobilize lambs)
- Behaviour rarely used in the control group can be referred to as abnormal

While cortisol (in most mammals, or corticosterone in reptiles and birds) consistently rises in response to emotionally or physically noxious experiences across a wide range of species, behavioural response show marked differences between species. As already noted, there are markedly divergent behaviours in predator versus prey species, but of course behavioural responses may differ amongst related species. The age, gender, reproductive status (reproductive hormone levels) and experience also affect perception of pain, and its expression. xix Therefore comparison of levels of noxiousness of treatments between species, ages, genders and reproductive groups on the basis of behaviour must be performed very carefully, or not at all.

The literature exploring pain and its control in routine husbandry procedures has extensively relied on measurement of blood cortisol and observation of behavioural indices. The following methods have also been applied, with comments.

Salivary cortisol and “free cortisol”
Collection of saliva and its analysis for cortisol has been used in sheep xlviii and calves xlix. Collection of saliva was considered to be less stressful than blood sampling (thus eliminating some of the stress response due to the collection procedure), and “free cortisol” (the biologically active fraction of the total blood cortisol value) was seen as a more powerful diagnostic tool. However, other researchers have not taken up salivary cortisol, perhaps because of the relative ease of blood sampling in lambs and calves, and because it is generally considered that free and total cortisol levels change in parallel. xix Non-parallelism in some stages of the cortisol response may contribute to ceiling effects seen in cortisol levels, and animals experiencing low-level distress may demonstrate low levels of total cortisol but elevated free cortisol. The original researchers from NSW Department of Agriculture (Richmond) used blood cortisol in one subsequent publication.1
β-endorphins

β-endorphins (endogenous morphine-like substances) are secreted in response to stress (including pain) and are believed to be an internal mechanism for coping with pain by stimulating the same receptors upon which morphine and other opioid drugs act to provide analgesia (and euphoria etc). Shutt et al interpreted the rise in β-endorphins as indicating a marked physiological response, and suggested that they may provide some degree of analgesia post-operatively. However, it has been questioned whether the presence of β-endorphins implies a reduction of suffering, or the presence of pain and suffering (albeit attenuated). Naloxone, an Opioid antagonist, has been used to eliminate the effects of β-endorphins in order to assess their analgesic effect. The authors concluded that the beneficial effect of β-endorphins was small.

Afferent activity (ascending nerve impulses) of the superior spermatic nerve

Measurement of electrical activity in anaesthetised, surgically prepared lambs subjected to various procedures and analgesic techniques has been performed, and while such techniques identify the source of nociceptive (pain) sensations, the cost in lambs and technical difficulty make this a relatively impractical technique for further investigation.

Noxious mechanical thresholds

The benefits of different analgesic treatments can be compared by the application of carefully graded, mechanically induced, stimuli to body tissues, such as the hoof wall. Response is seen by foot lifting or leg withdrawal. The stimulus can be pressure, electrical, or heat. To date, all methods have involved either restraint to enable delivery of the stimulus (pressure, heat), or connection of cables (electrical), and there has been some concern that such restraint may introduce its own errors. A laser-based thermal nociception method has also been described in cattle, which allows remote stimulation. However, the “target area” must be shaved in advance.

Electroencephalogram

While conventional EEG tracings have shown very few consistent correlations with pain, frequency spectral analysis has revealed strong correlations between certain spectral changes and reports of pain from humans. EEG frequency spectral changes are believed to reflect the cortical (brain) electrical activity associated with cognitive perception of pain. An electrical stimulus (4 ms pulses or varying current up to 20 mA) produced behavioural signs associated with pain (escape-avoidance), and very brief increases in the absolute power of delta 2, theta 2, alpha 1 and alpha 2 bandwidths, and this was interpreted that in sheep, as in humans, spectra analysis of the EEG would provide a good measure of acute pain in sheep. However, when the same techniques were applied to lambs undergoing castration, tail docking, mulesing, ear tagging, sham shearing, formalin injection (to induce lameness) or handling, the EEG changes were the reverse of those expected, with reduction in the mean power values across all bandwidths of the EEG. Further, the technique as performed requires surgically implanted recording electrodes. Clearly, further development is needed before this model can be used for interpretation of the level of pain-induced distress in sheep.

Observation of Inflammatory Lesions and Healing

While not an index of acute pain, observing the progression of inflammation and healing of castration and tailing wounds for up to 41 days after the event, and their correlation with behavioural signs of pain, enabled comparison of the effects of different methods of castration
and tailing, and of the effects of attempts at analgesia.\textsuperscript{ix} Comparison with cortisol values has also provided useful information.\textsuperscript{xii}

**Acute Phase Proteins**
Serum haptoglobin is an acute phase protein synthesised in the liver in response to tissue inflammation or infection. Although a useful marker of inflammation in sheep and cattle, haptoglobin levels remained at, or marginally above, the detection limit of the assay used in lambs castrated and tail docked with rubber rings within 7 days of birth.\textsuperscript{xiii} Haptoglobin was therefore not useful to discriminate between different analgesic regimens.

**Catecholamines**
Epinephrine (adrenaline), nor-epinephrine (nor-adrenaline) and heart rate have been measured in one study of the effects of different methods of branding on Angus calves. All three values rose within half a minute of application of a hot-iron brand, and were significantly higher than in sham and freeze branded animals. Measurements then dropped close to pre-treatment values and were not significantly different between groups again until 15-20 minutes after treatment, at which time all three values rose in the hot-iron brand group.\textsuperscript{xiv}

**Hands on and Hands off Measurements of Stress**
To date, most studies of the pain and distress of husbandry practices have used “hands on” methods to measure physiological parameters. Unfortunately, even in the best-acclimated subjects, the act of data collection induces some stress which affects the results. Comparison of treated and control (not-treated) subjects allows subtraction of the effect of the sampling protocol from the results, but researchers have sought better techniques.

Apart from blood, saliva and milk may also be used to assay certain blood chemicals, but obviously some handling is still required. Urine and faeces can be used, but the samples reflect events in the body for an unknown number of hours prior to sample acquisition. Remote blood sampling systems involving indwelling catheters, a peristaltic pump and rotor mounted collection vials offer the opportunity to sample animals at high frequency, over an extended period of time, with no handling during the sampling period to introduce errors, although some habituation to the sampling device is still required.

Telemetry devices which record physiological variables, process the data “on animal” and transmit summary data via radio waves, are also becoming available. Heart rate, body and environmental temperature, ECG and EEG, biosensors for cortisol and nitric oxide, and GPS (Global Positioning System) may all be available. Auditory evoked responses (an electrical manifestation of the central nervous system’s reception of and response to an external stimulus) vary with psychological state such as anxiety, and can be remotely evoked and measured. Microdialysis probes as small as 50 \(\mu\)m, offer breakthrough methods of measuring levels of neuro-transmitters in the brain of subjects. Finally, observation and analysis of behavioural data is becoming more complex and allows better assessment of the welfare state of animals, particularly when interpreted in conjunction with physiological data.\textsuperscript{xiv}

Such techniques offer great hope for our ability to assess the welfare implications of human intervention in the future. However, a large body of research has been performed whose findings are in the main consistent and repeatable, and allow both ranking of the distress of different techniques for performing various husbandry procedures, and estimation of the benefits of analgesic techniques. It would be indefensible to ignore this available information while awaiting the perhaps more accurate data which may flow from studies in the future.
It has quite rightly been argued, however, that the possible revision in ranking of the noxiousness of various procedures in the light of future research makes it inappropriate to set a “gold standard” – that is, to ban all procedures except the one currently accepted as providing the greatest welfare benefit. This approach would also alienate those farmers unable to meet the new standard, and would be discredited if it is ignored and cannot be enforced. Instead, a strategy of incremental improvement has been proposed and will be discussed later.
Comparison of techniques and analgesic regimes in husbandry procedures - Sheep

Non-surgical sterilisation
Injection of a sclerosing agent into the genitalia is a possible alternative to more tissue invasive/destructive methods. Injection of formaldehyde (10% in ethanol) into the epididymis appeared to only cause minor discomfort, but did not render all rams aspermic (95% chance that less than 5% of rams will be fertile at day 48). Of course, injections into the epididymis would have no effect on testosterone production and therefore treated sheep would still demonstrate male behaviours, including “nuisance” components.iii

Injection of a sclerosing agent (lactic acid) into the testes of Brahman bull calves took three times longer than surgical castration, and caused no less acute pain than the surgical method. Healing took about twice as long, and 25% of treated calves suffered scrotal necrosis. Technical failure is possible, and calves which retained testes after chemical injection behaved as males even though they were aspermic, causing management problems. The researchers concluded that this treatment was not an acceptable alternative to open surgical castration.iv

Surgical techniques

Castration

Surgical: While more complicated surgical procedures have been described, the routine method of surgical castration of sheep on farms is for the distal (lower) third of the scrotum to be cut off with a sharp, chemically sterilised, knife; the testes are then grasped (commonly with specially designed tongs) and drawn out individually. The spermatic cords (vas deferens, testicular artery, vein and nerve, cremaster muscle and associated soft tissue) rupture within the lamb’s body, but the stretching which occurs prior to breakage effectively seals the blood vessels and haemorrhage is usually minimal.

Rings: Sheep are commonly also castrated by application of tight rubber rings (Elastrator™) to the neck of the scrotum, above the testes. Structures distal to the ring have their blood supply interrupted, and die, necrose and drop off after a period of time. Rarely, the “short scrotum” method is employed, in which the testes are pushed up against the body wall, and the ring applied below the testes. The scrotum but not the testes die and drop off, and the testes survive. They continue to produce androgenic hormones (testosterone), but not spermatozoa. These lambs therefore grow faster under the influence of these hormones, and are infertile, but they will continue to behave as males.

Burdizzo: The Burdizzo or castration clamp is designed to crush tissue including blood vessels and nerves. It may be used alone, or in conjunction with a knife or rings, and in these studies was mostly used to provide more immediate cessation of transmission (nociceptive) nerve signals, to produce more rapid pain control. It may be applied across the full width of the
scrotum, or to the left and right halves separately, with a band of uncrushed skin between the sites of application of the two blades. Full width application is likely to induce scrotal necrosis and loss, while leaving an uncrushed band will generally allow the scrotum to survive. The testes will atrophy and cirrhose due to crushing of their blood supply.

Figure 3 – Anatomy and innervation of the scrotum and testis in the lamb - from

Tailing

Lambs are tailed between the 7th and 8th coccygeal vertebrae such that the remaining tail just covers the tip of the vulva (in females). This may be performed by cutting with a sharp knife, application of tight rubber rings, or by cautery. Cautery is performed using a “docking iron” – a gas powered device with a continuously heated chisel shaped copper jaw which closes onto an unheated steel jaw in a scissor action. Heat severs the tail, seals blood vessels, and destroys nerve endings, all within 2 seconds.

The Burdizzo has also been applied to the tail, but this application is considered to produce more pain than knife or ring tailing alone.

Research

Shutt and colleagues used observation of behaviour, and measurement of cortisol and $\beta$ endorphins to compare surgical (knife) versus rubber ring castration.\(^1\) Poll Dorset x Border Leicester-Merino lambs of 3-6 weeks of age were used. Their conclusion that surgical castration and docking caused less distress than the use of rubber rings, despite higher cortisol and $\beta$ endorphins, was based at least in part on their observation of differing behaviour in knife
versus ring treatment groups. Application of rubber rings caused almost no initial reaction, but within 2 minutes, lambs stamped their hind legs, shook their tails, bleated, looked around and ran back and forth in an increasingly frantic fashion. By 5 minutes most lambs were rolling on the floor of the pen, these behaviours reaching a peak at 15 minutes. By 60 minutes, almost all behaviour had returned to normal.

The surgical group, on the other hand, reacted more to cutting and removal of the testes. They then stood with a huddled stance for 15 minutes, and moved slowly toward their dams. They were observed to be behaving normally, except for some restriction in movement, by 60 minutes.

Barnett, and Mellor and Holmes, disagreed with the interpretation that rings were more painful than the knife, pointing out that too little was known of the behavioural repertoire of lambs to rank these behaviours, and that behaviours cannot be compared when tissue damage is different. Problems with the observation and interpretation of the cortisol data were also discussed.

Mellor and Murray, working in Edinburgh, investigated the behaviour and cortisol responses of lambs up to one week old, to tailing, or castration and tailing, using rubber rings. They described the restless behaviour characteristic of this technique, and reported that castration and tailing induced maximal release of cortisol as compared to that stimulated in control lambs by the injection of adreno-corticotrophic hormone (ACTH). They were able to rank the level of distress caused by handling alone, tailing and castration, and tailing using both behaviour and cortisol levels, which were in agreement.

The same investigators repeated the same techniques in two breeds of lambs at 6 ages between birth and 7 days of age. They found significant differences in cortisol response between the two breeds (Dorsets exhibiting more marked responses than Scottish Blackfaces), and observed a marked increase in apparent ACTH secretory responses to noxious stimuli during the first one to three days after birth. Whether this increased response to noxious stimuli reflects an increase in pain-induced distress was not determined, but if so, it accords with observations that newborn animals demonstrate a smaller behavioural response to such stimuli.

Further work in the same institution compared behaviour and cortisol responses in lambs (Dorsets), goat kids (mixed breed) (both 1 day old) and calves (Friesian – 1-7 days) to castration, tail docking (in lambs) and to ACTH injections. Good general correspondence was found between behavioural observations and cortisol responses, but there were distinct differences in the behavioural and cortisol responses between the three species. No behavioural differences were noted between lambs that were castrated and those which were castrated and tail docked, and the cortisol responses were similar, which suggests that there is minimal or no extra distress experienced when lambs are tailed at the same time as castration. It should be noted, though, that animals tailed only (female lambs) showed a significant response to this procedure.

The Edinburgh group investigated the effects of local anaesthesia and intravenous naloxone on the behavioural and cortisol responses to ring castration and tail docking in 5-6 days old, Dorset x Finnish Landrace lambs. Local anaesthesia (Lignocaine) was injected epidurally (around the spinal cord), into the scrotal neck, spermatic cords and testes 15-20 minutes prior to further treatment. Such treatment should block all afferent nociceptive transmissions. There were minimal or no differences in behaviour and cortisol response between control (handled), control (local anaesthetic), and local anaesthetic (castrated and tailed) lambs, suggesting that the
combination of local anaesthesia and ring treatment abolished all sensations of pain up to 4 hours.

Naloxone (an opioid inhibitor) was given to inhibit any analgesia associated with $\beta$-endorphins. Naloxone did not change cortisol responses but did increase abnormal behaviours (lateral lying) for up to one hour, though the differences were small. The authors concluded that the pain and distress of castration and tail docking cannot be significantly reduced by endogenous Opioid activity, but that it can be eliminated with local anaesthesia.

Lester and colleagues in New Zealand used cortisol to compare knife versus ring (castrated, castrated and tailed, “short scrotum” castrated, tailed with a docking iron) in 3-4 week old lambs. Cortisol responses were greater and of longer duration when a knife was used. They concluded:

- Use of the knife was more distressing than any other technique
- Use of the knife caused similar levels of distress whether for castration, tailing, or both
- Tailing with rubber rings was less distressing than for castration or castration and tailing
- Tailing with rubber rings, or a docking iron, caused similar levels of distress to the control group, though the docking iron induced a shorter response.
- Combinations of castration, short scrotum castration with rubber rings, and tailing with rubber rings or a docking iron, produced similar levels of distress.

