Review Article

Acute castration and/or tailing distress and its alleviation in lambs

D.J. Mellor [*§] and K.J. Stafford [†]

Abstract

Purposes and approach: Acute castration and/or tailing distress in lambs has been examined extensively during the last decade. At least 59 different approaches to assessing and alleviating this distress have been reported so that the literature is quite complex. The purpose of this paper is to provide an overview of the literature on castration and/or tailing distress, where the distress was assessed using acute changes in plasma cortisol concentrations. A method of analysis involving the integrated cortisol response (i.e. the areas under the cortisol curves while the plasma concentration is above pretreatment values) to each treatment and using treatments which were common to different studies as reference points, allowed meaningful comparison within and between studies. A 6-point ranking scale emerged, where rank 1 represented the least distress and rank 6 the most distress.

Comparison of acute distress responses: This analysis revealed the following major points. Surgical methods of castration and/or tailing cause the greatest cortisol responses (rank 5 or 6). Most ring and ring plus clamp methods of castration plus tailing or castration, used without a local anaesthetic or systemic analgesic, cause rank 4 responses. One form of ring plus clamp castration (i.e. applying the clamp for 10 s across the full width of the scrotum distal to the ring in lambs aged no more than 1 week) reduces the cortisol response to rank 1. When these lambs are also tailed by applying a ring and clamp in a similar manner to the tail, they also exhibit a rank 1 response. Local anaesthetic given 10-20 or 1-2 min or 10-15 s before or immediately after ring only castration and/or tailing can virtually abolish the cortisol response (rank 1), depending on the site(s) of injection. For ring or ring plus clamp castration, the most effective sites (as judged by cortisol responses) are the neck of the scrotum or the testes. Delivery of local anaesthetic to achieve successful nerve blockade can be by needle, high-pressure needleless administration or, for the tail only, by an aerosol spray. Local anaesthetic injected into the scrotal neck, spermatic cords and/or testes has little effect on the overall cortisol response to clamp castration. Reductions in cortisol responses to clamp castration or to ring tailing can occur after administration of non-steroidal anti-inflammatory drugs. Most tailing methods elicit cortisol responses that are several ranks lower than those caused by castration plus tailing or castration alone. Although tailing by most methods elicits rank 1 cortisol responses, the use of local anaesthetic or non-steroidal anti-inflammatory drugs can reduce the response within the rank 1 range.

Recommendation: Farmers should be encouraged to choose the lowest ranked method that is economically and practically feasible for them. Specific methods such as surgical castration should be discouraged.

(New Zealand Veterinary Journal 48, 33-43, 2000)

Introduction

During the last decade the pain-induced distress caused by castration and tailing methods, and the different strategies for its alleviation, have been investigated extensively in lambs (Tables I-III). The methods and circumstances have differed widely between studies, although, in some, subtle but important aspects of methods and circumstances have been explored. Consequently there is a need, first, to compare the pain-induced distress caused by the different methods of castration and/or tailing, second, to evaluate the efficacy of different ways of alleviating that distress and, third, to consider what practical advice can now be given to minimise animal welfare concerns.

Pain-induced distress and its assessment

It is necessary to clarify the meaning of the term "pain-induced distress" and how it can be assessed (see Mellor and Stafford, 1999a; Mellor *et al.*, 2000). The response to unpleasant experiences may be largely emotional (e.g. fear), largely physical (e.g. vigorous movement), or both (e.g. pain). The level of distress is assessed by variables used to measure physiological stress and may be described as "minor", "moderate", "marked" and "extreme". Although changes in these variables are objective measurements, any conclusions about the subjective experiences that cause those changes remain judgements and not statements of fact. That is because without sharing a common language an animal cannot tell us how painful or pleasant a particular experience is.

Two physiological systems are used to assess distress. These are the sympathetic adrenomedullary system which is primarily concerned with fast-acting "fight-flight" responses involving adrenaline, noradrenaline and heart rate, and the hypothalamic-pituitary-adrenocortical (HPA) system which initiates longer lasting metabolic and anti-inflammatory responses that can promote healing. Indices of HPA activity include plasma concentrations of cortisol, adrenocorticotropic hormone (ACTH) and corticotropin releasing factor (CRF). These hormones are useful indices because HPA activity generally increases in a graded way in response to the presumed noxiousness of different experiences. They do not measure pain, but provide an indication of how unpleasant the experience is emotionally and physically. The response time of the HPA axis makes it an insensitive index of the distress elic-

* Animal Welfare Science and Bioethics Centre, Institute of Food, Nutrition and Human Health, Massey University, Palmerston North, New Zealand.
† Animal Welfare Science and Bioethics Centre, Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand.
§ Author for correspondence

ited in the first few minutes after an insult. Changes in the sympathetic-adrenomedullary system may be more useful during this stage.

Behaviour is also a valuable index of distress because pain-related behaviours can be good indices of the duration and the different phases of an experience. However, behavioural changes are often poorly correlated with the maximum intensity of the noxious experience as indicated by physiological variables (Mellor *et al.*, 2000).

To date most assessments of castration and/or tailing distress in lambs have been conducted using behaviour and plasma cortisol concentrations. The comparative analysis provided here is based on the acute cortisol response. The strengths and weaknesses of this approach have been explored in detail elsewhere (Stafford and Mellor, 1993; Mellor and Stafford, 1997; Mellor *et al.*, 2000).

Castration and tailing methods

Castration and tailing methods used in lambs and calves are summarised in Table I.

In *surgical castration* the distal one third of the scrotum is cut off or incisions are made in each side of the scrotum, to expose the testes. They are then removed by drawing them out without cutting the spermatic cords, or after scraping and cutting, clamping or cauterising the spermatic cords. The anatomy of the scrotum and testes is shown in Figure 1.

In *clamp castration* the spermatic cords are crushed through the scrotum. The usual method is to apply the clamp to each cord once or twice while ensuring that medial scrotal tissues are uncrushed. Crushing the cords' blood vessels prevents blood flow to the testes which atrophy during the following 4 to 6 weeks.

Ring castration is done by applying a constrictive rubber ring to the neck of the scrotum with both testes distal to the ring. The ring obstructs blood flow through the testes and distal scrotal tissue, which atrophy and drop off after 4 to 6 weeks. Both "normal tension" and "tight rings" have been used.

In the *short scrotum* method a rubber ring is placed on the scrotum distal to the testes so that they are held against the abdominal wall (Probert and Davies, 1986). The distal scrotal tissue atrophies and drops off after 4 to 6 weeks.

Ring plus clamp castration involves placing a ring on the scrotal neck, proximal to the testes, immediately before or after applying a castration clamp once to each spermatic cord leaving some scrotal tissue intact, or after applying it once across the full width of the scrotum. Clamping durations of 1, 5, 6 or 10 s have been used.