Molony and Wood used cortisol and behaviour to assess the effect of ring castration +/- tail docking on 4-6 day old lambs. Analgesic treatments included local anaesthetic infiltration into the scrotal neck, spermatic cords and testes, and into the epidural space between Cd1 and Cd2 (i.e. around the spinal cord). In addition, reduction of nociceptive transmission was attempted using the opiates morphine or etorphine, or the $\alpha_2$ adrenergic xylazine, injected at the lumbo-sacral junction (segment T10). Naloxone was also given to antagonise any endogenous opioids.

Infiltration of local anaesthesia reduced behavioural and cortisol responses to levels not different from the control group. Epidural morphine and xylazine, and intra-thecal etorphine, did not significantly change the behavioural and cortisol response to castration, suggesting they were ineffective as painkillers at this dose rate. Naloxone administration caused a small increase in abnormal behaviours, and of teat seeking.

They concluded that ring castration induced pain which increased for about the first 30 minutes, then decreased gradually over the next 60-120 minutes. At its most severe, the effects of castration dominated the behaviour of the lambs. Afferent neural activity does not outlast the local anaesthetic effects of lignocaine, probably due to the retention of lignocaine in the scrotum due to the ring. Failure of the spinal analgesics was unexpected, and may have been due to failure to reach appropriate receptors, or lack of such receptors in lambs of this age. Naloxone may act at a supra-spinal site (since spinal opioids failed to provide analgesia). Teat seeking is probably one of the lambs’ pain reduction strategies.

Molony, Kent and Robertson compared behavioural responses to castration and tail docking using surgery (open castration including clamping the spermatic cord followed by heat cautery, clamping of the tail followed by cutting and cautery), rubber rings, or rubber rings followed by a Burdizzo clamp. Greyface x Suffolk lambs were treated at 5, 21 or 42 days of age. Behavioural signs differed between the surgical group and the ring groups, with much more “statue standing” amongst the surgically treated lambs. Application of the Burdizzo clamp significantly reduced the intensity and duration of abnormal behaviours compared to rubber ring
treated lambs. Although surgery appeared to be more painful in younger lambs than in older lambs, overall there was little difference between the ages in the pain produced by the three methods. xlvi

The same researchers compared cortisol concentrations in the same groups of lambs. Cortisol levels rose faster in lambs treated surgically or by rubber rings and burdizzo, reached similar peak concentrations in surgical and rubber ring groups, but persisted at higher levels in the surgical group for longer than 180 minutes, by which time cortisol had returned to normal values in rubber ring and ring plus burdizzo groups. Cortisol levels in the burdizzo group rose quickly, but to a lower peak level than the surgical group, and fell more quickly than in the ring only group. They found no substantial evidence to support the view that younger lambs suffered less acute pain than older lambs in any of the treatment groups. They concluded that the rubber ring plus burdizzo method was probably the least painful. lxxv

Researchers from the same institution compared behavioural and cortisol responses in 5 to 6 day old lambs (Suffolk x Greyface) using the Burdizzo alone, standard or small rubber rings, and a combined method. They found that the smaller rubber rings increased the severity but reduced the duration of the distress response (probably by more quickly interrupting nerve signals responding to ischaemia below the ring), but that the combined method produced the least behavioural and cortisol response. They believed that improvement was generated by either more careful positioning of the clamp, by extending the duration of clamping (from 6 to 10 seconds), or both. Whereas the clamp is applied in two actions when it is used alone, leaving a strip of uncrushed scrotum which may allow nerve transmission, in the combined method the Burdizzo is applied across the full width of the scrotum, and this appears to be the preferred method. lxxvi

The only paper using nerve isolation and recording of transmission discovered in the literature search, investigated the effects of standard and small rubber rings, and the effect of local anaesthesia on nerve impulses generated in response to castration. Cottrel and Molony concluded:

• Rubber rings initiated afferent activity for more than 90 minutes (consistent with behavioural and cortisol observations)
• Neither standard nor small rubber rings rapidly blocked such activity
• Intra-testicular injection of local anaesthetic rapidly blocks nerve transmissions through the superior spermatic artery, but may leave nerves from the scrotum and other tissues unblocked and still transmitting nociceptive signals. liii

Lester and colleagues reported on methods of castration and tailing assessed by behaviour and cortisol in 1996, using Romney lambs of 4-5 weeks of age. They reiterated that the behavioural responses to knife versus ring castration were largely treatment specific, and that the lack of a continuity of behaviours between the two procedures precludes using behaviour alone to rank the noxiousness of the two procedures. Their conclusions were that distress lasts for less than 4 hours with ring castration, but significantly more than 4 hours with knife castration, and that ring castration and tailing causes less overall acute distress than castration and tailing with a knife, but still considerable distress. Tailing with a docking iron appeared to reduce the distress of this procedure compared to knife or ring tailing. lxxvii

The New Zealand group reported the results of a trial comparing the effects of castration with rubber rings and/or a castration clamp, with or without local anaesthetic injected into the scrotal neck, the spermatic cord, or both, 15 minutes prior to castration. Clamp application alone did
not reliably cause atrophy of both testes, and caused no less a cortisol response than rings alone, and this was not reduced by local anaesthetic. Local anaesthetic, injected into either the scrotal neck or the spermatic cord, did reduce the cortisol response to the combined method. They considered that the noxious input from nerves from the testis was probably less than that from the scrotum. The cortisol response to ring castration can be virtually eliminated by prior injection into the scrotal neck or both testes. Leakage of local anaesthetic from the testis into the vaginal cavity of the scrotum is probably responsible for much of the benefit.

They proposed that the following may have relevance to reducing the distress of castration and tailing:

• Local anaesthetic injections into the testes or scrotal neck would abolish the pain-induced distress of ring castration. Injections into the testis are much easier for inexperienced operators
• Tailing (ring or docking iron) at the same time as castration after local anaesthetic, but without local anaesthetic injected into the tail, would add at most only low levels of distress.
• Clamp application across the full width of the scrotum seems to be much more effective than when applied in two places leaving some uncrushed scrotal tissue.
• Some lambs exhibited substantially higher cortisol responses to the clamp alone than to ring application alone, suggesting that this causes more distress

The Edinburgh group did further work on pain reduction after tail docking, reported in 1997. The behavioural and cortisol responses to tail docking of three week old lambs using rubber rings, Burdizzo and rings, or docking with a heated iron were compared, and each treatment group was subdivided into lambs treated with sub-cutaneous bupivacaine (a longer lasting local anaesthetic than lignocaine), epidural bupivacaine, application of cold analgesic spray, or intra-muscular injection of the anti-inflammatory drug diclofenac. Local anaesthetic was injected 1-2 minutes prior to docking, spray was applied immediately before docking, and diclofenac was injected 20 minutes prior to docking.

The combined method reduced behavioural and cortisol indicators of distress compared to ring tail docking alone, but tail docking with a heated iron induced no significant differences compared to control lambs. However, they did express concern about other effects of tailing with a docking iron – delayed healing, with a potentially greater risk of fly strike or infection.

Sub-cutaneous injection of local anaesthetic immediately (1-2 minutes) before tailing was the most effective method of reducing the behavioural and cortisol responses to ring tailing.

A further report in 1997 compared castration (Dorset x lambs, 3 weeks old) with bloodless castrators, with or without chemical analgesia. Treatment groups included lambs castrated with a Burdizzo alone, a powered bloodless castrator, Burdizzo and ring, intra-muscular Diclofenac then Burdizzo, intra-testicular Bupivacaine followed by Burdizzo, or intra-testicular Bupivacaine followed by Burdizzo and ring.

The first three treatments produced similar behavioural and cortisol responses. Intra-testicular injection of Bupivacaine provided some analgesia within 2 minutes, but not sufficiently reliable to be significant. Diclofenac provided significant analgesia. They noted that the higher pressures exerted by the powered bloodless castrator may produce more intense and more sustained pain. Although local anaesthesia (Bupivacaine) did not provide adequate analgesia, it did reduce cortisol responses in at least some animals. They noted that Diclofenac is not a very potent analgesic, and that other agents may work more quickly.
Further methods to reduce the acute pain of castration and tailing were also reported in 1998, using Suffolk x Greyface lambs, 5-8 days old. Treatment groups included ring only, ring and powered bloodless castrator, local anaesthetic (Lignocaine) applied by high pressure needleless injection into each testis prior to ring, high pressure needleless injection into the scrotal neck immediately after ring application, the bloodless castrator after similar injection into the scrotal neck, or local anaesthetic injection by needle into the tail or spermatic cord followed by ring.

The combined method reduced behavioural and cortisol responses compared to ring alone. All methods of local anaesthesia reduced responses compared to ring alone. The most effective method of analgesia for castration was injection of local anaesthetic at the site of the ring and application of the bloodless castrator, and this reduced by 50% the time spent in abnormal postures compared to the combined method alone. For tail docking, the needleless injector provided the most effective pain reduction.

Local anaesthetic at the time of crushing failed to reduce the immediate pain of the crush in castration, probably because of insufficient time for the drug to act. They speculated that 5 minutes delay might prevent most of the pain from the procedure.

The needleless injector has a number of advantages and disadvantages, which they list. Injection (by needle) into the scrotal neck was described as easy (thin, wool-less skin) and more effective than injection into the testis, while injection into the tail was found to be difficult (thick, inelastic skin).

Mears and Brown, working in Canada, measured plasma cortisol, β endorphins, and the thyroid hormones T3 and T4 in Suffolk lambs. Blood was collected via previously implanted jugular catheters. Lambs were tail docked (hot iron) and ear tagged at 1 day of age, and castrated (surgically) at 3 weeks of age. The same hormones were measured in response to weaning (at 7 weeks), partial or total isolation (at 14 weeks, 1 hour only), or restraint for sham shearing.

Basal concentrations of cortisol and β endorphins were higher at one day than later, and showed almost no response to tail docking. There was a slight rise in cortisol after 15 minutes. It is possible that the naturally high levels may mask any response to stress at this age. Both values increased markedly within 15 minutes of castration, β endorphin peaking at 15 minutes and cortisol at 60 minutes. Values remained elevated for several hours, with cortisol returning to normal by 24 hours, at which time β endorphin remained elevated. These results indicate marked distress in lambs for at least 24 hours after surgical castration.

Cortisol rose to a small degree after weaning (and ear tagging and vaccination), for just one hour, and then again at 24 hours. β endorphin remained unchanged. Both values rose by small but significant increments for the first three hours after isolation. Both hormones rose a small amount for a short time after restraint. T3 and T4 were unaffected by any of the treatments, despite reports of them rising in response to stress in cattle and pigs.

They concluded that surgical castration induced a severe stress response, and that the small stress caused by isolation was greater than that due to restraint, which in turn was greater than that due to weaning.

Thornton and Waterman-Pearson, working in Bristol, introduced new methods to the investigation of pain and its reduction in lambs. They used a visual analogue pain scale (VAS)
(the recorder marks his interpretation of the pain experienced on a line 100mm long, one end of which indicates no pain, the other the worst possible pain), mechanical nociceptive thresholds, and cortisol responses. Their treatment groups included control handled, rubber ring, combined ring and Burdizzo, and surgical castration, and each group was treated with either no anaesthetic, pre-treatment with local anaesthetic (time not specified) injected into three locations, or general anaesthesia (halothane by mask). The VAS was used to assess active pain avoidance behaviours, unresponsive behaviours, and scrotal pain induced by palpation.

Active pain behaviour was highest in ring-castrated lambs, while unresponsive behaviours were highest in the surgical group. Local anaesthetic injections into the scrotum and its contents abolished the active pain behaviours and attenuated the unresponsive behaviours in ring and combined lambs, but had little or no effect on these behaviours in surgically castrated lambs. This is most likely because at least some of the pain from surgical castration emanates from ruptured tissues in the abdominal spermatic cord. In addition, the local anaesthetic can diffuse out of the scrotum (compared to its retention in ring lambs), and it is removed with the testes.

General anaesthesia had no effect on active, and only minimal effect on unresponsive pain behaviours in ring and surgical lambs, but abolished active pain behaviours in “combined” lambs, indicating that in the combined technique, pain is due to the procedure itself, while in the other two techniques, there is substantial post-operative pain. Scrotal pain was reduced by local anaesthetic in ring and combined lambs, but was increased in surgically treated lambs, suggesting that local anaesthetic has little beneficial effect on the long term post-operative pain associated with surgical castration.

Nociceptive thresholds were not affected by local or general anaesthetic in control lambs. Ring castration did not affect these thresholds, but the combined and surgical methods increased the thresholds for lengthy periods. Local anaesthetic abolished these changes in the combined lambs but not in the surgical lambs.

The combined method produced minimal increases in cortisol levels, while the surgical and ring methods significantly increased these values. Local anaesthetic abolished the cortisol increase in ring lambs and significantly reduced it in surgical lambs. General anaesthesia had no effect on cortisol levels, which implies that it is the pain of the procedure and not the experience of the procedure which induces the cortisol response.

The new information from the nociceptive threshold data implies that stress-induced analgesia (activation of descending inhibitory fibres in the spinal cord, or humorally mediated) is induced by treatments without anaesthesia – raised thresholds indicate a higher degree of suffering. That general anaesthesia also abolished this effect shows that it is the lamb’s experience of the procedure which induces these effects and not the pain per se.

Although scrotal pain persisted in ring and combined lambs, the absence of raised nociceptive thresholds or increased cortisol concentrations indicate a lack of central sensitisation or long-term distress.

Surgical castration was confirmed as the most severe procedure, followed by ring alone. The combined method produced the least distress, but the application of the clamp is still painful.¹

The New Zealand group published, in 1999, the results of observations of the behavioural responses to 20 different treatments in 4-9 week old Romney lambs, using rubber rings, a
castrating clamp, or both; with or without local anaesthetic injected into various locations. They showed once again that the behavioural responses to different treatments (ring, clamp) differed, and that local anaesthetic (15 minutes prior to treatment) significantly lowered or effectively abolished behavioural indicators of pain. They concluded that:

- Restlessness was a useful indicator of ring (ischaemia) induced distress
- A lower incidence of normal standing/walking may be a useful indicator of the pain caused by ring or ring plus clamp methods
- Lateral recumbency may indicate (extreme) deep testicular pain caused by hypoxic/anoxic damage, and this was easily prevented by local anaesthesia
- Ventro-lateral recumbency is not as injury specific, and may be a highly sensitive sign of pain or distress. It occurred in all forms of castration, but pain is probably derived from the scrotum
- Ring and ring plus clamp castration caused similar levels of restlessness and lateral recumbency, and therefore probably caused similar levels of distress (which is supported by cortisol data)
- Short scrotum methods caused similar restlessness but much less lateral recumbency, therefore this technique is likely less noxious
- Clamp only, and ring plus clamp castration did not cause similar behaviours and so their relative noxiousness cannot be compared by behaviour alone
- A single behaviour may be misleading, but a suite of behaviours may be more useful. For example, ring castration causes restlessness for less than one hour (and has therefore been previously assumed to be less noxious) but lateral recumbency (and cortisol responses) for about 3.5 hours.

This group published the results of studies into the cortisol responses to ring castration (and tail docking) with or without local anaesthetic (Lignocaine) injected into the scrotal neck, or into the testes, 5 to 10 seconds prior to castration. Cortisol responses were reduced but not abolished, and the scrotal neck injections produced a greater effect than testicular injections. While some of the cortisol response was considered to be due to the tail, which was docked without local anaesthetic, a figure of 57% reduction in cortisol response was recorded compared to castrated and tailed lambs without local anaesthetic. Other studies show a 75%-78% reduction due to local anaesthetic when castration alone is performed.

They concluded that local anaesthetic injections into the scrotal neck (or testes, relying on leakage into the scrotal sac) 15 seconds before ring application would substantially reduce castration distress and significantly reduce the distress of castration and tailing. About 2 minutes would be required to eliminate castration distress, a period which they considered may be impractically long for farm use. This paper established that it is not necessary to allow 15 minutes between local anaesthetic injection and castration, at least using Lignocaine, which is a rapid acting local anaesthetic.

In 1999, the Edinburgh group reported the results of studies into the effect of age (size) of lamb on chronic inflammatory responses to ring castration. They examined castration sites and observed behaviour for 49 days. Lesion size was correlated to age of lamb at castration, with the smallest (and fastest resolving) lesions in lambs castrated at 2 days, intermediate at 28 days, and worst at 42 days of age. The scrotum was shed within 31 days, 34 days and 35 days, for each group, respectively.

There was a correlation between lesion score and incidence of certain active behaviours in the 42-day group, only. They concluded that the lesion induced by the rubber ring was more likely
to become septic in older lambs, and that the smaller lesion seen in younger lambs may be a less aversive stimulus than the larger lesion seen in older lambs.\textsuperscript{xiv}

The Edinburgh group reported in 2000 the effects of Burdizzo or local anaesthetic on wound healing and long-term behaviours in Dorset cross lambs ring castrated and tail docked at less than 2 days of age. Scrotal lesions were examined twice weekly, and graded, and behaviour was assessed for 6 hours on days 10, 20, 31 and 41 after treatment. They looked for behaviours indicative of irritation at the scrotum, and for play and interactive behaviours, and for posture.

All but one tail had been lost by day 28. Burdizzo and local anaesthetic treatments increased the lesion scores (because of pus) compared to ring only tailing. The burdizzo did cause the lesion to develop and heal faster. Scrota were shed in 19 to 41 days, but local anaesthetic and burdizzo lambs shed their tails faster. Lesion scores were unaffected by method of castration.

Active behaviours (foot stamping, kicking, tail wagging etc) were more pronounced in ring only lambs, reaching a maximum at day 31, while the maximum scores for ring and local anaesthetic lambs were much lower and reached a maximum on day 21. Behaviours were the same as control lambs by day 41. Ring only lambs also played less. Certain active behaviours (head turning to the scrotum) reached a maximum when their lesion scores were also at a maximum.

All methods induced an inflammatory reaction. Burdizzo and local anaesthetic treatments did not increase the severity of lesions, and the Burdizzo method reduced the healing time. Local anaesthetic not only reduced healing time, but also prevented the increase in abnormal behaviours and activities seen later in lambs without such treatment. Such long-term benefits of a short-term (2 hour) period of local anaesthesia have also been observed in human male circumcision. There were no effects on daily weight gains and the effects on long-term (6 week) behaviour of castration and tail docking were considered to be limited.\textsuperscript{x}

The New Zealand group investigated the effect of ring + clamp castration and tail docking of 3-6 week old lambs in 2000. Coopworth lambs were treated by ring only castration and docking, by castration and docking with application of a Burdizzo clamp for 6, or 10, seconds across the full width of the scrotum immediately after ring application, or by ACTH injection (control). Cortisol was measured in blood for more than 4 hours, and the wounds were observed for healing over 6 weeks.

In all groups, cortisol peaked at 40 to 60 minutes, and returned to normal by 170 minutes. Magnitude of the cortisol response was lower at 60 minutes (only) in the ring + clamp 10 seconds group, and is consistent with the small (almost insignificant) benefit due to the clamp in older lambs.\textsuperscript{v} There was a tendency for more rapid shedding of scrota and healing of wounds in ring + clamp lambs, but at 6 weeks the difference was not significant. There were no complications in any of the lambs at any observation.

The authors concluded there was no benefit to support the use the clamp in lambs older than 1 week of age. They observed flinching in every lamb to which the clamp was applied, which they considered would discourage farmers from adopting this procedure.\textsuperscript{i}

In 2001, Price and Nolan, working in Glasgow, investigated the use of suckled sucrose and administration of the non-steroidal anti-inflammatory drug Carprofen as analgesics for ring castration and tail docking of newborn lambs. Texel x Greyface lambs were used. Warmed colostrum or 0.5M sucrose were provided by bottle and teat for about 5 minutes prior to
treatment, or Carprofen was injected subcutaneously 30 minutes prior to treatment. Suckled sucrose has been used successfully as an analgesic for blood sampling or circumcision in newborn humans, and in rat pups in experimental situations.

Neither suckling nor Carprofen had any effect on distress behaviours in these lambs, and the haptoglobin assay (previously discussed) yielded no further information. It should be noted that Carprofen was used at a relatively low dose rate (0.5 mg/kg) because of concern about reduced drug clearance in newborn lambs, and the prolonged half-life of Carprofen in adult sheep.\textsuperscript{xii}

**Mulesing**

Two papers from the Hawkesbury Agricultural Research Unit explore responses to mulesing. A modified mules operation was performed on 6-7 month old Merino wethers, and these animals were compared with controls. Marked elevation of plasma cortisol and $\beta$ endorphin occurred between 5 and 15 minutes after the operation. The highest levels of both hormones were recorded during the 24 h post-operative handling. At 48 h post-operation there was apparently little hormonal response to handling. An analgesic effect, associated with the release of the $\beta$ endorphin, was evident in the sheep behaviour for 1-2 h post-operation. Thereafter, paddock behaviour of mulesed sheep was characterized by abnormal posture and locomotion at first, then by significantly increased time spent standing and significantly reduced time spent lying, grazing and feeding from a trough. After 72 h the mulesed sheep resumed normal behaviour in the paddock. Arena testing at intervals from day 1 to day 37 post-operation revealed a pronounced aversion to the human handler (male) who had held the sheep during the operation. At day 114 this aversion was no longer evident. The regular handler (female) who normally fed the sheep produced significantly less aversion between days 42 and 114. The authors concluded that mulesing of weaners by contractors (rather than owners) and minimal post-operative handling may be indicated as means of reducing stress from mulesing.\textsuperscript{lxxxv}

The effect of chemical mulesing with a quarternary ammonium compound was compared with surgical mulesing in 9-10 month Merino sheep. After surgical mulesing, plasma total cortisol concentration increased immediately and rapidly and reached a peak value in 15 minutes, whereas after non-surgical treatment an immediate rise did not occur, but a similar peak value was observed in blood samples collected 24 h after treatment. The concentrations were lower in both groups at 48 h. Likewise postural changes indicative of discomfort were immediately apparent in the surgically treated sheep, but not until 3 to 4 h later in those treated non-surgically. Arena testing revealed that a lasting aversion to the person who restrained them during treatment developed in the surgically mulesed sheep, but not in those treated non-surgically. The non-surgical procedure did not create large open wounds, as did the surgical operation, but still achieved similar enlargement of the bare area on the breech, and healing was quicker in the non-surgically treated sheep.\textsuperscript{xiii} These results suggest that, overall, chemical mulesing may cause a little less discomfort than surgical mulesing, with smaller risk of complications (e.g. fly strike). However, it is clear that chemical mulesing causes significant and long lasting suffering.
Systemic Analgesics in Sheep

One technique which could be perceived as providing an easy answer to reducing the pain-induced distress of castration and tail docking in lambs (and perhaps of mulesing), would be the systemic administration of analgesic drugs. A simple injection under the skin or into the muscle, even if it needed to be given 30 minutes prior to castration and tailing, could provide both immediate and prolonged pain relief. In dogs and cats, drugs such as Meloxicam, Carprofen, Ketoprofen, Tolfenamic Acid and Etodolac are either registered for, or in practice seem effective for, up to 24 hours after a single dose. lxxxvi

Several classes of systemic analgesic drugs are available including the opioids (morphine like drugs), the non-steroidal anti-inflammatory drugs (NSAID), and the $\alpha_2$-adrenoreceptor agonists. Most or all opioid drugs have potential addictive properties, and their use is strictly controlled by human health authorities. Their use requires individual patient assessment and recording by a health professional (in this case a veterinarian), and these requirements are extremely unlikely to be relaxed. In many cases, their duration of effect is relatively short.

NSAIDs, on the other hand, are not controlled, although all injectable forms are still “prescription only” products, and should only be used in species and ways for which they are licensed. There are currently no analgesic drugs registered for use in sheep in Australia. Use of such drugs, particularly in a food-producing animal, would require consultation with “control of use” authorities and specific prescription by a veterinarian for the product’s “off label” use.

Diclofenac sodium was administered 20 minutes prior to ring tail docking, and in a separate study, 20 minutes prior to the Burdizzo alone for castration, both in 3 week old Dorset or Suffolk cross lambs. Diclofenac produced conflicting results as an analgesic for tail docking – while cortisol values were significantly reduced compared to ring only docking, the incidence of active behaviours and time spent in abnormal postures was significantly increased. The authors considered that this apparent increased response may reflect the variety of individual responses seen within a group of lambs to individual treatments. They could not, of course, conclude that Diclofenac was an effective analgesic for tailing in lambs. lxxviii

The same group were able to conclude, however, that Diclofenac was an effective analgesic for Burdizzo castration in lambs because it both reduced Cortisol levels and reduced the time spent in abnormal postures. They noted that the main effects of Diclofenac were seen after the first 12 minutes, suggesting that the beneficial effects were due to the drug’s anti-inflammatory effects rather than by reducing the pain of the procedure itself. Mediators of inflammation (which are inhibited by NSAIDs) are typically released in response to tissue trauma and their effect builds over time, in contrast to the almost instantaneous sensation of pain transmitted by nerves and stimulated by nociceptors in acutely damaged tissues. lxxix

NSAIDs are recommended as analgesics for sheep in at least one recent text on Pain Management lxxxvii, and Ketoprofen and Carprofen are recommended as analgesics in a recent update on Caesarean section in the ewe lxxxviii. Flunixin and dipyrone have been shown to produce a small but significant increase in pain thresholds (18% and 21% of maximum possible effect respectively). lxxix

However, other research questions the efficacy of these agents in sheep. Welsh and Nolan, working in Glasgow, found that a single dose of Flunixin meglumine at 1 or 2 mg/kg, failed to raise nociceptor thresholds (mechanical stimulus) in healthy and in lame sheep, suggesting that
the drug induced no analgesic effect. (Welsh and Nolan 95) Others working in South Australia used an electrical stimulus to compare Buprenorphine and Methadone (opioids), Flunixin meglumine, and xylazine (an α2-adrenoreceptor agonist). Only xylazine produced any measurable effect on the response of sheep to electrically produced pain, despite investigation at varying doses for all drugs. Xylazine produced analgesia without, or with only minimal, sedation. (xliii) Oral acetyl salicylate (26 mg/kg) failed to show evidence of effective analgesia when given at time of ring tail docking to 3-6 week old Romney X lambs, when judged by observation of 15 postures and 37 behaviours. However, the authors suggested that the dose for aspirin in sheep should perhaps be 50-100 mg/kg. xc Finally, Carprofen at 0.5 mg/kg, failed to provide any behavioural evidence of pain relief in newborn lambs after ring castration and tailing. xci

The failure of the opioids Buprenorphine and Methadone to provide measurable analgesia is interesting since a group working in Bristol have reported that Buprenorphine, Butorphanol and Pethidine all provided significant analgesia against a thermal stimulus, but no, or very brief, analgesia when a mechanical stimulus was applied. xcii xciii Opioids have also been shown to exert a greater effect in females than in males, which would make them relatively less effective in castration. xciiv

α2 adrenoreceptor agonists are commonly used in veterinary medicine, chiefly for their sedative properties. xcv The only documented site of action for analgesia induced by parenterally administered α2 adrenoreceptor agonists is the spinal cord. xcvi Ruminants are much more sensitive to their effects than other species. xcvii

While the α2 adrenoreceptor agonist Medetomidine (40 µg/kg IM) was shown to produce recumbency for 58 +/- 1 minutes and analgesia for 30 to 45 minutes in sheep xcviii, xylazine at doses up to 0.2 mg/kg produced only head drooping and reduced alertness in sheep (G & U 1996). Variation in the analgesic effect of xylazine has been reported in sheep dosed at 50 µg/kg (0.05 mg/kg). Using a mechanical threshold test, Clun sheep (mean weight 68.7 +/- 4.4 kg) showed the greatest analgesic effect, with Swaledales (50.2 +/- 1.7 kg) and Welsh Mountains (45.6 +/- 5.0 kg) showing reduced analgesic effects apparently proportional to body weight. xcix Recent research in South Australia has, however, shown no variation in the effect of xylazine associated with body weight. Merino lambs ages 4-6 weeks and weighing 12.8+/-. 2.0 kg were given 50 µg/kg by intra-muscular injection, and subjected to an electrical threshold test delivered by a modified peripheral nerve stimulator. Xylazine induced effective analgesia without sedation or other side effects in lambs, and there were no differences between the effect on adult sheep or lambs (same blood lines). c

Dosed at 0.05 mg/kg, xylazine has been shown to be safe, producing no significant change in heart rate, mean arterial blood pressure, cardiac output, or arterial carbon dioxide tension. A 10% reduction in arterial oxygen tension was observed. cit Low dose xylazine (0.02 mg/kg) combined with ketamine (1 mg/kg) has been shown to be ineffective at reducing the behavioural and cortisol responses to post-operative pain (thiopentone induction, halothane maintenance, laparotomy and hysterotomy). cii
Summary – Sheep

As reported, the scientific literature exploring aspects of the pain and distress caused by castration and tail docking is lengthy and complex. Studies have been performed on sheep of different breeds, at different ages, using different methods of castration and tailing, and using different investigation techniques and protocols. Is it possible to interpret these studies, and to suggest recommendations which benefit the animals and yet are practical and acceptable to farmers? This summary will look simply at the scientific evidence about castration and tail docking of sheep; later discussion will consider possible recommendations.

Stafford and Mellor in 1993, Mellor and Molony in 1995, and Mellor and Stafford in 2000, have summarised and interpreted the literature to date. The paper by Stafford and Mellor offers a good review of the reasons that these procedures are performed, and a discussion of the pain/stress involved. The latter paper summarises methods for gauging levels of pain and distress, and clearly describes methods of performing castration and tail docking. Each paper reviews the evidence concerning levels of pain, to date, and the latter paper establishes a ranking system for acute pain, based on cortisol levels only.