Chemical castration is done by injecting corrosive agents into the testes causing necrosis or sufficient impairment of testicular tissue to cause infertility. The agents used include α-hydroxypropionic acid, lactic acid and formaldehyde in ethanol (Mercy *et al.*, 1985; Fordyce *et al.*, 1989; Cohen *et al.*, 1990).

Surgical tailing is done by cutting the tail off with a sharp knife.

Surgery plus clamp tailing involves cutting the tail off after applying a castration clamp to the tail. The tail stump

Table I: Castration and tailing methods used in lambs and calves. References refer to different combinations of castration and tailing methods, or castration or tailing done separately by different methods.

Castration

Surgery
- Spermatic cords torn.[8] [9] [10] [22]
- Spermatic cords clamped and cut, with or without cautery.[5] [16] [17] [27]

Clamp (each spermatic cord).[1] [3] [17] [18]

Ring (ring proximal to testes)
- Normal ring.[1] [3] [5] [6] [9] [10] [12] [13] [14] [16] [17] [22] [25] [27] [28]
- Tight ring.[6]

Ring + clamp
- Each spermatic cord clamped.[1] [2] [3]
- Full-width of scrotum clamped.[1] [3] [5] [6] [16] [17] [18] [26] [27]

Short scrotum (ring distal to testes).[1] [3] [9] [10] [19]

Chemical [15]

Tailing

Surgery [9] [10] [20] [22]

Surgery + clamp [11] [21]

Surgery + clamp + cautery [5] [16]

Docking iron (severed by cautery) [4] [9] [10] [11] [23] [24]

Ring [4] [7] [9] [10] [11] [12] [13] [14] [20] [21] [22] [23] [24]

Ring + clamp [2] [4] [7] [11]

(1) Dinniss *et al.*, (1997a), (2) Dinniss *et al.*, (1997b), (3) Dinniss *et al.*, (1999), (4) Graham *et al.*, (1997), (5) Kent *et al.*, (1993), (6) Kent *et al.*, (1995), (7) Kent *et al.*, (1998), (8) Lester *et al.*, (1991a), (9) Lester *et al.*, (1991b), (10) Lester *et al.*, (1996), (11) Mazzaferro *et al.*, (1993), (12) Mellor & Murray (1989a), (13) Mellor & Murray (1989b), (14) Mellor *et al.*, (1991), (15) Mercy *et al.*, (1985), (16) Molony *et al.*, (1993), (17) Molony *et al.*, (1995), (18) Molony *et al.*, (1997), (19) Molony & Kent (1997), (20) Morris *et al.*, (1994), (21) Rhodes *et al.*, (1995), (22) Shutt *et al.*, (1988), (23) Stillwell *et al.*, (1994), (24) St. Louis *et al.*, (1994), (25) Sutherland *et al.*, (1999), (26) Sutherland *et al.*, (2000), (27) Thornton & Waterman-Pearson (1999), (28) Wood *et al.*, (1991).

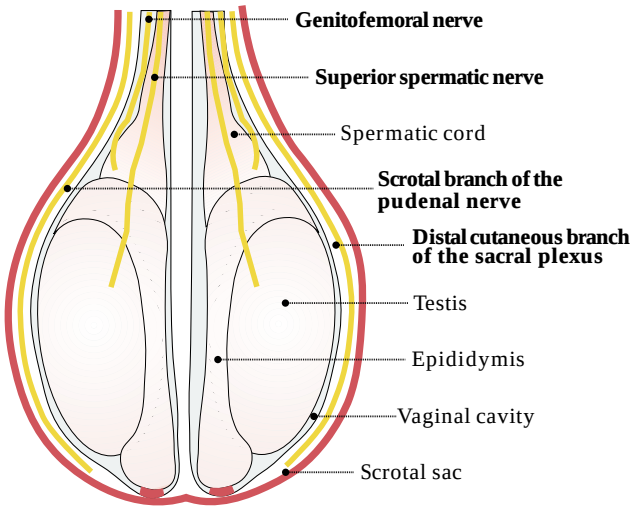

Figure 1: Anatomy of the scrotum and testes of lambs.

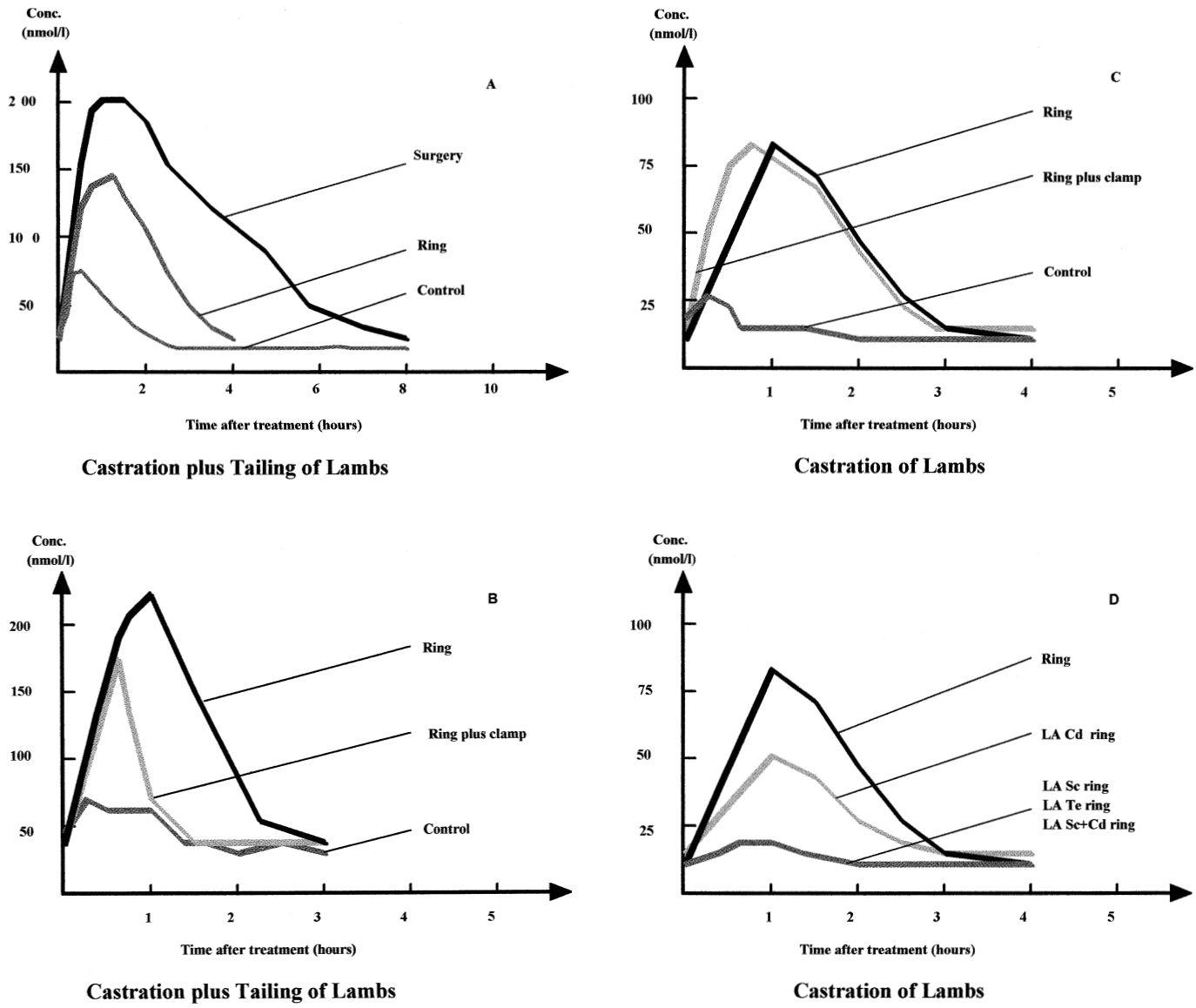

Figure 2: Examples of acute changes in the plasma cortisol concentrations: A, after surgical or ring castration plus tailing and during control handling of lambs aged 4-6 weeks (redrawn from Lester *et al.*, 1991a,b; reproduced with permission of In Practice); B, after castration plus tailing of 1-week-old 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)

may be cauterised after amputation.

Tailing with a docking iron involves severing the tail by cautery using a heated chiselled metal device designed for the purpose. An alternative less common method is to cut the tail off with a knife and immediately cauterise the tail stump with a heated iron.

Ring tailing is done by applying a rubber ring to the tail to prevent blood flow through the distal tissues which atrophy and drop off after 4 to 6 weeks.

Ring plus clamp tailing involves placing a ring on the tail and then clamping it with a castration clamp distal to the ring.

Strategies for alleviating acute castration and tailing distress

Castration and tailing methods which cause immediate and severe tissue damage (surgery, clamp, docking iron) elicit a barrage of nerve impulses in pain pathways when the injury is inflicted and for a period thereafter, as indicated by maximal rates of rise in plasma cortisol concentrations (Figure 2). This initial barrage is usually followed by "inflammatory pain" (Ren and Dubner, 1999). With other methods (ring, corrosive chemical) an initial nerve

impulse barrage is followed by further tissue damage and presumably impulse traffic which may take 30 minutes or longer to cause maximum effects, as indicated by submaximal rates of increase in plasma cortisol concentrations (Figure 2). When the method used (e.g. surgery) does not obstruct impulse transmission from the area of damage, the inflammatory pain would be expected to increase over a period of hours and then decline until the pain-producing features of inflammation resolve. On the other hand, when the method used progressively impedes pain impulse transmission, as occurs within about 1.5 hours of applying rubber rings for castration (Cottrell and Molony, 1995), transmission of inflammatory nerve impulses is known to end earlier.

Physical alleviation

Physical methods that obstruct transmission in pain nerve pathways or prevent blood flow and thus disable pain receptors, have the potential to reduce castration and/or tailing distress. Thus, when a castration clamp damages the nerves in crushed tissues it interrupts nerve transmission from tissues distal to each crush line. When each cord is clamped separately and the impulse barrage that accompanies clamp application has subsided, pain impulses from the testes and parts of the scrotum stop, but impulses in nerves in the uncrushed medial parts of the scrotum may continue. The full width crush approach, applied to the scrotum during ring plus clamp castration, obstructs impulse transmission from both testes and all scrotal tissue distal to the crush. This approach can reduce the ischaemic pain which occurs with ring-only castration of young lambs. Ring-only castration causes ischaemia which produces pain-induced distress, but the distress is subsequently limited by the hypoxia/anoxia which disables the pain receptors in the tissues distal to the ring. The same principles would apply to ring plus clamp and ring-only tailing methods. Severing the tail by cautery using a docking iron can also limit pain input from the tail stump possibly by destroying pain receptors in the burnt tissues (Lester *et al.*, 1991b).

Pharmacological alleviation

General anaesthesia renders an animal unconscious but is impractical for use with large numbers of farm animals (Table II). Local anaesthetic injections block impulse transmission in the treated nerves for the duration of action of the anaesthetic, which is usually about 2 hours for lignocaine (Dinniss *et al.*, 1997a) and 3 hours or more for bupivacaine (Molony *et al.*, 1997). The duration of action is extended when rings obstruct blood flow and prevent clearance of the anaesthetic from tissues distal to the rings. Injection sites for castration include the neck and/or body of the scrotum, both spermatic cords or both testes, and for tailing the epidural space or subcutaneously around the tail (Table II). Injections can be made by needle, by a high-pressure needleless technique, or the local anaesthetic can be sprayed on externally (Table II). Local anaesthetic may be delivered 10-20 min before treatment, or more practically 1-2 min or 15-20 s before or 15-20 s after treatment (Table III).

The analgesic non-steroidal anti-inflammatory drugs (NSAIDs), given intramuscularly or intravenously (Molony *et al.*, 1997; McMeekan *et al.*, 1998), have two advantages over local anaesthetics: their systemic distribution allows actions on damaged tissues which are not accessible to nerve blockade and their duration of action

Table II: Pharmacological pain relieving strategies used for castration and tailing. References refer to castration and tailing together or separately (see Table I footnote for number code).

Castration

General anaesthetic
Halothane + oxygen.[27]

Local anaesthetic injection
Into neck of scrotum.[1] [3] [7] [19] [25]
Into both spermatic cords.[1] [3] [7]
Into both testes.[1] [3] [7] [19] [25]
Into scrotal neck + spermatic cords.[1] [3]
Into spermatic cords + scrotal neck + testes.[27] [28]

Non-steroidal anti-inflammatory drug
I.m. for systemic distribution.[18]

Tailing

Local anaesthetic injection
Into the epidural space.[4] [20] [28]
Subcutaneously around the tail.[4] [20]

Local anaesthetic spray
Applied externally onto the skin around the tail.[4]

Non-steroidal anti-inflammatory drug
I.m. for systemic distribution.[4]

Table III: Methods and timing of local anaesthetic administration for castration and tailing. References refer to castration and tailing together or separately (see Table I footnote for number code).