The letter by Mellor and Molony, leaders in research teams at Massey University, New Zealand and the Royal (Dick) School of Veterinary Studies, University of Edinburgh, Scotland, respectively, was written in response to the British Government’s response to the (UK) Farm Animal Welfare Council’s 1994 report on the welfare of sheep. This report called for a ban on surgical castration, and suggested modifying the law in the UK to allow castration by ring for lambs up to 6 weeks of age. The law at that time forbade ring castration for lambs more than 7 days of age. The Government rejected these suggestions and offered to fund more research.

Mellor and Molony argued that there was a considerable body of scientific evidence assessing and comparing levels of pain and distress caused by castration and tail docking. They stated that surgical methods of castration and tail docking should not be permitted without both anaesthesia and analgesia, because the duration of pain and distress caused by surgical procedures (8 hours) exceeds the duration of local anaesthetics and the duration of distress caused by rings (3 hours). While they agreed with the proposal to allow rubber rings to be used in older lambs instead of cutting or the Burdizzo alone, they pointed out that this method still caused substantial pain and that alternate methods should be developed and encouraged. They concluded with a call that further recommendations or legislative change should be based on scientific evidence, rather than on opinion.

Since only males are castrated, but both male and female lambs are tail docked, it is necessary to compare the effects of different methods of castration alone, tailing alone, and castration and tailing. Rarely, male lambs may be castrated but not tail docked if slaughter was envisaged before perineal soiling was likely to be a problem. This was the approach taken in the most recent review article, and it will be summarised here. However, this paper only considered acute pain considerations (hours to days), and only used cortisol responses as a basis for comparison. The authors did briefly discuss the issues of chronic pain and the benefit of behavioural assessment in this situation.

The use of cortisol only as a basis for comparison is valid for acute pain, since:

- cortisol responses return to normal after 8 hours in even the most noxious situation,
- most studies have found that cortisol responses parallel behavioural responses,
- very little work has been done on the long-term consequences of different procedures.

The page number and date are not relevant to the content.
I will endeavour to address both the behavioural interpretation of pain and the long-term issues, where appropriate.

The authors used the integrated cortisol response to compare methods of castration and tailing, and assigned an arbitrary value of 100% for the cortisol response to tailing and docking with rings alone. They then assigned “rank” scores such that rank 1 = 1-30%, rank 2 = 30-55%, rank 3 = 70-85%, rank 4 = 75-125%, rank 5 = 165-170%, and rank 6 = 190-205%.

Figure 2: Examples of acute changes in the plasma cortisol concentrations: A, after surgical or ring castration plus tailing and during control handling of lambs aged 4-6 weeks (redrawn from Lester et al., 1991a,b; reproduced with permission of In Practice); B, after castration plus tailing of 1-week-old lambs using rings or rings plus clamp (10 s full width), and during control handling (redrawn from Kent et al., 1995); and C, and D, after castration of lambs aged 4-8 weeks using a ring, ring plus clamp (10 s each cord), or ring 15-20 min after local anaesthetic injection into both spermatic cords (Cd), the scrotal neck (Sc), the scrotal neck plus spermatic cords (Sc+Cd) or both testes (Te) (redrawn from Dinniss et al., 1997a)

Figure 3, from cv

Castration and Tailing

Surgical castration and tail docking induces the highest cortisol response, indicating that it is the most noxious method (rank 6). The cortisol response has been used to enable interpretation of the behaviour after surgical castration, and it is now accepted that “statue standing” and immobility reflects greater pain than the more active behaviours seen after other methods of castration and tailing.
Ring castration and tailing induces a cortisol response about half that of cutting, but it is still substantial (rank 4). Short scrotum castration, or tail docking with an iron, does not alter the level of pain substantially. However, addition of a castration clamp to ring castration, and to castration and tailing, confers some additional benefit, with full width clamping, for 10 seconds, being better. The use of tight rubber rings at one week of age reduces the rank to 3, but this is unlikely to be practical in most Australian husbandry systems. Ring and clamp methods at 1 week also reduce pain and distress, in the best scenario, to rank 1.

Significant benefit is conferred by the addition of local anaesthetic to castration and tailing. Local anaesthetic injected into the scrotal neck 10-15 seconds before ring castration was measured at rank 2, and more involved local anaesthetic treatment 15-20 minutes before produces the lowest score within rank 1 (except for control lambs). Multiple handling of lambs is, of course, unlikely to be practical.

Table 2: Ranking of the overall levels of acute pain-induced distress, as judged by cortisol responses, caused by different methods of castration plus tailing with and without local anaesthetic in lambs.

<table>
<thead>
<tr>
<th>Rank - (Cortisol Response 1)</th>
<th>Castration plus tailing method</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 (190-205%)</td>
<td>CT surgery (cords torn), 4-6 weeks 2</td>
</tr>
<tr>
<td>5 (165-170%)</td>
<td>None</td>
</tr>
<tr>
<td>4 (75-125%)</td>
<td>CT ring, 1-8 weeks (standard response: 100%) SS ring T ring, 4-5 weeks C ring T iron, 4-5 weeks C ring + clamp (6 s each cord) T ring, 6-8 weeks C ring + clamp (6 s each cord) T ring + clamp (6 s), 6-8 weeks C ring + clamp (6 s full width) T ring + clamp (6 s), 3 weeks C ring + clamp (6 s full width) T ring + clamp (6 s), 6 weeks C ring + clamp (6 s full width) T ring + clamp (6 s), 3-6 weeks C ring + clamp (10 s full width) T ring, 3-6 weeks C clamp (10 s each cord) T clamp (3 s), 1 week LA Te (10-15 s after) CT ring, 6 weeks</td>
</tr>
<tr>
<td>3 (70-85%)</td>
<td>CT tight ring, 1 week C ring + clamp (6 s each cord) T ring + clamp (6 s), 1 week</td>
</tr>
<tr>
<td>2 (30-55%)</td>
<td>LA Sc (10-15 s before) CT ring, 6 weeks Control handling, 4-8 weeks</td>
</tr>
<tr>
<td>1 (1-30%)</td>
<td>C ring + clamp (10 s full width) T ring + clamp (10 s), 1 week LA Cd Sc Te Epi (15-20 min before) CT ring, 1 week Control handling, first week LA control (15-20 min before), 1-8 weeks LA control (10-15 5 before/after), 3-6 weeks</td>
</tr>
</tbody>
</table>

1 Integrated (overall) cortisol response as a percentage of that caused by CT ring, expressed to the nearest 5%.
2 Data obtained only during the first 4 h after treatment (Lester et al., 1991a) were corrected by assuming that 72% of the complete response occurred before and 28% after 4 h (Lester et al., 1991b).
C = castration; T = tailing, SS = short scrotum, LA local anaesthetic; Cd = spermatic cords; Epi = epidural; Sc = scrotal neck; Ta = tail; Te = testes.

Table 2, from **cv**
There is evidence of benefit of earlier castration and tailing, with maximum benefits seen when these procedures are performed during the first week of age.

The use of local anaesthetic has also been shown to confer long-term benefits to lambs, preventing abnormal behaviours otherwise seen in ring only lambs up to 41 days after treatment. In the same study, the use of the Burdizzo in conjunction with rings led to earlier shedding of scrota and tails, and quicker healing of wounds. (xlvi)

See table 2 for a summary.

**Castration**

As expected, methods of castration and pain control for castration parallel those for castration and tailing. Cutting induces the worst cortisol (and behavioural) response, rank 6. Clamp alone produces varying ranks depending on age (rank 5 at 4-8 weeks, rank 4 at 3 weeks, each for 10 seconds), and duration of clamping (rank 3 with a 1 second clamp), but failure of castration has been recorded.

Ring alone produces a rank 4 response at 1-8 weeks of age, and addition of the castration clamp does not reduce this response greatly unless performed at 1 week of age (rank 1) or if local anaesthetic is also added (rank 3). NSAIDs can reduce the response to clamp only castration at 3 weeks to rank 3, but see the earlier comments about the use of these drugs.

Addition of local anaesthetic reduces the response to ring and ring plus clamp methods, and although many studies have shown benefit of the application of local anaesthetic 15-20 minutes before treatment, application 15-20 seconds before was beneficial in ring only castration and tailing at 6 weeks and in ring castration at 1 week of age. It is likely that 15-20 seconds before provides significant benefit in all cases, with greatest benefit occurring with injection into the scrotal neck. As noted, addition of the clamp to local anaesthetic/ring methods may confer both short term and long-term benefits.

See Table 3 for a summary.

**Tailing**

Surgical tailing induces the most severe response – rank 5. All other methods are ranked 1 or 2, indicating that tailing (except by knife) is a less aversive experience than castration. Ring and iron methods induce similar response (the iron is slightly less noxious), and in both cases the rank is reduced at earlier ages. Local anaesthetic before (or even just after) ring tailing confers benefit, with lower response recorded at earlier ages.

The addition of the clamp to tailing procedures is beneficial compared to ring only, or ring and local anaesthetic methods respectively, but the benefit is minor (no change in rank), and several authors have drawn attention to likely operator aversion to crushing the tail. NSAIDs administered 20 minutes prior to tailing are also beneficial.

There is a benefit of treatment at an earlier age.

There are difficulties in applying local anaesthetic to the tail – injection is difficult because of the small volume available in the tail to receive the injection, epidural injection is technically
Table 3: Ranking of the overall levels of acute pain-induced distress, as judged by cortisol responses, caused by different methods of castration with and without local anaesthetic or a non-steroidal anti-inflammatory drug in lambs.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Cortisol Response</th>
<th>Castration method</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 (190-205%)</td>
<td>6 (190-205%)</td>
<td>Surgery (cords torn), 4-5 weeks&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>5 (165-170%)</td>
<td>5 (165-170%)</td>
<td>Clamp (10 5 each cord), 4-8 weeks</td>
</tr>
<tr>
<td>4 (75-125%)</td>
<td>4 (75-125%)</td>
<td>Ring, 1-8 weeks (standard response: 100%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ring + clamp (10 s each cord), 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ring + clamp (5 s each cord), 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ring + clamp (1 5 each cord), 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ring + clamp (10 s full width), 3 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clamp (10 s each cord), 3 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA Sc (15-20 min before) clamp (10 s each cord), 4-8 weeks</td>
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<td></td>
<td></td>
<td>LA Cd (15-20 min before) clamp (10 s each cord), 4-8 weeks</td>
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<tr>
<td></td>
<td></td>
<td>LA Te (1-2 min before) clamp (10 s each cord), 3 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA Te (1-2 min before) ring + clamp (10 s full width), 3 weeks</td>
</tr>
<tr>
<td>3 (70-85%)</td>
<td>3 (70-85%)</td>
<td>Short scrotum ring, 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clamp (1 s each cord), 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA Cd (15-20 min before) ring, 4-8 weeks</td>
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<tr>
<td></td>
<td></td>
<td>LA Cd (15-20 min before) ring + clamp (10 s each cord), 4-8 weeks</td>
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<tr>
<td></td>
<td></td>
<td>LA Ne-Sc (5-10 s after) ring, 1 week</td>
</tr>
<tr>
<td>2 (30-55%)</td>
<td>2 (30-55%)</td>
<td>NSAID (20 min before) clamp (10 s each cord), 3 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Control handling, 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ring + clamp (10 s full width), 1 week</td>
</tr>
<tr>
<td>1 (1-30%)</td>
<td>1 (1-30%)</td>
<td>LA Cd Sc (15-20 min before) ring, 4-8 weeks</td>
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<tr>
<td></td>
<td></td>
<td>LA Sc (15-20 min before) ring, 4-8 weeks</td>
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<td>LATe (15-20 min before) ring, 4-8 weeks</td>
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<td></td>
<td></td>
<td>LA Sc (15-20 min before) ring + clamp (10 s each cord), 4-8 weeks</td>
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<td></td>
<td>LA Ne-Te' (5-10 s after) ring, 1 week</td>
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<td>LA Sc (5-10 s after) ring, 1 week</td>
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<td></td>
<td></td>
<td>LA Sc (5-10 s after) ring + clamp (10 s full width), 1 week</td>
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<td></td>
<td></td>
<td>Control handling, first week</td>
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<tr>
<td></td>
<td></td>
<td>LA control (15-20 min before), 1-8 weeks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>LA control (10-15 s before/after), 3-6 weeks</td>
</tr>
</tbody>
</table>

1 Integrated cortisol response as a percentage of that caused by CT ring, expressed to the nearest 5%.

2 Data obtained only during the first 4 h after treatment (Lester et al., 1991a) were corrected by assuming that, as for CT surgery, 72% of the complete response occurred before and 28% after 4 h (Lester et al., 1991 b).

3 Needleless injection into the testes through the scrotum would also anaesthetise the scrotum. Ne = needleless injection; LA local anaesthetic; Cd = spermatic cords; Sc = scrotal neck; Te = testes; NSAID = non-steroidal anti-inflammatory drug.

Demanding and carries major risks of spinal infection unless performed with hospital levels of sterility, needleless injectors are expensive and frustrating to use (the drug cartridge would need to be changed every 1-3 lambs), and sprays reportedly require clipping of the hair. Sprays are also alcohol based and flammable, precluding their use with a docking iron. However, my personal experience in other species is that local anaesthetic liquids can be applied through hair, and this method should be considered.

See Table 4 for summary.
Table 4: Ranking of the overall levels of acute pain-induced distress, as judged by cortisol responses, caused by different methods of tailing with and without local anaesthetic or a non-steroidal anti-inflammatory drug in lambs.

<table>
<thead>
<tr>
<th>Rank - (Cortisol Response)</th>
<th>Tailing method</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 (165-170%)</td>
<td>Surgery, 4-5 weeks&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>2 (30-55%)</td>
<td>Ring, 4-5 weeks</td>
</tr>
<tr>
<td></td>
<td>Iron, 4-5 weeks</td>
</tr>
<tr>
<td></td>
<td>Control handling, 4-8 weeks</td>
</tr>
<tr>
<td></td>
<td>Ring, 3 weeks</td>
</tr>
<tr>
<td></td>
<td>Ring, first week</td>
</tr>
<tr>
<td></td>
<td>Iron, 3 weeks</td>
</tr>
<tr>
<td>1 (1-30%)</td>
<td>Ring + clamp (10 5), 3 weeks Ring + clamp (10 5), 1 week</td>
</tr>
<tr>
<td></td>
<td>NSAID (20 min before) ring, 3 weeks</td>
</tr>
<tr>
<td></td>
<td>LA Ta (1-2 min before) ring, 3 weeks</td>
</tr>
<tr>
<td></td>
<td>LA Epi (1-2 min before) ring, 3 weeks</td>
</tr>
<tr>
<td></td>
<td>LA Spray (5-15 5 before) ring, 3 weeks</td>
</tr>
<tr>
<td></td>
<td>LATa (5-10s after) ring, 1 week</td>
</tr>
<tr>
<td></td>
<td>LA Ne-Ta (5-10 5 after) ring, 1 week</td>
</tr>
<tr>
<td></td>
<td>LA Ne-Ta (5-10 5 after) ring + clamp (10 s), 1 week</td>
</tr>
<tr>
<td></td>
<td>Control handling, first week</td>
</tr>
<tr>
<td></td>
<td>LA control (15-20 min before), 1-8 weeks</td>
</tr>
<tr>
<td></td>
<td>LA control (10-15s before/after), 3-6 weeks</td>
</tr>
</tbody>
</table>

1 Integrated cortisol response as a percentage of that caused by CT ring, expressed to the nearest 500.
2 Data obtained only during the first 4 h after treatment (Lester et al., 1991a) were corrected by assuming that, as for CT surgery, 72% of the complete response occurred before and 28% after 4 h (Lester et al., 1991b). Epi = epidural; LA local anaesthetic; Ne = needleless injection; NSAID = non-steroidal anti-inflammatory drug; Spray = externally applied; Ta = subcutaneously into the tail.
Conclusion

Lambs should be castrated and/or tailed as early as management permits. Early (less than one week) lamb marking is impractical in extensive situations, because of the need to muster the flock frequently, and because of the risk of mismothering. It might be considered when “drift lambing” is practised, but the stress of the procedures in addition to weather, condition of the mother etc must also be considered.

Surgical castration and/or tailing should not be practised. There is ample evidence that this is the most noxious method, and it has been shown that local anaesthetic does not reduce the pain of surgical castration.

Clamp only methods of castration and tailing are more painful than clamp and ring methods, and may fail, leaving lambs exhibiting male behaviours and/or fertile. They should probably not be considered.

Ring castration should remain the basic animal husbandry method, with ring or (preferably) docking iron tailing. However, these methods are noxious, and techniques are available to reduce the distress experienced by lambs.

If prescription drugs are not available, the Burdizzo should be used in addition to the ring for lambs less than one week of age, at least for castration, being applied for 10 seconds, across the full width of the scrotum.

Local anaesthetic should ideally be injected into the scrotal neck, preferably before, but even just after, ring application. Local anaesthetic injection or spray into or onto the tail at time of ring application confers small but valuable benefits.

NSAIDs may confer additional benefit to sheep undergoing these procedures, but the evidence regarding their efficacy is contradictory, and they add additional cost and difficulty to the procedure. Further research may establish the role of such drugs, and should be encouraged. I do not recommend their use at this stage.

Evidence is accumulating of the efficacy and safety of xylazine as a safe and effective analgesic for sheep, and its use should be considered. Although a prescription drug, due to risks to human and animal health if overdosed, xylazine is inexpensive. A model for its supply to and use by farmers exists in the deer industry. This program includes farmer training and accreditation by an industry body, which must be maintained.

It is hard to envisage modifications to the surgical mules procedure which might reduce pain and suffering, and the advent of non-surgical, non-chemical methods holds greatest hope. Performing mulesing in conjunction with other procedures would minimise the duration of suffering in sheep, and, if systemic analgesics were used, might reduce at least the acute suffering caused by this procedure. Research into the effect of such analgesic treatments is to be encouraged.
Comparison of techniques and analgesic regimes in husbandry procedures - Cattle

Castration

Approximately 9,282,000 head of cattle were predicted to be slaughtered in or exported from Australia in the financial year 2000-2001. Half of these, or more than 4.5 million head, would have been males that would have been castrated. In New Zealand, 85% of farmers use rubber rings (at an average age of 2.2 months), and 18% used a surgical method (at an average age of 4.3 months). A very few used a clamp method (clearly, some farmers use a combination of methods). 32% of male cattle slaughtered in the UK were not castrated. 2% of farmers in New Zealand castrated calves over 6 months of age, compared to 5% of farmers in the UK, while 60% of farmers castrated calves before 12 weeks (62% in the UK). A few castrated calves within the first week of life, in the paddock. In New Zealand, it is illegal for farmers to castrate calves over 9 months of age, and yet 1% of farmers did this. Agriculture, Fisheries and Forests Australia have advised that such data is not available for Australia.

Available methods for castration include:

- injection of chemical to induce testicular sclerosis
- application of tight rubber rings (Elastrator™)
- crushing of the scrotal skin and spermatic cord (including vas deferens, blood vessels and nerves) with a castration clamp (e.g. Burdizzo). Each side is crushed independently, once for 10 seconds.
- Cutting the scrotum (ventral aspect, generally two incisions parallel to the median raphe (midline)), withdrawing the testes (individually) followed by either
  - Pulling the testes and cords, causing rupture of the cords within the abdomen
  - Crushing and severing the cords with an emasculator
- Application of a tight, heavy rubber band (Callicrate band) with a proprietary device.

Chemical Castration

A solution of α-hydroxypropionic acid (88% lactic acid) (Chem-Cast® Bio-Ceutic Laboratories inc, Missouri, USA) can be injected into the testis on a volume per kg live weight basis. A study in Australia compared such treatment with standard (on farm) surgical castration, and found that the injection took three times longer than surgical castration, caused no less acute pain, and caused “considerable” swelling and discomfort at an 8 hour observation. Healing took twice as long as following surgical castration. Some calves subsequently developed some scrotal necrosis, and although
all were satisfactorily sterilised, some maintained some testosterone production and behaved as males. The investigators did not consider this a satisfactory method of castration.\textsuperscript{lxvii}

Cohen \textit{et al}, working in Canada, compared surgical and chemical castration using blood Packed Cell Volume (PCV), cortisol, testosterone, glucose, protein, free fatty acids, creatinine and urea nitrogen. In addition, scrotal circumference and live weight were recorded for these 7-9 month old, Holstein calves.

PCV and Plasma metabolites did not differ between groups. Cortisol was highest in the surgical group (at 6 hours), and somewhat lower in the chemical group at 3 hours. The area under the curve for 12-hour cortisol was highest in the surgical group. Cortisol levels remained within the normal range for the following six days, although the values for the surgery group were somewhat higher.

Testosterone levels fell rapidly in both the surgical and chemical groups, although they rose again and remained at low levels in the chemical group. The control (entire) and chemical castration groups achieved a higher average daily (weight) gain (ADG) than the surgical group for the first 27 days. Over 133 days, the chemical group grew at 1.2 kg/day, the controls at 1.1 kg/day, and the surgical group at 0.9 kg/day. Chemical vs. control values were not significantly different, but chemical vs. surgical were significantly different. They concluded that chemical castration caused less stress than surgical castration (at 7-9 months), and that this group grew more rapidly than surgical castrates. Chemical treatment did take longer and required more care than surgical castration. They made no comment about behavioural results of the treatments, and it is possible that there were difficulties managing the animals with slightly elevated testosterone levels.\textsuperscript{cx}

\textbf{Non-Chemical Castration}

Fell \textit{et al} used salivary cortisol and behaviour to investigate the stress of ring vs. knife castration in 4-11 week old Friesian and mixed beef breed calves. The calves had been hand reared, and had received a great deal of handling. Surgical castration was achieved using race restraint, and two incisions were made on the ventral aspect of the scrotum, through the skin and tunica vaginalis. The testes were exteriorised, and the spermatic cord severed by scraping with a scalpel blade.

Surgery induced severe struggling and kicking during the procedure, followed by standing still for 1-2 hours. One calf which continued to bleed showed discomfort the next day. Application of the ring induced less severe reactions, followed by some efforts to touch their scrotum to the ground, a leg or their muzzle, for up to one hour, by which time normal behaviour had resumed.

Cortisol levels were markedly higher in the surgical group, but also elevated in the ring group. Values had returned to normal by four hours. Maximum values in these calves were similar to values induced in the same calves by transport. The concluded that castration induced a stress response similar to that induced by other husbandry procedures, for up to 4 hours, but that the response to ring castration was much less than that to surgical castration.\textsuperscript{xlvi}

Calves aged one to seven days exhibited almost no behavioural signs of distress and did not demonstrate any significant cortisol response to ring castration in an experiment in Edinburgh. Hand reared Friesian calves were used. In contrast to control calves, ring calves mostly slept for the first hour post treatment. This may represent an association with the “lying out” or
“hiding” behaviour exhibited by calves in the first week of life. Kids demonstrated less marked behavioural and cortisol responses than lambs, though more than calves, and this may represent the same phenomenon.\textsuperscript{ LXII }

Further studies at the same institution used Ayreshire calves at 6, 21 or 42 days of age. Treatments included surgery, Burdizzo clamp (applied to each cord separately), or rubber rings, all performed using manual restraint. The ring group exhibited more restless behaviours than the surgical or clamp groups. Burdizzo calves exhibited “abnormal standing, for 24 minutes in 6 day old calves and for longer periods in older calves”. The surgical group exhibited similar behaviour, but for a relatively shorter time in the 42 day group.

Cortisol rose rapidly in the Burdizzo and surgical groups, peaking between 12 and 24 minutes. Values were highest in the surgical group, intermediate in the Burdizzo group, and lowest in the ring group. Cortisol values for the ring group rose more slowly and in some cases persisted for longer, peaking at 36 to 90 minutes. For all methods, the cortisol response was lowest in the 21-day-old calves. The pain of Burdizzo castration appears to be due to the crush itself, with cortisol values returning to normal more quickly than in the other groups, although values did peak higher than in the rubber ring group.

They concluded that abnormal standing and foot stamping appear to be indicators of pain due to castration in calves. Younger calves probably experienced less pain than older calves. The Burdizzo probably induced the least pain over the three-hour study period.\textsuperscript{ EXI }

The same investigators compared surgery, ring, Burdizzo and a combined method of castration in one-week-old Ayreshire calves. Cortisol, behaviour and observation of lesions were used. Active behaviours were more frequent in the ring group, and adding the clamp reduced these behaviours to a value intermediate between ring and surgical groups. Surgical and Burdizzo (and combined) calves showed more “statue standing”.

Cortisol responses were greatest in the surgical group (peaks at 12-24 minutes and again at 60 and 96 minutes), while the ring group showed the lowest cortisol peak, but values were sustained longer than when a clamp was used. The combined method produced a lower first peak than clamp alone, and there was a second small peak at about 84 minutes coinciding with a second peak for ring calves.

Healing occurred most rapidly after surgical castration (<9 days); the Burdizzo group had healed by 15 days. Both ring groups exhibited severe swelling, inflammation and some infection, peaking at 15-18 days (combined) and at 27-30 days (ring only). Healing was incomplete in a few ring only calves at 51 days. Addition of the Burdizzo reduced the time for scrotal loss and healing compared to ring only calves. During the first 42 days, ring and combined calves exhibited more abnormal standing, and the Burdizzo and combined calves more abnormal lying.

Surgery produced more acute pain than other methods. The combined method reduced the acute pain of ring only castration, but to a much smaller degree than that seen in lambs. Methods of castration using rubber rings produced long lasting inflammation and sepsis, and by inference, chronic pain. This may have been because of the relatively poorer “seal” achieved by the ring due to the thicker skin of calves compared to lambs. The authors concluded that surgical and Burdizzo methods appear to be less painful than ring or combined methods. Local anaesthesia has been shown to be an effective method to eliminate the acute pain of clamp
castration in lambs, and therefore the Burdizzo was considered to be the most humane method of castration for young calves.\textsuperscript{cxii}

Researchers in New Zealand have compared ring, surgery (cut and pull or cut and emasculator), clamp, and band (Callicrate bander) castration in calves at 3 months of age. In addition, the effects of local anaesthetic (Lignocaine) infiltration into the testes and scrotum (20 minutes prior) +/- Ketoprofen (3 mg/kg IV) given at the time of castration were explored. Integrated cortisol responses (over 4.5 hours) and behaviour were recorded.

Cortisol responses (first 8 hours) were similar in ring, band and surgery (pull) calves, and were significantly higher than in control calves. Values for clamp and surgery (emasculator) calves were not significantly greater than for control calves. Local anaesthetic reduced the cortisol responses to ring, band and clamp calves to those of control calves, but the response of both surgical groups was still higher than for control calves. The addition of Ketoprofen reduced the cortisol response of all groups to that of the control calves.

The investigators comment that many of the surgery (cut) calves had cortisol responses little different to control animals, while the surgery (pull) calves all had higher cortisol responses. It may be that once local anaesthetic was applied, the cords of the surgery (cut)(LA) group were inadvertently pulled more than in the surgery (cut) group, thus stimulating more pain and response.\textsuperscript{cxiii}

Activity was greater during surgical, band and clamp castration than during ring application. Local anaesthetic reduced activity, at least for the surgical group.

Principles derived from the work:
1. If local anaesthetic is held \textit{in situ} (ring or band), it remains effective much longer than the two hours expected (no cortisol response)
2. Local anaesthetic will not be as effective if it cannot reach a site of damage (e.g. intra-abdominal cord rupture in cut and pull techniques, and cortisol and distress will be greater.
3. Inflammation above the ring or band is probably limited, because addition of Ketoprofen did not further reduce the cortisol response seen when local anaesthetic is given.

Considerations in selecting a castration method for calves:

<table>
<thead>
<tr>
<th>Effectiveness</th>
<th>Ring</th>
<th>Band</th>
<th>Surgery (Pull)</th>
<th>Surgery (Cut)</th>
<th>Clamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Few failures</td>
<td>Unknown</td>
<td>No failures</td>
<td>No failures</td>
<td>Some failures</td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>All ages</td>
<td>All ages</td>
<td>All ages</td>
<td>All ages</td>
<td></td>
</tr>
<tr>
<td>58 days</td>
<td>58 days</td>
<td>48 days</td>
<td>48 days</td>
<td>&gt;63 days</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td>Moderate</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td></td>
</tr>
</tbody>
</table>
Conclusion

Where possible, calves should be castrated at a younger age.

Ring castration may be acceptable in young calves, when combined with local anaesthesia. However, prolonged healing and greater risk of complications (wound infection, fly strike) make this less desirable.

Surgical methods of castration lead to more rapid healing, with fewer complications and reduced chronic pain. However, they produce more acute pain, unless this is ameliorated with additional techniques. An emasculator should be applied to the cords in a surgical technique, rather than the cords being pulled and broken. Local anaesthetic should be used prior to surgical castration to reduce the acute pain response. Additional systemic analgesia (e.g. a non-steroidal anti-inflammatory drug) should also be given to prevent the pain and distress which otherwise follows.

If drugs cannot be given, Burdizzo castration is the most humane option, followed by surgery (emasculator) then ring and band methods.

Chemical castration should be considered, if available.