Castration

Local anaesthetic injected by needle
10-20 min before treatment.[1] [3] [25] [28]
1-2 min before treatment.[18]
5-15 s before treatment.[25]
5-15 s after treatment.[7] [25]

Local anaesthetic given with a high pressure needleless device
5-15 s before treatment.[7]
5-15 s after treatment.[7]

Tailing

Local anaesthetic injected by needle
10-20 min before treatment.[28]
1-2 min before treatment.[4]
5-15 s after treatment.[7]

Local anaesthetic given with a high pressure needleless device
5-15 s before treatment.[7]
5-15 s after treatment.[7]

Local anaesthetic spray
Applied externally onto the skin around the tail 5-15 s before treatment.[4]

is longer than for most local anaesthetics. However, NSAIDs do not significantly affect the pain impulse barrages associated with the initial tissue injury.

Chronic consequences of castration/tailing

The long-term consequences of castration and/or tailing, which may include chronic pain, hyperalgesia, phantom pain and neuropathic pain (Wood and Molony, 1992), have not been well researched.

Chronic pain is likely to be of low intensity with tailing because plasma cortisol concentrations remain low or at control levels for at least 4 days afterwards (Stillwell *et al.*, 1994; Rhodes *et al.*, 1995). However, changes in cortisol concentrations may not be a sensitive index of low-grade pain, and behaviour might be better (Molony *et al.*, 1995; Sutherland *et al.*, 2000). If chronic pain occurs, it may arise from slow resolution of inflammation in the damaged tissues, or from pathophysiological changes in pain thresholds or pain receptor input from healed tissues as occurs with hyperalgesia and phantom pain. The incidences of hyperalgesia and phantom pain are unknown in livestock but are well known in people (Bach *et al.*, 1988; McQuay *et al.*, 1988; Wall, 1988; Katz *et al.*, 1992). Neuromas on cut nerves are a source of continuing impulse traffic in pain pathways and may also be foci of persistent pain (Blumberg and Janig, 1982; French and Morgan, 1992).

The long-term effects of castration and/or tailing on production are usually insignificant, except for some reduction in growth rate in castrates (Wohlt *et al.*, 1982) due to the absence of testosterone (Probert and Davies, 1986). The incidence of post-treatment systemic infections is usually low, but local lesions, often accompanied by pus formation, are common for up to 6-8 weeks especially with ring methods (Molony *et al.*, 1995; Sutherland *et al.*, 2000).

Ranking acute cortisol responses to castration/tailing

A system of analysis has been developed which allows meaningful comparisons of the cortisol responses of lambs in a range of studies where the breed and age and the precise features of the cortisol assay methods differed. The analysis could only be applied when plasma cortisol concentrations were measured at sufficient frequency to define the cortisol response adequately.

The integrated cortisol responses to all treatments were used to rank their relative noxiousness. The integrated cortisol response is the area between the plasma cortisol concentration-time curve and a horizontal line drawn through the pretreatment value while the concentrations are above that value (Mellor and Murray, 1989b; Lester *et. al.*, 1991b). Most reports present the transient increases in plasma cortisol concentrations that followed castration and/or tailing graphically (Figure 2), and sometimes they also quote the associated integrated cortisol responses. For those studies where the integrated responses were not reported, the responses were calculated from the cortisol concentration-time graph.

The integrated response for castration plus tailing with rings was taken as the reference point because it was common to most studies. It was assigned a value of 100%. Several other treatments, including ring castration at 1 or 4-6 weeks of age and ring plus clamp castration and tailing at 3 or 6 weeks, also elicited 100% cortisol responses, which allowed them to be used instead of ring castration plus tailing for reference purposes when required. The relative values of all the integrated cortisol responses in each study were then calculated as the ratio of the response for each treatment against the response for the reference group, expressed as a percentage.

Treatments that caused similar responses were assigned the same rank and those causing different responses were assigned different ranks. The existence of similarities and differences was determined by reference to the significance of between-treatment differences in the plasma cortisol concentrations or the integrated responses, or both, reported in the source papers. The ranks were identified as: rank 1 = 1-30%, rank 2 = 30-55%, rank 3 = 70-85%, rank 4 = 75-125% (includes the 100% reference groups), rank 5 = 165-170%, and rank 6 = 190-205%. By definition, therefore, the most benign treatments are in the low ranks and the most noxious are in the high ranks.

The percentages assigned to ranks 3 and 4 overlapped because within-group variability differed between studies. In some studies the differences between the cortisol responses to several treatments were not significant, whereas in other studies similar differences between the responses to other treatments did differ significantly. Rank 1 contains some cortisol responses that were significantly different, but they were assigned the same rank because they were all low.

Evaluation of methods for castration plus tailing

Surgical castration plus tailing elicits the largest cortisol response and is therefore the most noxious method (rank 6, Table IV; Figure 2A). Two approaches have been used. The spermatic cords have been broken by tearing and the tail simply cut off, or the cords and tail have been clamped and cut with or without cautery (Table I). Unfortunately the assessment of the latter treatment ended before the acute cortisol response was complete (Kent *et al.*, 1993), so the two approaches could not be compared here. Nevertheless, both surgical approaches cause significantly larger cortisol responses than does ring castration plus tailing (Table IV).

Although ring castration plus tailing elicits an acute cortisol response which is approximately half that caused by surgery (Table IV; Figure 2A), the response is still substantial (rank 4). Likewise, short scrotum plus ring tailing, and castration with a ring plus tailing with a docking iron, also elicit rank 4 responses (Table IV). Therefore, less noxious alternatives have been sought. A small reduction in the response is achieved by using tighter than normal rubber rings (rank 3). However, the most benign castration and tailing method (rank 1) produces an acute cortisol response equivalent to that seen in control lambs which are familiar with handling. It involves injecting local anaesthetic into the scrotal neck, both spermatic cords, both testes and the epidural space 15-20 min before ring castration and tailing (Table IV). Despite its effectiveness in virtually abolishing the cortisol response this method is impractical for general farm use. A more practical alternative of injecting local anaesthetic into the scro-

tal neck 15-20 s before applying rings to the scrotum and tail, is not as effective but does reduce the cortisol response to rank 2. In contrast, injecting local anaesthetic into both testes 10-15 s after ring application to the scrotum and tail confers no significant benefit (rank 4).

The combined ring plus clamp method of castration plus tailing is among the least noxious (rank 1), but only in 1-week-old lambs and when the castration clamp is applied for 10 s across the full width of the scrotum and tail distal to the rings (Table IV; Figure 2B). Applying a clamp in a similar manner for 6 s after ring placement effects a smaller reduction in the cortisol response at 1 week of age (rank 3), and has little or no effect at 3 or 6 weeks (rank 4). Other variants of the ring plus clamp method confer no significant benefit between 3 and 8 weeks.

Using a castration clamp for castration plus tailing (10 s on each spermatic cord and 3 s on the tail) in 1-week-old lambs elicits a rank 4 cortisol response, like ring castration plus tailing (Table IV).