Ancillary methods which may reduce distress include:
- Castration of artificially reared calves within 7 days (no distress response to rings)\textsuperscript{lxii}
- Isolation of calves from their mothers immediately prior to the procedure (no distress response in 11 week old beef calves to surgical or Burdizzo castration c.f. 24 week old calves)\textsuperscript{xvi}

Disbudding and Dehorning

As previously discussed, the removal of the horns of cattle is valuable for their own welfare (long term), for the safety of humans, to minimise bruising to meat and is a requirement for entry to many feedlots. Clearly, the most humane way to avoid horn problems is to breed polled cattle. Currently, farmer choice and market forces dictate the continuance of horned breeds. The following methods are available to remove horns:

Calves – Cautery (electric or other source to heat a tube which, when placed over the horn bud, destroys horn germinal tissue and cauterises blood vessels)

- Cryosurgery (freezing)
  - Chemical – a caustic chemical can be painted on the horn bud. Special care must be taken to prevent the chemical irritating the eye or skin, especially in wet weather
  - Mechanical devices - designed to cut out the horn bud
    - tube calf dehorner (cuts out the bud like an apple corer)
    - Scoop dehorners (opposing convex blades meet under the horn bud)
    - Saws (stiff bladed, such as a butcher’s saw)
    - Guillotine shears (small shears with a cutting hole of 60x80mm)
    - Embryotomy wire (wire saw with detachable handles, passed around the horn bud and used with a reciprocating drawing action)

Older cattle – surgical methods using handsaws, electric saws, guillotine style shears, wire saws. In each case, a 1 cm ring of skin around the base of the horn must be
removed to prevent re-growth. Firm restraint is necessary to enable dehorning and to prevent injury to cattle and operators. Local anaesthetic and perhaps sedation are sometimes used for welfare reasons and to facilitate the procedure – these drugs require veterinary presence or at least prescription. Haemorrhage, infection, fly worry and infestation, and damage to the sinuses are potential complications. Secondary haemorrhage caused by trauma from fighting or rubbing can be quite serious. Cattle may fight because “they do not recognise each other” after the dehorning procedure. The horn is generally hollow at the core, and opens into a sinus, which easily becomes contaminated with the debris of horn amputation and from the environment. Infection may follow and be debilitating, possibly requiring further surgical drainage.\textsuperscript{cxvi}

Research

Dehorning of cattle has been shown to elevate Cortisol levels, and, by implication, to cause stress. Carter and colleagues investigate the use of an electro-immobiliser to assist with the restraint of cattle undergoing dehorning. 18-24 month old Jersey cattle were used. All dehorned cattle showed significantly elevated cortisol levels compared to controls, but there was no significant difference between cattle dehorned with no anaesthetic, local anaesthetic (a cornual nerve block) or restrained with the electro-immobiliser. One third of immobilised cattle bellowed, and demonstrated eye movements and flinching, which were interpreted as signs of pain. This did not occur when local anaesthetic was used.\textsuperscript{cxvii}

Morisse and colleagues, working in France, compared behavioural and cortisol effects of cautery disbudding (at 4 weeks of age), and heat cauterisation (at 8 weeks), in hand raised Montbelliard calves. Caustic disbudding was applied using a potassium hydroxide stick for 2 minutes, while an electric horn bud cauteriser was applied for about 1 minute at 600°C. Local anaesthesia was injected around the cornual nerve to some calves in each group. Behaviours observed included standing and lying over 24 hours, self grooming, rubbing, social behaviours (head contacts, sucking etc), scratching at the head, and acute behaviours after treatment such as tail flapping, moving back and falling down.

There was no difference in the ratio of time spent standing up to lying down between any of the treatments. The intensity of immediate reactions did not differ between unanaesthetised caustic or cautery calves, but administration of anaesthesia reduced the intensity in both treatments – 60% of animals stood motionless and showed no discernible evidence of pain. Caves stood up and laid down more frequently during the first two hours after treatment, but behaviour had largely returned to normal by 4 hours. Other behaviour patterns (grooming, rubbing, social behaviours) were also altered in frequency during this initial phase. Alterations to the frequency of these behaviours was unaffected by application of anaesthesia.

Cortisol was measured at 0, 1, 4 and 24 hours. Cortisol rose 1 hour after treatment; values were higher for calves treated with cautistic disbudding than with cautery, and the application of local anaesthesia reduced the cortisol response (but not to control levels). Values had returned to normal in the caustic group by 4 hours, and remained normal at 24 hours. In the cautery group, cortisol values had returned to control values by 4 hours (and remained there at 24 hours in the unanaesthetised group) while anaesthetised caves displayed an elevated cortisol value at 24 hours.
Behavioural and cortisol effects seem to change in parallel, however behavioural studies were
hampered by the lack of control calves in this observation group. Caustic disbudding seemed to
be more acutely painful on the basis of cortisol values. In calves treated with local anaesthetic,
cortisol values from caustic disbudding dropped quickly and remained low, while in cautery
calves, cortisol values increased over time, suggesting an increase in discomfort. While local
anaesthesia eliminated the immediate response to disbudding in 60% of calves, it appeared
ineffective in the other 40%. This suggests either poor technique, or alternate innervation,
in some calves.

Preliminary studies have been conducted into the use of Cryosurgery (freezing) to arrest horn
growth in young calves. Two devices used in humans, one using nitrous oxide and one using
liquid nitrogen, were employed. Both required 10 minutes application, and caused bellowing
and struggling. The nitrous oxide device failed to arrest horn growth. The authors considered
that these devices should not be used in unsedated, unanaesthetised animals. This technique
appears to be impractical and to have no benefit over other options.

Virtually all of the remaining studies into the welfare aspects of disbudding and dehorning have
been conducted in New Zealand by Mellor, Stafford and colleagues. They compared the
cortisol responses to two methods of disbudding, with or without local anaesthesia, in 6-8 week
old Friesian calves. A Barnes scoop dehorner, or a gas fired disbudding iron, were used, and
Lignocaine was injected to induce a corneal nerve block 20 minutes prior to disbudding.

Scoop disbudding caused a marked rise in cortisol concentrations, peaking within one hour, and
falling to a plateau for about 5 hours. Values were normal by 6.5 hours. When local
anaesthesia was added to the regime, a small rise was seen, which paralleled the rise seen in
control calves which had had local anaesthetic injected. However, this was followed by a steep
rise after two hours and elevated levels were maintained until 7.5 hours after the procedure.
Between 2.5 hours and 8.5 hours, cortisol levels were higher in the scoop + LA caves than in
the scoop calves.

Cautery disbudding caused a rise in cortisol within 30 minutes, which peaked at values about
2/3 those of scoop calves. By 1.5 hours, values had fallen and were only slightly higher than
those of control calves. Cautery + LA induced a small peak of cortisol before 30 minutes,
which quickly returned to control values.

The integrated cortisol response (ICR), the area under the cortisol curve above pre-treatment
values) for scoop calves was significantly greater than for other treatments during the first two
hours. The ICR for cautery calves was higher than for control and treatment + LA calves
during this period, but less than the scoop calves’ value. LA Scoop and LA cautery induced the
same ICR in this period.

During the final 7.5 hours, the ICR of LA scoop calves was significantly greater than that of
other calves, followed by scoop calves. Cautery and LA cautery calves had moderate ICRs,
with LA cautery calves showing a slightly higher ICR than cautery calves.

Over the whole period, scoop treatments induced a higher ICR than cautery treatments, but the
difference was not significant.

The authors concluded that scoop and LA scoop caused the greatest amount of distress, and
although local anaesthetic reduced the immediate cortisol response, the overall response was not
reduced. Cautery disbudding induced less distress than scoop dehorning, and the response was much shorter in duration. They noted that the duration of the distress response to scoop disbudding was about 5.5 hours; in the case of LA scoop, this period of distress was merely delayed by the two-hour duration of local anaesthesia. That the cortisol response was then higher than in the scoop calves at an equivalent period may have been due to the lack of stress induced analgesia (with endogenous opiates) in the initial period. When they were stimulated to “kick in”, there were larger quantities of inflammatory mediators inducing a greater stress response at 2+ hours than in the scoop only calves at 0+ hours.

Cautery induced a smaller response of short duration, presumably because of almost immediate destruction of nociceptive receptors. LA cauter calves did not display the delayed stress response seen in LA scoop calves, supporting this view. The authors observed only marginal benefits from local anaesthesia in cauter calves, although these calves did show fewer escape behaviours during the procedure. Cautery disbudding appears to induce less distress than scoop disbudding, at least in the first 9 hours.\textsuperscript{cxxi} The limited benefit in overall cortisol response in calves treated with local anaesthetic led to some contention amongst veterinarians in New Zealand, which were addressed by Professors Mellor and Stafford in a subsequent publication.\textsuperscript{cxxi}

McKeekan and colleagues compared the cortisol response to shallow versus deep scoop dehorning, noting that the depth of the scoop cut was proportional to the diameter of the horn bud and hence to the weight of the calf. 14-16 week old Friesian calves (91-120 kg) were used.

Control calves (firm restraint) showed a small rise (5 mg/ml) in cortisol which returned to resting values within 30 minutes. Shallow and deep scoop dehorning induced a marked, sustained rise in blood cortisol levels (28-29 ng/ml for 4.5 hrs, normal values by 8 hours). There were no differences in cortisol levels between the two scoop groups at any time. There were no significant correlations between integrated cortisol responses or time to return to normal and scoop wound depth, wound area, horn bud area, height or weight.

The authors concluded that, in the absence of local anaesthesia or analgesia, scoop dehorning was a markedly distressing experience for at least 6-8 hours. However, there was no evidence that the depth of the wound influenced the magnitude or duration of the distress response.\textsuperscript{cxxxii}

Researchers from the same institution compared the cortisol responses of 60 5-6 month old Friesian calves to scoop dehorning with or without local anaesthetic (LA) and/or immediate post scoop wound cautery. Local anaesthetic (lignocaine) was injected about 30 minutes prior to further treatment. Cautery following scoop dehorning was achieved using a custom-built gas heated cautery iron, with a 30 mm diameter, hemispherical head, which was generally applied for about 6 seconds.

Control (LA and handling) treatment induced small, transient increases in blood cortisol. Scoop dehorning induced a marked response, peaking at 30 minutes. It then declined to a plateau between 1.5 and 3 hrs, and then decreased to pre-treatment levels by 6-7 hours. LA almost abolished the cortisol response for the first three hours. LA scoop calves then showed a rise in cortisol to values similar to scoop only calves, which then declined in parallel to the values from scoop only calves.

Cauterising the wound caused a marked cortisol rise which peaked at 30 minutes, plateaued between 2 and 3 hours, and then returned to pre-treatment values between 5 and 6 hours. Mean
plasma cortisol values were lower than scoop calves at each time, with significant differences noted at 0.5, 2.5 and 3 hours post treatment. LA, scoop and cautery calves demonstrated a transient rise in cortisol and subsequent fall similar to that observed in control (handled) calves.

Local anaesthesia almost abolishes the cortisol response to dehorning for the first 3 hours. Local anaesthesia and immediate wound cautery almost abolished the cortisol response throughout the 9 hours of the study. The authors noted that the cortisol responses which occurred after LA had worn off (3 hours) were greater in 6-week-old calves than in this study.

Cautery effected a small reduction in the distress caused by dehorning, compared to the marked decrease seen in lambs tailed using a docking iron. The authors noted that cortisol values were at or below pre-treatment values at 36 hours in all but the scoop only calves, suggesting that little distress is experienced at this stage.

A further paper compared cortisol response to four methods of dehorning in 5-6 month old Friesian calves. Scoop saw, guillotine shears and embryotomy wire all resulted in very similar cortisol responses including peak height and time, duration, and integrated cortisol response. All methods appeared to induce a similar level of distress, presumably because of similar levels of tissue damage. There was a slightly (not significant) greater peak response for scoop calves, and guillotine calves (with the shallowest wounds) showed slightly lower cortisol responses at 2 and 2.5 hours. The pattern of cortisol response in these 5-6 month old calves was similar to that seen in 6 and 14-week-old calves after scoop dehorning.

The effects of duration of local anaesthetic were then investigated in 3-4 month old Friesian calves (62-110 kg). Scoop dehorning was used, preceded (20 minutes) by local anaesthetic injection with 0.25% bupivacaine, which lasts approximately 3-4 hours. In some calves, the injection was repeated at 4 hours.

As could be expected from previous experiments, LA prevented the rise in plasma cortisol values for its duration, 4 hours or 8 hours. In calves given a single injection, a marked rise in cortisol occurred at 4.33 hours and persisted until 8.33-9.33 hours post treatment. At 6.33 and 7.33 hours, the mean cortisol level was significantly greater than the value in scoop only calves at that time. In other words, the cortisol response had been postponed, but not eliminated by the administration of local anaesthetic.

A group of calves received bupivacaine immediately before scoop dehorning (rather than 20 minutes before). The initial cortisol response was eliminated, as in the 20-minute LA calves, but the cortisol levels rose about 4.83 hours after treatment. However, calves in this group did demonstrate behavioural evidence of distress during the procedure, although the cortisol response was too slow to reveal it. The local anaesthetic delayed the anticipated rise in cortisol for its duration.

Administration of a second LA injection 4 hours post dehorning postponed the cortisol rise until 8.33 and 9.33 hours, at which point the cortisol was higher than in scoop only calves at the same time. There was also a transient rise in cortisol at 3.83 hours, when the initial injection would be expected to be wearing off.

Although the cortisol response was much reduced in calves given bupivacaine for the duration of the LA, compared to those not injected, the overall cortisol response was not reduced in calves given a single injection compared to those not injected. A second injection reduced but
did not eliminate the subsequent cortisol increase. Additional measures are required to reduce the overall cortisol response. The decline in cortisol response in non-injected calves may have occurred due to habituation to noxious sensations, compared to the single injection calves which, at 4 hours, experienced the pain for the first time. The LA calves may have been prevented from developing an early stress induced analgesic response, hence experiencing greater pain at 4 hours than their non-injected counterparts.

Although the cortisol response to LA immediately before dehorning was not different to that in calves injected 20 minutes prior, behavioural responses indicate the need to allow LA time to act. The lack of cortisol response during 8 hours of local anaesthesia suggests that inflammatory mediators (which were not impeded) do not directly induce a cortisol response.\textsuperscript{cxxxv}

These investigators then explored the effect of a non-steroidal anti-inflammatory drug (Ketoprofen 10\%, 3 ml IV, 20 minutes prior to treatment) on calves scoop dehorned with or without prior injection with lignocaine or bupivacaine. 3-4 month old Friesian calves were used. Control group calves (control handled, control with bupivacaine, or Ketoprofen, or lignocaine and ketoprofen, or bupivacaine and ketoprofen) all showed a transient, small rise in cortisol values during the first 20 minutes after handling and injections, which then returned to and remained at pre-treatment values.

Dehorned calves showed a cortisol response equal to that previously described. In calves treated with Ketoprofen 20 minutes prior to dehorning, a similar peak was seen at 0.33 hours, but cortisol values had returned to normal by 1.83 hours. The addition of lignocaine showed a small peak in cortisol at 0.33 hours, and thereafter no significant differences from control calves. The addition of bupivacaine induced a small peak at 0.83 hours, and the cortisol was somewhat higher than in control calves at 9.33 hours. Otherwise, these calves had cortisol values not significantly different from control calves. Bupivacaine only induced a delayed rise cortisol, as previously described.

The addition of Ketoprofen, and its efficacy at eliminating the second phase of the cortisol response, shows that this response is due to inflammation compared to the initial rise due to the (pain of the) procedure itself. Giving ketoprofen alone only slightly reduced the initial cortisol response, since the analgesic action of non-steroidal anti-inflammatory agents is primarily through their anti-inflammatory effects, but these agents have a variable central analgesic action also. However, the combination of regional analgesia and an anti-inflammatory agent has been shown to eliminate the stress response altogether.\textsuperscript{cxxxvi}

The behavioural responses of calves to similar treatments were then described. Increased foot stamping, head and tail shaking, ear flicking, vocalisation and general restlessness have been observed in cattle undergoing procedures generally thought of as painful. The same calves as in the previous studies were observed for lying, grazing or ruminating, tail shaking or ear flicking, for seven one minute periods over 3 days (at 2, 4, 6, 22, 26, 46 and 50 hours after treatment).