Evaluation of castration methods

Of all the castration methods assessed, surgical castration at 4-5 weeks of age elicits the largest cortisol response (rank 6; Table V). Clamp castration (10 s on each spermatic cord) causes a rank 5 response at 4-8 weeks and a rank 4 response at 3 weeks of age (Table V). The difference between these responses, which were quantified in separate studies (Dinniss *et al.*, 1997a; Molony *et al.*, 1997), could be due to the effects of postnatal age, breed of sheep or to the use of different clamps or clamping techniques.

Ring castration elicits rank 4 cortisol responses in lambs aged between 1 and 8 weeks (Table V). Short scrotum creation reduces the cortisol response to rank 3 (Table V). However, no significant reduction in the response occurs when ring castration is combined with full width scrotal clamping for 10 s at 3 weeks (Table V), or with clamping each spermatic cord separately for 1, 5 or 10 s at 4-8 weeks of age (Table V; Figure 2C).

Injecting local anaesthetic into both spermatic cords or into the scrotal neck 15-20 or 1-2 min before clamp castration (10 s each cord) does not reduce the cortisol response below rank 4, nor does injecting it into both testes 1-2 min before ring plus clamp castration (10 s full width) (Table V).

Some local anaesthetic strategies can markedly reduce the cortisol responses to several castration meth-

Table IV: 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.

Rank - (Cortisol Response[1])	Castration plus tailing method
6 (190-205%)	CT surgery (cords torn), 4-6 weeks[2]
5 (165-170%)	None
4 (75-125%)	CT ring, 1-8 weeks *(standard response: 100%)*[1]
	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 (6 s full width) T ring, 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
3 (70-85%)	CT tight ring, 1 week
	C ring + clamp (6 s full width) T ring + clamp (6 s), 1 week
2 (30-55%)	LA Sc (10-15 s before) CT ring, 6 weeks
	Control handling, 4-8 weeks
1 (1-30%)	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 s before/after), 3-6 weeks

[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.

ods that elicit rank 4 responses (Table V; Figure 2D). Thus, ring castration elicits rank 1 cortisol responses when local anaesthetic is administered as follows: by needle into the scrotal neck plus spermatic cords, into the scrotal neck or into the testes 15-20 min before treatment; by a needleless high-pressure device into the testes 5-10 s before ring application; or by needle into the scrotal neck 5-10 s after ring application. Likewise, injecting local anaesthetic into the scrotal neck 15-20 min before ring plus clamp castration (10 s each cord) reduces the cortisol response to rank 1 (Table V). These delivery methods usually place local anaesthetic into the vaginal cavity of the scrotum (Figure 1). The scrotal neck injections achieve that directly, the testicular injections by leakage after needle withdrawal (Dinniss *et al.*, 1997a), and the high-pressure needleless administration during transit of the anaesthetic bolus from the wall of the scrotum to the testes. Local anaesthetic placed in the vaginal cavity at least partially anaesthetises the scrotum and the testes. The cortisol responses suggest that these delivery methods achieve complete or almost complete anaesthesia from about 10 minutes after castration. However, some distress may occur earlier, when the local anaesthetic has had little time to act, but that would not be detected by the cortisol response because of the slower response time of the hypothalamic-pituitary-adrenocortical axis compared to the sympathetic adrenomedullary system.

Some other local anaesthetic strategies are less effective but do confer some benefit. These include injecting local

Table V: 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.

Rank - (Cortisol Response[1])	Castration method
6 (190-205%)	Surgery (cords torn), 4-5 weeks[2]
5 (165-170%)	Clamp (10 s each cord), 4-8 weeks
4 (75-125%)	Ring, 1-8 weeks *(standard response: 100%)*[1]
	Ring + clamp (10 s each cord), 4-8 weeks
	Ring + clamp (5 s each cord), 4-8 weeks
	Ring + clamp (1 s each cord), 4-8 weeks
	Ring + clamp (10 s full width), 3 weeks
	Clamp (10 s each cord), 3 weeks
	LA Sc (15-20 min before) clamp (10 s each cord), 4-8 weeks
	LA Cd (15-20 min before) clamp (10 s each cord), 4-8 weeks
	LA Te (1-2 min before) clamp (10 s each cord), 3 weeks
	LA Te (1-2 min before) ring + clamp (10 s full width), 3 weeks
3 (70-85%)	Short scrotum ring, 4-8 weeks
	Clamp (1 s each cord), 4-8 weeks
	LA Cd (15-20 min before) ring, 4-8 weeks
	LA Cd (15-20 min before) ring + clamp (10 s each cord), 4-8 weeks
2 (30-55%)	LA Ne-Sc (5-10 s after) ring, 1 week
	NSAID (20 min before) clamp (10 s each cord), 3 weeks
	Control handling, 4-8 weeks
1 (1-30%)	Ring + clamp (10 s full width), 1 week
	LA Cd Sc (15-20 min before) ring, 4-8 weeks
	LA Sc (15-20 min before) ring, 4-8 weeks
	LA Te (15-20 min before) ring, 4-8 weeks
	LA Sc (15-20 min before) ring + clamp (10 s each cord), 4-8 weeks
	LA Ne-Te[3] (5-10 s before) ring, 1 week
	LA Sc (5-10 s after) ring, 1 week
	LA Sc (5-10 s after) ring + clamp (10 s full width), 1 week
	Control handling, first week
	LA control (15-20 min before), 1-8 weeks
	LA control (10-15 s before/after), 3-6 weeks

[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*., 1991b).

[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.

anaesthetic into the spermatic cords 15-20 min before ring castration, or ring plus clamp castration (10 s each cord), which reduces the cortisol response to rank 3 in both cases (Table V). Likewise, high-pressure needleless administration of local anaesthetic into the scrotal neck (affecting nerves in the scrotum, vaginal cavity and spermatic cords) 5-10 s after ring castration, reduces the usual rank 4 response to rank 2 (Table V).

Ring plus clamp castration (10 s full width) of 1-week-old lambs elicits a rank 1 response, a marked improvement on the response to ring only castration (rank 4). With this same method, injecting local anaesthetic into the scrotal neck 5-10 s after ring placement and clamping further reduces the response within rank 1 (Table V).

Finally, cortisol responses to clamp castration can be reduced. At 4-8 weeks of age, applying the clamp to each spermatic cord for 1 s as opposed to 10 s reduces the cortisol response from rank 5 to rank 3, and at 3 weeks, injecting the NSAID, diclofenac intramuscularly, 20 min before clamp castration (10 s each cord) reduces the response from rank 4 to rank 2 (Table V).

Evaluation of tailing methods

Surgical tailing causes the largest cortisol response (rank 5), but the responses to all other tailing methods are ranked 1 or 2 (Table VI). In order to interpret the responses of lambs to the non-surgical methods, it is first necessary to note that responses to control handling at 4-8 weeks of age (rank 2) are usually greater than those elicited during the first week (rank 1). This is probably due to older paddock-reared lambs being far less used to handling than are younger lambs born and reared indoors (Mellor and Murray, 1989a; Lester *et al.*, 1991b). Like control handling, tailing with a ring or a docking iron elicits rank 2 responses at 4-5 weeks of age, but this does not mean that tailing by these methods is pain free. It is more likely to be simply fortuitous that the pain-induced distress caused by these tailing methods and the predominantly emotional distress of unfamiliar control handling elicit similar cortisol responses at this age (Lester *et al.*, 1991b). In younger lambs tailing with rings causes greater cortisol responses than does familiar control handling (Mellor and Murray, 1989a; Graham *et al.*, 1997; Kent *et al.*, 1998), but both are in rank 1 (Table VI). Moreover, various modifications to the ring tailing method at 1 or 3 weeks of age can reduce the cortisol responses even within rank 1 (Table VI). Thus, injecting diclofenac intramuscularly 20 min before ring application, or injecting local anaesthetic into the epidural space or subcutaneously around the tail 1-2 min before or spraying it onto the tail 5-15 s before ring application, or injecting it by needle or by the high-pressure needleless approach 5-10 s after ring application, all elicit lower cortisol responses than does ring tailing alone (Graham *et al.*, 1997; Kent *et al.*, 1998). In addition, lower responses are also elicited by the docking iron and the ring plus clamp (10 s) methods of tailing (Mazzaferro *et al.*, 1993; Stillwell *et al.*, 1994;

Table VI: 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.

Rank - (Cortisol Response[1])	Tailing method
5 (165-170%)	Surgery, 4-5 weeks[2]
2 (30-55%)	Ring, 4-5 weeks
	Iron, 4-5 weeks
	Control handling, 4-8 weeks
1 (1-30%)	Ring, 3 weeks
	Ring, first week
	Iron, 3 weeks
	Ring + clamp (10 s), 3 weeks
	Ring + clamp (10 s), 1 week
	NSAID (20 min before) ring, 3 weeks
	LA Ta (1-2 min before) ring, 3 weeks
	LA Epi (1-2 min before) ring, 3 weeks
	LA Spray (5-15 s before) ring, 3 weeks
	LA Ta (5-10 s after) ring, 1 week
	LA Ne-Ta (5-10 s after) ring, 1 week
	LA Ne-Ta (5-10 s after) ring + clamp (10 s), 1 week
	Control handling, first week
	LA control (15-20 min before), 1-8 weeks
	LA control (10-15 s before/after), 3-6 weeks

[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.*, 1991b).

Epi = epidural; LA= local anaesthetic; Ne = needleless injection; NSAID = non-steroidal anti-inflammatory drug; Spray = externally applied; Ta = subcutaneously into the tail.

Kent *et al.*, 1998), but high-pressure needleless administration of local anaesthetic into the tail 5-10 s after ring plus clamp (10 s) tailing does not further reduce the response (Kent *et al.*, 1998).

Once cortisol concentrations return to control values at 2-3 hours after ring tailing, they apparently remain there until at least 24 hours after treatment (Rhodes *et al.*, 1994, 1995), and for a further 3 days (Stillwell *et al.*, 1994).

Evaluation of particular features of some methods

Tightness of rings

Rings that are tighter than the normal rings might disable nerve impulse transmission from the distal tissues earlier, thereby accounting for the reduction in the cortisol response to ring castration plus tailing from rank 4 to rank 3 when tight rings are used (Kent *et al.*, 1995). As the duration of response is reduced, but not the magnitude, the question of whether the duration or the magnitude of the response is more important from the animal's perspective becomes pertinent.

Clamping with rings

The most effective way to minimise the distress caused to 1 week old lambs by ring castration plus tailing without local anaesthetic, is to use the combined ring plus clamp (full width) method on the scrotum and tail, with the clamp applied for 10 s. In older lambs this approach is not as effective. The age limit for its effective use, the cost of the clamp, the skill required to use it, and the flinching of the lambs each time the clamp is applied, may be impediments to acceptance of this method by farmers.

Use of local anaesthetic

Ring methods

The efficacy of local anaesthetic in reducing the cortisol distress responses to ring castration plus tailing or ring castration depends on the timing, the sites and the mode of injection (Tables IV, V and VI).

Although it may be desirable to wait 10-20 min between injection and ring application to maximise efficacy, major reductions in the cortisol distress responses can be achieved with intervals of 1-2 min, and even as short as 10-15 s. Moreover, injecting lambs immediately after ring application can also be very effective.

It is not necessary to inject all major sites (scrotal neck, testes and spermatic cords) to achieve effective local anaesthesia for castration. The most effective injection sites are apparently the neck of the scrotum or both testes. It is important for the anaesthetic to be deposited in the vaginal cavity of the scrotum. Injection of local anaesthetic into the spermatic cords only is less effective than injections into the other sites.

Injecting the tail subcutaneously at the site of ring application requires less skill than epidural injections and both are effective in reducing the cortisol distress response to ring tailing.

High-pressure needleless administration is apparently as effective as conventional needle delivery of local anaesthetic in reducing the cortisol distress response to ring castration and to ring only or ring plus clamp tailing. However, the cost of the high-pressure equipment and the skill required to use it are disadvantages. For tailing, spraying the local anaesthetic together with an evaporative coolant onto the tail where the ring is to be applied is also effective, but the need to shear the area first is an impediment.

Clamping

Local anaesthetic is much less effective in reducing the cortisol response to clamp than to ring castration (Dinniss *et al.*, 1997a; Molony *et al.*, 1997).

Non-steroidal anti-inflammatory drugs (NSAIDs)

Prior intramuscular injection of an NSAID reduces the cortisol response to clamp castration (10 s each cord) and to ring tailing (Molony *et al.*, 1997; Graham *et al.*, 1997). Although some NSAIDs have central analgesic effects (McCormack and Brune, 1991; Dart, 1992; Urquhart, 1993), their main action is on inflammation-related pain, so that little or no alleviation of the pain caused by clamping itself and possibly by ring application can be expected. The cortisol response appears to reflect this. It is not known whether or not the 20 min interval between injection and treatment is necessary for maximum beneficial effects, but if it is, this delay would constitute a significant practical impediment to use of NSAIDs, as would their cost.

NSAID use with surgical castration should be investigated as it may deal more effectively with areas of tissue damage that are inaccessible to uncomplicated nerve blockade techniques. The benefits of using an NSAID together with local anaesthesia would also be worth exploring. Such approaches could reduce castration distress when it is necessary to use surgical as opposed to other methods to castrate animals.