There were significant differences in the incidences of these behaviours in different groups of calves, especially at 2 and 4 hours after dehorning. The administration of lignocaine plus ketoprofen markedly reduced the difference between lying, grazing or ruminating, tail shaking and ear flicking between control and dehorned groups in the first 4 hours. This reduction was not so evident when either agent was given alone. Lignocaine had probably largely worn off by the first observation period (2 hours), and appears to have no long-term effect on behaviour.
Lignocaine and ketoprofen appear to reduce, but not totally eliminate, the pain of dehorning in cattle. Lignocaine alone, and Ketoprofen alone, appear to reduce behavioural signs of pain according to time frames to be expected from their pharmacology and previously quoted cortisol responses.

Graf and Senn, working in Switzerland, used a wider range of physiological and behavioural observations to explore the effect of local anaesthesia prior to cautery disbudding. 4-6 week old calves of three breeds and their crosses were used; no injection, saline injection, or lignocaine injection were given 2 days before actual disbudding, in conjunction with simulated dehorning, and then repeated in conjunction with cautery dehorning. Blood was collected via an implanted catheter and analysed for vasopressin, ACTH and cortisol. Vasopressin is rapidly released (in some species) in response to stressors and stimulates the secretion of cortisol and ACTH, and therefore may be used as an acute indicator of stress and pain.

Local anaesthetic was injected both around the corneal nerve and infiltrated around the horn bud, to provide the greatest effective pain prevention. Behaviour during injection was recorded on video cameras, and analysed for five behaviours – tail wagging, head moving, tripping, forcing ahead, and rearing. Behaviour was continuously observed for 4 hours post dehorning, and observed for backward locomotion, head shaking, head pushing, and feeding.

The frequency of tail wagging, head moving, tripping, forcing ahead and rearing were at least twice as high during saline injections as during local anaesthetic injections. Vasopressin and ACTH showed small, transient rises in saline injected calves, and cortisol rose sharply and remained elevated for about 90 minutes after simulated dehorning in these calves. These effects were not seen in control (not injected) or local anaesthetic calves, except that cortisol rose a little in local anaesthetic, and to a slightly greater degree, in control calves after simulation. The frequencies of all behaviours were higher in saline and control calves during simulation than in local anaesthetic calves.

Dehorning led to a marked increase in all behaviours in control and saline calves, which was only marginally increased in local anaesthetic calves. In particular, dehorned calves moved backward for no apparent reason, showed a drastic increase in head shaking for the first hour, and avoided head pushing in the first 4 hours. Feeding behaviour was also reduced in the first 2 hours. These behavioural changes were not observed in the local anaesthetic calves. Dehorning induced a sharp rise in vasopressin, ACTH and cortisol, which in each case was higher in the saline injected calves than in control calves. The higher peak hormone concentrations in saline calves were mainly due to the addition of the effect of the injection (observed in LA simulation calves) upon the effect of the treatment observed in control calves. Local anaesthetic prior to cautery dehorning almost completely prevented increases in plasma hormone concentrations. There was a slight but significant rise in cortisol at 10 minutes which had returned to baseline by 40 minutes, and a second smaller increase at 2 hours which led to values significantly higher than in control and saline calves at this stage.

These results showed that an injection per se induces changes indicative of distress, but that these are eliminated if the injection is local anaesthetic. Clearly, the local anaesthetic rapidly takes effect and is unlikely to produce any significant stress or pain. This treatment also almost eliminated behavioural and physiological signs of stress and pain after cautery dehorning. Some post-operative pain was clearly experienced by animals as the local anaesthetic was wearing off, and while the authors concluded that this might be a direct effect of the injected
anaesthetic, it is also possible that the local anaesthetic (and cautery) blocked any pain induced analgesic response. The authors concluded that cautery dehorning causes considerable pain and stress and that local anaesthetic reduces that reaction during and up to at least 2 hours after dehorning.\textsuperscript{cxxviii}

The New Zealand researchers also observed behavioural responses to amputation dehorning, for 8 hours using 6-week-old Friesian bull calves. The behaviour of calves injected with local anaesthetic prior to dehorning differed significantly from control calves and was similar to calves dehorned without local anaesthetic, in most respects, during the period of activity of the anaesthetic. They speculated that abnormal behaviour may be due to bleeding and the irritation caused by it, or due to the effects of the injection itself. However, there may be less variation in behavioural responses to serious injury than expected, and the observation of behaviour may be inadequate to assess and compare pain caused by any specific insult.\textsuperscript{cxxix}

The New Zealand researchers reassessed the cortisol response to dehorning with local anaesthesia and wound cautery over 24 hours, using 3-4 month Friesian calves. In this instance, nerve blockade was achieved for 5 hours with two local anaesthetic injections. The results confirmed previous observations that cortisol rose when local anaesthetic wore off, in the absence of wound cautery, but did not rise above immediate pre-treatment values for at least 24 hours in calves treated with local anaesthetic and wound cautery. They concluded that the combined treatment did “substantially reduce the acute cortisol response and by inference the pain induced distress caused by amputation dehorning.”\textsuperscript{cxxx} No complications were seen in any calf.

Summary

Mellor and Stafford presented a summary of the current research into dehorning and disbudding in 2000. They noted that amputation dehorning induced a marked cortisol response, which peaks at 30 minutes and lasts for 7-9 hours. This effect is seen in calves at 6 weeks, 3-4 months or 6 months. All methods of amputation dehorning induce a response which is essentially identical, and depth of wound is unimportant. Prior local anaesthetic injection delays the cortisol response but does not significantly reduce its magnitude. Prior injection of a non-steroidal anti-inflammatory drug (Ketoprofen) does not much influence the initial cortisol response, but virtually eliminates the rest of the cortisol response. Prior injection with both local anaesthetic and ketoprofen virtually eliminates the cortisol response to amputation dehorning. (see following graphs – all from cxxxi)

When bupivacaine is used in the combined approach, there is a non-significant delayed cortisol response when the bupivacaine has worn off. Previously unpublished data revealed that if lignocaine is followed by bupivacaine (giving 6 hours of analgesia), there is very little reduction in the cortisol response when the local anaesthetic wears off. Thus, the longer the local anaesthetic effect, the less the effect of the non-steroidal anti-inflammatory drug.
Figure 1: Changes in plasma cortisol concentrations after dehorning without or with prior injection of lignocaine and in control calves.

Figure 2: Changes in plasma cortisol concentrations after dehorning using four amputation methods, using a scoop with prior injection of lignocaine, and in control calves injected with local anaesthetic.

Figure 3: Changes in plasma cortisol concentrations after dehorning without or with bupivacaine local anaesthetic, and in control calves.

Figure 4: Changes in plasma concentrations of cortisol after dehorning without or with prior injection of NSAID (ketoprofen), and in NSAID control calves.

Figure 5: Changes in plasma cortisol concentrations after dehorning without and with prior injection of local anaesthetic (bupivacaine) plus NSAID (ketoprofen), and in local anaesthetic/NSAID control calves.

Figure 6: Changes in plasma cortisol concentrations after dehorning without or with subsequent wound cauterity, and with prior injection of lignocaine plus subsequent wound cauterity, and in control calves.
Cauterising the amputation dehorning wound non-significantly reduces the cortisol response, and is not recommended. However, combining prior injection with local anaesthetic and post-operative wound cautery virtually eliminates the cortisol response throughout the first 24 hours, including the delayed cortisol response which occurs when the local anaesthetic wears off. It is believed that the use of local anaesthetic maintains the pain threshold at higher levels than occurs with amputation without local anaesthetic, and the cautery destroys sufficient pain receptors to keep the pain impulse input below the pain threshold after the local anaesthetic wears off.

Cautery disbudding induces a significant but short lived cortisol response (peak 30 minutes, resolved by 2 hours). Prior cornual nerve injection with local anaesthetic non-significantly reduces the cortisol response, but cornual nerve injection and infiltration around the horn bud virtually abolishes the cortisol response.

The authors then ranked the distress caused by these different methods, in some cases using behavioural observations to separate different treatments. See table 4

Table 4: Ranking dehorning and disbudding procedures from most to least severe.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Procedure</th>
<th>Struggling</th>
<th>Acute Cortisol Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.</td>
<td>Amputation dehorning During amputation and cautery + wound cautery</td>
<td>Marked (75%)*</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Amputation dehorning During amputation only</td>
<td>Marked (100%)*</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Prior local anaesthetic + amputation dehorning None/little</td>
<td>Marked (100%)* and delayed</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Cautery disbudding During disbudding</td>
<td>Moderate (55%)*</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Prior local anaesthetic + cauter disbudding None/little</td>
<td>Moderate (55%)*</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Prior NSAID + amputation dehorning During amputation</td>
<td>Mild (35%)*</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Prior local anaesthetic and NSAID + amputation dehorning None/little</td>
<td>Very mild (25%)*</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Prior local anaesthetic + amputation dehorning + wound cautery None/little</td>
<td>Very mild (25%)*</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Prior local anaestheticV + cauter disbudding None/little</td>
<td>Very mild (?%)</td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Non-treated controls None/little</td>
<td>Very mild (~20%)*</td>
<td></td>
</tr>
</tbody>
</table>

* - Percentage of the acute cortisol response to amputation dehorning in each study.
# - injected near the cornual nerve supplying each horn bud.
V - Injected near the cornual nerve and around the base of each horn bud (cxxviii). (??%) - Percentage not known. From cxxxi
There are concerns about the effect on wound healing of wound cautery. This has not been studied in detail, but “no significant problems became apparent” when cattle were observed over a period of weeks after dehorning wound cautery.

Conclusion

Disbudding and dehorning are routine and, for the time being, essential management practices for cattle. There is no question that these procedures cause significant pain and distress, and that efforts should be made to minimise this distress.

The most effective way to minimise pain and distress is to breed cattle without horns, and this should be encouraged.

Where possible, calves should be disbudded (by cautery) at or before 6 weeks of age. This appears to cause less pain and distress than amputation dehorning at a later age.

Prior local anaesthesia (preferably both cornual nerve block and local infiltration) plus cautery disbudding induces the least pain and distress, and should be encouraged.

Where amputation dehorning is to be performed, this should be either preceded by local anaesthesia and systemic analgesia, or preceded by local anaesthesia and followed by wound cautery. However, as noted by Keith Stafford, the long term effects (pain, complications, healing time) of dehorning wound cautery have not been investigated to date. Either of these options greatly reduces the behavioural and cortisol reactions to amputation dehorning.

Branding

Lay and colleagues compared hot iron with freeze branding in Simmental cross, Angus calves and Dairy cows (Holstein and Jersey). Freeze branding is perceived to be less painful, is easier to read from a distance, and does not damage the hide, however, application is more difficult and takes longer (5s vs. 17s).

Nine to ten month old calves were trained to be familiar with a race and restraint area. An electric brander (521°C) was applied for 5 seconds, producing immediate reactions including lurching away from the brand and (in some cases) falling to their knees. Alternatively, a copper/bronze, liquid nitrogen cooled, brander was applied for 17s to a shaved, methanol treated area of skin. No reaction was seen for the first 8 seconds, but then the calves reacted similarly to those heat branded. About half the Angus calves vocalised, compared to a smaller proportion of cross bred calves and none of the dairy cattle.

Epinephrine (adrenaline) values peaked at 30 seconds in hot iron calves, but were essentially unchanged in freeze branded calves. Epinephrine levels were also a little higher than control values at 15 and 20 minutes, in Angus calves only. Angus calves also showed elevated Nor-epinephrine (nor-adrenaline) levels at 30s, 15 and 20 minutes, an effect not seen in cross bred calves. Neither sex nor previously recorded temperament had any effect on these catecholamine values.

Angus calves displayed higher heart rates at 30s for heat than freeze branding, while both heat and freeze branding elevated the heart rate of cross bred calves at this time. All heart rates had
returned to, or below, normal by 10 minutes post branding. Heart rate was affected by the temperament of the calf.

Cortisol values rose during the 20 minute sampling period in all calves. In cross bred calves, cortisol values for heat branded calves exceeded those of freeze branded calves, although there were no significant differences between treatments (including control calves), while in Angus calves, freeze branding induced higher cortisol values than other treatments, which were significantly different at 1, 3, 15 and 20 minutes. Cortisol values were correlated with temperament. Elevated cortisol values in all calves showed that restraint induced a stress response, while the higher values for freeze branded Angus calves at 20 minutes suggests prolonged pain sensations.

Heat branded cattle appear to suffer more acute pain than freeze branded, but, at least in Angus calves, the distress experienced may be more prolonged after freeze branding. The authors suggested that the pain of heat branding may be too brief to cause ongoing cortisol elevations, but a more likely explanation may be the destruction of nociceptors (3rd degree burns). They offered no explanation for the different effect on cortisol values between cross bred and Angus calves. Fewer calves in the cross bred study vocalised, which may be because these calves were treated in isolation, while in the study involving Angus calves, they were in visual and audible proximity to other calves. However, there appears not to have been enough other differences between results to suggest that this isolation reduced the distress suffered.

A clear limitation of these studies is the short observation period (20 minutes). A much longer period of observation, including interactive behavioural observations, would be necessary to consider long term effects (healing time, complications, ongoing pain etc) caused by the two treatments.

The use of Freon 22 (chlorodifluoromethane) applied with a template and spray, as an alternative to chilled metal "brands" has been described. A number of compounds, applied topically or by injection, have been used to trial as depigmentary agents. Although some compounds produced depigmentation for up to three months, none produced a permanent effect.

A series of experiments in Canada have investigated behavioural and other effects of branding. Hot iron branded calves (320 kg) showed more active responses (tail flick, kick, fall and vocalisation) than freeze or sham branded cattle, and freeze branded showed more tail flick than sham branded. When average and peak intensity and duration of force against the restraining head bale were recorded, hot iron had greater values than freeze branded which had greater values than sham branded. These results indicate that hot iron branding causes more discomfort than freeze branding. All treatments resulted in increased handling effort for up to 6 days.

Branding by hot iron or freezing did not affect body weight or antibiotic usage rates when applied to Charolais-cross calves either on the day of arrival, or twenty days after arrival, in a feedlot. Freeze branded steers required more handling pressure on day 6, perhaps indicating some lingering pain. The authors concluded that branding may not be a severe enough stressor to negatively affect weight gain or health in cattle.

When cortisol and pain sensitivity were examined in mixed breed yearlings after hot iron or freeze branding, hot iron cattle showed higher cortisol values at 40 minutes, while hot iron and freeze branded cattle showed values higher than controls at 20 minutes. No treatment
differences were noted in foot lift latency when a laser was applied to the foot, or in sensitivity to touch. The authors concluded that both methods produced discomfort to cattle, however hot iron appeared to produce a greater acute response than freeze branding.\textsuperscript{cxli}

An infra-red thermograph was used to measure inflammation at brand sites. Between 2 and 168 hours after branding, hot iron brand sites were 1.9 +/- 0.3 °C higher than controls, while freeze brand sites were 1.6 +/- 0.3 °C. Freeze brand sites were warmer at 2 and 8 hours, while hot iron sites were warmer at 144 hours. The authors concluded that both methods caused tissue damage, but that the prolonged inflammatory response in hot iron branded sites indicated more tissue damage and perhaps more discomfort.\textsuperscript{cxlii}

A videotaped record of head movements, together with head bale strain gauge recordings, was used to assess reactions in heat, freeze and sham branded cattle. It was concluded that hot iron branded steers experienced more discomfort than freeze branded steers, which experienced more discomfort than sham branded steers. Image analysis was a better technique for detecting treatment differences compared with exertion force measurements and frequency counts of tail-flicks, kicks, falls and vocalisation during branding.\textsuperscript{cxliii}

Recordings of vocalisations of hot iron branded and control calves were made during the procedure, digitised, and were used to generate an audio-spectrogram and a power spectrum for each call. Significantly more branded than non-branded animals vocalized (58/95 compared with 7/94). Branded animals showed a greater frequency range in the fundamental, or lowest harmonic, of the audio-spectrogram. Four prior days of restraint did not alter the probability of vocalising, or any characteristics of the calls. It is suggested that measuring vocal response may be particularly useful when the effects of relatively severe stressors are being investigated.\textsuperscript{cxliv}

Alternatives to branding exist and are practical. The National Livestock Identification scheme uses radio frequency (RF) transponders (microchips) applied either as part of an ear tag, or as a rumen bolus. The transponder is coded with a unique number which identifies the district, property and individual animal, and is read with a fixed or portable RF reader.\textsuperscript{cxlv,cxlvii} Disadvantages include:

- Ear tags can be lost
- Rumen boluses cannot be used in calves (although loss rates in older cattle are zero)
- They cannot be read from a distance

\textbf{Conclusion}

Both freeze and hot iron branding cause pain and distress, especially acutely, but continuing for some time. Cattle care practices and alternate identification methods are reducing, and should continue to reduce, the practice of branding, but where it must be performed, freeze branding would appear to be preferable.
Conclusion

This review has considered some 120 scientific papers which reveal, either directly or indirectly, information about the welfare status of sheep and cattle undergoing routine husbandry procedures. Neither the authors of these pieces of original research, nor the reviews, would claim that they represent the final word about the level of pain and distress suffered by livestock, nor about its amelioration.

For example, few of these papers mention the mental state of animals. Animals which are subjected to conditions which humans would describe as “helplessness”, such as the inability to predict the arrival of shocks, have been shown to suffer more physical ailments (e.g. gastric ulcers) than animals subjected to the same shocks but with warning of their arrival. It could be that providing predictability or choice to animals undergoing livestock husbandry procedures may decrease suffering and improve immune function and healing. However, it is not necessary to find some tangible or health benefit to justify a consideration of the animal mind. The animal mind has been described as “the single most important entity in the well-being of animals” and is likely to be the next frontier for animal welfare scientists and others concerned for animal well-being.

Even ignoring the issue of “state of mind”, this author, and all the cited authors, recognise that as further research is conducted, the body of knowledge about pain and distress caused by castration, tail docking, dehorning and the like, will grow. Further interpretation of this data may lead to altering the rankings of pain associated with a procedure, or new methods or combinations of methods to alleviate pain and to minimise suffering. New production systems or new markets may make some of these procedures unnecessary, for example the rise in the bull meat market in New Zealand and the UK. The increasing knowledge of the genome of livestock animals, and our ability to manipulate it, may lead to the elimination of, for example, horns from cattle, thereby nullifying the need for disbudding and dehorning. This review has discussed the possibility of a commercial, non surgical alternative to mulesing in the next five years.

But we have information now which should not be ignored. This large body of data leads, in this author’s opinion, to the inescapable conclusion that animals in Australia’s current production systems are suffering avoidable pain and distress, and that we have the knowledge to improve their quality of life. Further, those who own and use animals, those who care for animals, and those who have the right to regulate or encourage for regulation about animals, have a “duty of care” which includes minimising suffering and improving quality of life. “In terms of social ethics, animal welfare is not a private good which individuals can choose to purchase or not, as they wish. More realistically, it is considered to be a particular kind of public good, not open to individual choice but something which in that society ….everyone has an obligation to subscribe to as part of a collective ethic…. It is evident, therefore, that animal welfare as a public good requires regulation (not market forces) to determine its standards.”

It would be all too easy to encourage regulation which sets a high standard of welfare in animal husbandry. It could be justified to enforce that every animal undergoing surgical intervention (castration, tail docking, mulesing, dehorning) should receive anaesthesia and analgesia according to the best of modern knowledge, and indeed that the surgery should be performed in sterile surroundings and using sterile instrumentation, to minimise risks of infection, inflammation, and post-operative pain and suffering. This is now the standard expected of
surgery on humans, and on companion animals such as dogs, cats, and horses, so why should farm animals not receive the same standard of care?

Animal welfare scientists have long argued that such an approach would be counter-productive to the interests of animals. The so called “gold standard” approach is open to criticism on many grounds. It excludes those who cannot meet its requirements for practical or financial reasons, it leads to resentment, alienation, non-compliance and/or rejection, resulting in no improvement in animal welfare. Even if the measures suggested are not the highest currently recognised, welfare is not enhanced if farmers reject the recommendations because they are, or it is perceived that they are, impractical.

The adoption, on the other hand, by advisory groups and regulatory authorities, of a strategy of “incremental improvement” (the setting of reachable targets in a planned sequence of enhancement) encourages participation and “buy in”. A sense of achievement by participants, a willingness to recruit others, and openness to further improvement should follow.

Development of the information presented here into Regulations (setting minimum standards) and perhaps Codes of Practice (providing information of a practical nature for those wishing to exceed the minimum and enhance the well-being and perhaps the productivity of their animals) requires discussion, in a cooperative manner, between

- animals owners (livestock producers),
- animal users (e.g. feed-lotters),
- animal husbandry educators (e.g. CIT, universities, etc)
- animal health care providers (veterinarians, AVA),
- animal medication regulators (NRA, State and Territory “control of use” regulators (chief pharmacist in the ACT)),
- animal welfare advocates (RSPCA, Animals Australia etc),
- animal welfare advisory groups (AWAC)
- and animal welfare regulators (Government).

Criteria for consideration of techniques have been listed:

- Ease of execution and speed – to minimise training needs, the hazards to stock-handlers, and time consuming and costly intrusions into busy farming schedules
- Minimal handling and restraint – to reduce the duration of exposure to these potential sources of distress and to ensure that animals are returned to their dams or pasture in the shortest possible time
- Minimal hazards to the stock – to minimise the risks of haemorrhage, sepsis, swelling and so on
- Low-pain methods preferred – to enhance the welfare of animals

Certain procedures could, perhaps, be considered for banning by regulation, based on the available evidence. These would include

- the surgical castration and surgical tail docking of lambs, because the use of rings is common, practical, and is less detrimental to welfare; and
- the amputation of the horns of older calves/cattle unless local anaesthesia and cautery or a non-steroidal anti-inflammatory drug are used, since the cautery disbudding of calves, and the combined techniques in older calves, have been shown to be so much less noxious to the animal.
This author believes that the parties listed above have a common interest in enhancing animal welfare and can work together to ensure that practical and effective recommendations result in tangible, beneficial outcomes for livestock species.
References

1 Thornton PD and Waterman-Pearson AE 1999 “Quantification of the pain and distress responses to castration in young lambs” Research in Veterinary Science 66: 107-118
4 Webb Ware JK, Vizard AL and Lean GR 2000 “Effects of tail amputation and treatment with an albendazole controlled-release capsule on the health and productivity of prime lambs” Australian Veterinary Journal 78 (12) 838-842
7 Australian Veterinary Association Draft Policy 2000: Tail Docking of Cattle
8 Mellor D and Stafford K 1999 “Assessing and minimising the distress caused by painful husbandry procedures in ruminants” In Practice (supplement to the Veterinary Record) September 1999, 436-446
10 Senate Select Committee on Animal Welfare: Inquiry into Sheep Husbandry 1989 Chapter 4 “The Sheep Blowfly and its Control” pp 45-66
12 Chapman, RE 1993 “Progress towards a non-surgical alternative to the Mules operation for the control of blowfly strike.” Wool Technology and Sheep Breeding 41 (1) 1-10
14 Sorell, GC, Hynd, PI, Hocking, JE, Kuchel, T and DeSaram, W 1990 “The use of high-energy electrons to depilate the breech of sheep.” Australian Veterinary Journal 67 (2) 51-55
15 ABC Website Rural News November 2001 “New non-surgical treatment for blowflies”
16 Martin, Paul, Research and Development Manager for Virbac Australia Pty Ltd, pers. comm. March 2001
17 Australian Veterinary Association (Australian Sheep Veterinary Society) Draft Statement on Mulesing in Sheep 2001
18 Plant J 2002 pers. comm.
19 Mellor DJ and Stafford KJ 2001 “Integrating practical, regulatory and ethical strategies for enhancing farm animal welfare” Australian Veterinary Journal 79 (11) 762-768
20 Zimmerman M 1986 “Behavioural investigation of pain in animals” in Duncan AH and Molony V eds. Assessing pain in Farm Animals pp 16-20, Commission of European Communities, Luxembourg
21 Livingston A 1994 “Neurologic Confirmation of the Clinical Signs of Effective Control or Prevention of Animal Pain” in Animal Pain and its Control – Proceedings 226, the Post Graduate Committee in Veterinary Science, University of Sydney.
25 Morton DB and Griffiths PHM 1985 “Guidelines on the recognition of pain, distress and discomfort in experimental animals and an hypothesis of assessment” Veterinary Record 116: 431-436
26 Anon 1998 “American College of Veterinary Anaesthesiologists’ position paper on the treatment of pain in animals” Journal of the American Veterinary Medical Association 213 (5) 628-630
28 Rollins B 1987 “Animal pain, scientific ideology, and the reappropriation of common sense” Journal of the American Veterinary Medical Association 191 (10) 1222-1226
animals

healthy and lame sheep

castration, tail docking and mulesing

57

and intravenous noloxone on the changes in behaviour and plasma concentrations of cortisol produced by castration and tail docking with tight rubber rings in young lambs

63

Medical Association 191

Medical Association 210

measures used to determine the severity of post-operative pain in dogs

Welfare” in Smidt D (ed) Indicators Relevant to Farm Animal Welfare Martinus Nijhoff Publishers

Rushen J 1986 “Some problems with the physiological concept of stress” Australian Veterinary Journal 63 (11) 359-361


Houpt KA “Animal behaviour and animal welfare” Journal of the American Veterinary Medical Association 198 (8) 1355-1360

Dinnsis AS, Mellor DJ, Stafford KJ, Bruce RA and Ward RN 1997 “Acute cortisol responses to castration using a rubber ring and/or a castration clamp with or without local anaesthetic” New Zealand Veterinary Journal 45: 114-121

Molony V Kent JE and Robertson IS 1993 “Behavioural responses of lambs of three ages in the first three hours after three methods of castration and tail docking” Research in Veterinary Science 55: 236-245


Fell LR, Wells R and Shutt DA 1986 “Stress in calves castrated surgically or by the application of rubber rings” Australian Veterinary Journal 63 (1) 16-18

Shutt DA, Fell LR, Connell R and Bell AK 1988 “Stress responses in lambs docked and castrated surgically or by the application of rubber rings” Australian Veterinary Journal 65 (1) 5-7

Franklin RJM 1986 “Endogenous opioids and slaughter induced stress (letter)” Veterinary Record 119: 311


Cottrell DF and Molony V 1995 “Afferent activity in the superior spermatic nerve of lambs – the effects of application of rubber castration rings” Veterinary Research Communications 19 (6) 503-515

Welsh EM and Nolan AM 1995 “Effect of flunixin meglumine on the thresholds to mechanical stimulation in healthy and lame sheep” Research in Veterinary Science 58: 61-66


Cook CJ 1997 “Sex related differences in analgesia in sheep” New Zealand Veterinary Journal 45 (4) 169-170


Jongman EC, Morris JP, Barnett JL and Hemsworth PH 2000 “EEG changes in 4 week old lambs in response to castration, tail docking and mulesing” Australian Veterinary Journal 78 (5) 339-343


Carter PD, Johnston NE, Corner LA and Jarrett RG 1983 “Observations on the effect of electro-immobilisation on the dehorning of cattle” Australian Veterinary Journal 60 (1) 17-19


Bengtsson B, Menzel A, Holtenhuis P and Jacobson S “Cryosurgical dehorning of calves: a preliminary study” The Veterinary Record 138: 118-122

Petrie NJ, Mellor DJ, Stafford KJ, Bruce RA and Ward RN 1995 “Cortisol responses to two methods of disbudding used with or without local anaesthetic” New Zealand Veterinary Journal 44: 9-14

Mellor DJ and Stafford 1997 “Interpretation of cortisol responses to calf disbudding studies” (letter) New Zealand Veterinary Journal 45: 126-127

McKeekan CM, Mellor DJ, Stafford KJ, Bruce RA, Ward RN and Gregory NG 1997 “Effects of shallow scoop and deep scoop dehorning on plasma cortisol concentrations in calves” New Zealand Veterinary Journal 45: 72-74

Sylvester SP, Mellor DJ, Stafford KJ, Bruce RA and Ward RN 1998 “Acute cortisol responses of calves to scoop dehorning using local anaesthesia and/or cautery of the wound” Australian Veterinary Journal 76 (2) 118-122

Sylvester SP, Stafford KJ, Mellor DJ, Bruce RA and Ward RN 1998 “Acute cortisol responses of calves to four methods of dehorning by amputation” Australian Veterinary Journal 76 (2) 123-126

McMeekan CM, Mellor DJ, Stafford KJ, Bruce RA, Ward RN and Gregory NG 1998 “Effects of local anaesthesia of 4-8 hours duration on the acute cortisol response to scoop dehorning in calves” Australian Veterinary Journal 76 (4) 281-285

McMeekan CM, Stafford KJ, Mellor DJ, Bruce RA, Ward RN and Gregory NG 1998 “Effects of regional analgesia and/or a non-steroidal anti-inflammatory analgesic on the acute cortisol response to dehorning in calves” Research in Veterinary Science 64: 147-150


Stafford KJ, Mellor DJ, Ward RN and Cann B 2000 “Behavioural responses to amputation dehorning with or without local anaesthesia” Proceedings of the New Zealand Society of Animal Production 60: 234-236

Sutherland MA, Mellor DJ, Stafford KJ, Gregory NG, Bruce RA and Ward RN 2002 “Effect of local anaesthetic combined with wound cauterisation on the cortisol response to dehorning in calves” Australian Veterinary Journal 80 (3) 165-167


Mellor DJ pers. comm. March 2002


Schwartzkopf, KS, Stookey, JM, Hull, PR and Clark, EG “Screening of depigmenting compounds for the development of an alternate method of branding beef cattle.” *Journal of Animal Science* **72** (6) 1393-1398


Anon 2000 “NLIS and cattle identification” (pamphlet) Meat and Livestock Australia, North Sydney NSW


McMillan FD 1999 “Influence of mental states on somatic health in animals” *Journal of the American Veterinary Medical Association* **214** (8) 1221-1225

McMillan FD and Rollin BE 2001 “The presence of mind: on reunifying the animal mind and body” *Journal of the American Veterinary Medical Association* **218** (11) 1723-1727


Mellor DJ 1999 “What determines minimum animal welfare standards – animals actual needs, animals perceived needs or economics?” *Proceedings of the 16th Annual Seminar of the Society of Dairy Cattle Veterinarians of the NZVA, Foundation for Continuing Veterinary Education, Massey University, No. 192*: 143-152