Use of distress ranking to improve animal welfare

Having ranked the available methods, the next issue to be addressed is how that information should be used to improve animal welfare. As noted elsewhere (Mellor and Stafford, 1999b), two approaches suggest themselves – the "gold standard" approach and the "incremental improvement" approach. The "gold standard" is not to castrate or tail any animal. However, when it is necessary the next best "gold standard" is to select rank 1 procedures and ban all others. Alternatively, adopting "incremental improvement", we can draw attention to the ranking of the different procedures and recommend the use of the lowest ranked procedure that is practically feasible in each particular circumstance. Also consistent with "incremental improvement" is very strongly discouraging the most noxious procedures, provided that more benign and practical alternatives are readily available.

Imposing bans based on a "gold standard" has three main disadvantages. First, further study of acute distress responses may reveal a need to revise the ranking, thereby calling into question the wisdom of the original ban and reducing the credibility of subsequent bans. It is common in science to revise initial interpretations as further work is completed. The area of distress assessment is no exception, as an account of the chronological development of ideas about castration and tailing distress would reveal. Moreover, little is known about chronic pain (Thornton and Waterman-Pearson, 1999) and, if it occurs, about what association it has with wound healing

after castration and/or tailing by different methods (Molony *et al.*, 1995; Sutherland *et al.*, 2000). Second, an inflexible ban may alienate those who want to make improvements but cannot meet the new higher standard. Third, a ban becomes discredited if it is ignored and cannot be enforced.

The alternative "incremental improvement" approach is preferred because it is likely to recruit more farmers into making some welfare improvement. For those who cannot meet the highest standard immediately, their small changes for the better are recognised as a good start, they feel positive about them, and that makes them more open to make other improvements in the future as their own circumstances change and as consumers demand higher welfare standards. The emphasis is on farmers making the greatest improvement that is economically and practically feasible for them in their particular circumstances.

In light of this, the present analysis does give several direct pointers on how castration and/or tailing of lambs should be carried out. It is usually not practical for farmers in New Zealand to castrate and tail lambs under 1 week of age and encouraging early castration and tailing may interfere with ewe-lamb bonding. Moreover, castration is rarely carried out on male lambs without tailing. Therefore recommendations for New Zealand need to be directed towards older lambs and towards castration plus tailing or tailing alone.

Wherever lamb management permits, castration should be avoided. Castration plus tailing by surgery (knife) or clamp should be phased out as should tailing by surgery. Of the alternative castration methods, short-scrotum should be preferred to the ring method if management permits. The widespread use of local anaesthesia or systemic analgesia is not likely to be acceptable in the near future, but the use of local anaesthetic given into the scrotal neck followed by ring castration plus tailing, which significantly reduces the cortisol distress response, should be encouraged. Tailing will be necessary for the immediate future. It can be done using a ring or iron as both methods cause a response similar to handling.

Animal welfare organisations and marketing chains are influencing farm management practices and may determine what methods of castration and tailing are acceptable in specific markets. It is important for research to identify practical methods which both satisfy the requirements of the market and meet our ethical responsibility to devise and use approaches which are as welfare-friendly as we can make them.

Acknowledgements

We are grateful to MAF Policy for providing financial support for our castration and tailing studies, to Dr A.C.D. Bayvel for helpful discussion and to Associate Professor Alex Davies and Ms Jean Arnott for preparing Figure 1.

References

Bach S, Noreng MF, Tjellden NU. Phantom limb pain in amputees during the first 12 months following limb amputation, after preoperative lumbar epidural blockade. Pain 33, 297-301, 1988.

Blumberg H, Janig W. Activation of fibres via experimentally produced stump neuromas of skin nerves: ephatic transmission or retrograde sprouting. Experimental Neurology 76, 468-482, 1982.

Cohen RDH, King BD, Thomas LR, Janzen ED. Efficacy and stress of chemical versus surgical castration of cattle. Canadian Journal of Animal Science 70, 1063-1072, 1990.

Cottrell DF, Molony V. Afferent activity in the superior spermatic nerve of lambs - the effects of application of rubber castration rings. Veterinary Research Communications 19, 503-515, 1995.

Dart CM. The basis for the use of steroids/non-steroidal anti-inflammatory drugs (NSAID) for pain control in clinical practice. In: Animal Pain and its Control, Proceedings 226, 351-366. Postgraduate Committee in Veterinary Science, University of Sydney, NSW, Australia, 1992.

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

Dinniss AS, Stafford KJ, Mellor DJ, Bruce RA, Ward RN. Acute cortisol responses of lambs castrated and tailed using rubber rings with or without a castrating clamp. Australian Veterinary Journal *75*, 494-497, 1997b.

Dinniss AS, Stafford KJ, Mellor DJ, Bruce RA, Ward RN. The behaviour pattern of lambs after castration using a rubber ring and/or castrating clamp with or without local anaesthetic. New Zealand Veterinary Journal 47, 198-203, 1999.

Fordyce G, Hodge PB, Beaman NJ, Laing AR, Campero C, Shepherd RK. An evaluation of calf castration by intratesticular injection of a lactic acid solution. Australian Veterinary Journal 66, 272-276, 1989.

French NP, Morgan KL. Neuromata in docked lambs' tails. Research in Veterinary Science 52, 389-390, 1992.

Graham MJ, Kent JE, Molony V. Effects of four analgesic treatments on the behavioural and cortisol responses of 3-week-old lambs to tail docking. The Veterinary Journal 153, 87-97, 1997.

Katz J, Kavanagh BP, Sandler AN, Nierenberg H, Boylan JF, Friedlander M, Shaw BF. Preemptive analgesia: clinical evidence of neuroplasticity contributing to postoperative pain. Anesthesiology 77, 439-446, 1992.

Kent JE, Molony V, Graham MJ. Comparison of methods for the reduction of acute pain produced by rubber ring castration or tail docking of week-old lambs. The Veterinary Journal 155, 39-51, 1998.

Kent JE, Molony V, Robertson IS. Changes in plasma concentrations of cortisol in lambs of three ages in the first three hours after three methods of castration and tail docking. Research in Veterinary Science 55, 246-251, 1993.

Kent JE, Molony V, Robertson IS. Comparison of the Burdizzo and rubber ring methods for castrating and tail docking lambs. Veterinary Record 136, 192-196, 1995.

Lester SJ, Mellor DJ, Holmes RJ, Ward RN, Stafford KJ. Behavioural and cortisol responses of lambs to castration and tailing using different methods. New Zealand Veterinary Journal 44, 45-54, 1996.

Lester SJ, Mellor DJ, Ward RN. Effects of repeated handling on the cortisol responses of young lambs castrated and tailed surgically. New Zealand Veterinary Journal 39, 147-149, 1991a.

Lester SJ, Mellor DJ, Ward RN, Holmes RJ. Cortisol responses of young lambs to castration and tailing using different methods. New Zealand Veterinary Journal 39, 134-138, 1991b.

Mazzaferro EM, Nippo MM, Fleming MW, Gross WA, Rhodes III RA. Physiologic and behavioral changes associated with different methods of tail-docking lambs. Journal of Animal Science 71 (Suppl. 1), 118, 1993.

McCormack K, Brune K. Dissociation between the antinociceptive and anti-inflammatory effects of the non-steroidal anti-inflammatory drugs. Drugs 41, 533-547, 1991.

McMeekan CM, Stafford KJ, Mellor DJ, Bruce RA, Ward RN, Gregory NG. 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, 1998.

McQuay HJ, Carrol D, Moore RA. Postoperative orthopaedic pain - the effect of opiate premedication and local anaesthetic blocks. Pain 33, 291-295, 1988.

Mellor DJ, Cook CJ, Stafford KJ. Quantifying some responses to pain as a stressor. In: Moberg GP and Mench JA. (eds) The Biology of Animal Stress: Assessment and Implications for Welfare. CAB International, Wallingford, Oxon, UK. (in press), 2000.

Mellor DJ, Molony V, Robertson IS. Effects of castration on behaviour and plasma cortisol concentrations in young lambs, kids and calves. Research in Veterinary Science 51, 149-154, 1991.

Mellor DJ, Murray L. Effects of tail docking and castration on behaviour and plasma cortisol concentrations in young lambs. Research in Veterinary Science 46, 387-391, 1989a.

Mellor DJ, Murray L. Changes in the cortisol responses of lambs to tail docking, castration and ACTH injection during the first seven days after birth. Research in Veterinary Science 46, 392-395, 1989b.

Mellor DJ, Stafford KJ. Interpretation of cortisol responses in calf disbudding studies. New Zealand Veterinary Journal 45, 126-127, 1997.

Mellor DJ, Stafford KJ. Assessing and minimising the distress caused by painful husbandry procedures. In Practice 21, 436-446, 1999a.

Mellor DJ, Stafford KJ. A "gold standard" or "incremental improvement" as ethical strategies for enhancing animal welfare. Proceedings of 16th Annual Seminar of the Society of Dairy Cattle Veterinarians of the NZVA, No. 192, pp 153-161. Foundation for Continuing Veterinary Education, Massey University, 1999b.

Mercy AR, Peet RL, Johnson T, Cousins DV, Robertson GM, Batey RG, McKenzie DP. Evaluation of a non-surgical technique for sterilising rams. Australian Veterinary Journal 62, 350-352, 1985.

Molony V, Kent JE. Assessment of acute pain in farm animals using behavioural and physiological measurements. Journal of Animal Science 75, 266-272, 1997.

Molony V, Kent JE, Hosie BD, Graham MJ. Reduction in pain suffered by lambs at castration. The Veterinary Journal 153, 205-213, 1997.

Molony V, Kent JE, Robertson IS. 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, 1993.

Molony V, Kent JE, Robertson IS. Assessment of acute and chronic pain after different methods of castration of calves. Applied Animal Behaviour Science 46, 33-48, 1995.

Morris DG, Kuchel JE, Maddocks S. Stress responses to different tail docking methods. Proceedings of the Australian Society for Animal Production 20, 202-205, 1994.

Probert AD, Davies AS. A study of short scrotum, castrated and entire ram lambs. Proceedings of the New Zealand Society of Animal Production 46, 55-58, 1986.

Ren K, Dubner R. Inflammatory models of pain and hyperalgesia. Institute of Laboratory Animal Research Journal 40,111-118, 1999.

Rhodes III RC, McAndrews K, Nippo MM. Age at tail docking affects physiology and behaviour of lambs. Proceedings of the 29th International Congress of the International Society for Applied Ethology, 3-5 August, Exeter, UK, Universities Federation for Animal Welfare, Herts, UK, pp 217-218, 1995.

Rhodes III RC, Nippo MM, Gross WA. Stress in lambs (*Ovis aries*) during a routine management procedure: evaluation of acute and chronic responses. Comparative Biochemistry and Physiology 107A, 181-185, 1994.

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

Stafford KJ, Mellor DJ. Castration, tail docking and dehorning - What are the constraints? Proceedings of the New Zealand Society of Animal Production 53, 189-195, 1993.

St Louis PA, Stillwell HJ, Nippo MM, Rhodes III RC. Method of tail-docking cause differential behavioral responses in 3- and 7-day old lambs. Journal of Animal Science 72 (Suppl. 1), 208, 1994.

Stillwell HJ, St Louis PA, Nippo MM, Rhodes III RC. Physiological responses associated with tail-docking in 3- and 7-day old lambs. Journal of Animal Science 72 (Suppl. 1), 323, 1994.

Sutherland MA, Mellor DJ, Stafford KJ, Gregory NG, Bruce RA, Ward RN, Todd SE. Reduction in the acute cortisol response of lambs to ring castration plus tailing by injecting lignocaine into the scrotum or testes at the time of ring application. Australian Veterinary Journal 77, 738-741, 1999.

Sutherland MA, Stafford KJ, Mellor DJ, Gregory NG, Bruce RA, Ward RN. Acute cortisol responses and healing of scrotal wounds after rubber ring castration plus tailing with additional scrotal application of a castrating clamp in lambs at 4-5 weeks of age. Australian Veterinary Journal (in press), 2000.

Thornton PD, Waterman-Pearson AE. Quantification of the pain and distress responses to castration in young lambs. Research in Veterinary Science 66, 107-118, 1999.

Urquhart E. Central analgesic activity of non-steroidal anti-inflammatory drugs in animal and human pain models. Seminar in Arthritis and Rheumatism 23, 189-205, 1993.

Wall PD. Editorial: The prevention of postoperative pain. Pain 33, 289-290, 1988.

Wohlt JE, Wright TD, Siroirs VS, Kniffen DM, Lelkes L. Effect of docking on health, blood cells and metabolites and growth of Dorset lambs. Journal of Animal Science 54, 23-28, 1982.

Wood GN, Molony V. Welfare aspects of castration and tail docking of lambs. In Practice 14, 2-7, 1992.

Wood GN, Molony V, Fleetwood-Walker SM, Hodgson JC, Mellor DJ. Effects of local anaesthesia and intravenous naloxone on the changes in behaviour and plasma concentrations of cortisol produced by castration and tail docking with tight rubber rings in young lambs. Research in Veterinary Science 15, 193-199, 1991.

Accepted for publication 8 December 1999.