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DEHORNING OF CALVES – METHODS OF PAIN AND STRESS ALLEVIATION – A REVIEW*

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Abstract

Dehorning of calves is intended to facilitate handling and increase the safety of people and animals. The study aimed to review the methods of calf dehorning and use of pharmacological analgesic, anaesthetic and sedation drugs, as well as their impact on pain perception. Regardless of the age of calves, dehorning is always associated with pain and stress. The changes in behaviour, physiological parameters, changes in heart rate, respiratory rate and increased cortisol secretion are observed during this procedure. The welfare of calves is significantly reduced during dehorning. Many studies point to minimization of the pain perceived by the use of pharmacological agents. Beneficial effects were observed with the combined use of anaesthetics and non-steroidal anti-inflammatory drugs.

Key words: calves, dehorning, stress, cortisol

Large-scale cattle breeding and husbandry are related to the need of a range of technological solutions and procedures facilitating the handling and improvement of human and animal safety. One of zootechnical-veterinary procedures is dehorning. In the EU countries, dehorning is performed in over 80% of the dairy cattle farms (Gottardo et al., 2011). There is a range of reasons for performing dehorning: decreased risk of fights, animal injuries, and increased staff safety. In free-stall barns it is an indispensable procedure, since it decreases unprofitable consequences of dominance. The aim of dehorning is to increase mental and physical comfort of the animals and thus improve work safety (Gottardo et al., 2011).

The horns in natural conditions are used by the animals for the defence and maintenance of the position in the herd. Hornedness is a male secondary sex character. Knierim et al. (2009) claim that horned animals are more aggressive. According to Goonewardene et al. (1999) maintenance of horned animals is unpractical. These

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animals cause more trouble in maintenance due to the risk of injuries of animals and workers, which often negatively affects the performance (Goonewardene et al., 1999; Gottardo et al., 2011). During the transport, the horns may be a reason for damage of edible carcass tissues which considerably reduces meat quality (SANCO, 2009).

In numerous countries, inter alia in the United States, dehorning is performed without an anaesthesia application (Faulkner and Weary, 2000). Stilwell et al. (2010) revealed that only 12.4% of the US dairy cattle breeders use analgesic agents during this procedure. A similar situation is observed in Australia, where local anaesthesia is not applied even up to 6th month of age (Misch et al., 2007). In some European countries, this treatment procedure is not allowed without anaesthesia in calves older than 7 days (Doherty et al., 2007). General standards of calf protection in the area of the European Union are based on Council Directive 91/629/EEC and Council Directive 97/2/EC. However, numerous European countries have not included more detailed legal regulations in their local national law so far.

Dehorning (disbudding) procedure may be performed more easily in young calves compared to older ones. However, as demonstrated in the study of Stafford and Mellor (2005), its performance is related to pain and stress occurrence at any age. In practice, an application of suitable analgesics is recommended, however generally they are not obligatory. Having in mind calf welfare, the dehorning should be performed during the first weeks of life (Goonewardene et al., 1999; Stafford and Mellor, 2005). According to Stilwell et al. (2010) the final date to perform this procedure is an age of eight weeks.

Dehorning methods

Three methods of dehorning used in young calves may be distinguished: surgical, chemical and thermal (Knierim et al., 2009; Stilwell et al., 2009). In some countries, thermal dehorning constitutes 67% of performed procedures (Fulwider et al., 2008). Chemical and surgical methods are used more rarely (Duffield et al., 2010).

The surgical method of calf dehorning is used the most rarely. It may be performed in three-month-old and older calves. This method involves an application of Roberts dehorner. This device is in the form of a steel sharp tube of a diameter of 2.5 cm. Also curved knife and guillotine shears may be used for this purpose. The device is put to head skin so that its edges include horn buds. Rotating movements of the knife cut the skin, and device inclination enables removing the bud. After its retting, the wound should be disinfected and dressed. Wound healing usually lasts about a month. This is a quick but bloody method (Parsons and Jensen, 2006). This method is rarely used due to frequent complications (SANCO, 2009).

Horn buds in young calves are removed the most often using thermal or chemical methods (Faulkner and Weary, 2000). In the case of chemical method, the best effect is obtained between 8 and 14 days of life. The chemical method involves coating of the horn buds with a paste containing caustic substance such as concentrated sulfuric, nitric, salicylic acids and calcium, potassium or sodium hydroxide. This method is less common than thermal dehorning, however, as revealed in the research, it is less painful (Stewart et al., 2009). Also ointments or adhesive plasters soaked with

substances mentioned above are used in this method. It was observed that an activity of alkaline compounds (protein denaturation) is stronger compared to acids (Knierim et al., 2009). Incomplete damage of horn tissue resulting in deformed horns may be observed in older calves.

The thermal method (cauterization) involves the application of metal cauteries for removing horn buds (so called hot iron method), which may be heated using an electric current or gas. Disbudding is carried out when horn buds are 5–10 mm long, easily palpable and a heated disbudding iron can be used alone usually on calves up to around 8 weeks of age (Stafford and Mellor, 2005). This method is quick and does not cause any abundant bleeding when performed properly. Cauterization is performed at a temperature of about 600ºC, for 15 to 60 seconds (Stilwell et al., 2012). The time for the procedure is prolonged when the dehorning device is not heated enough. High temperature causes the damage of skin tissues and horn buds. It concurrently causes cauterization of blood vessels and prevents bleeding (Faulkner and Weary, 2000; Knierim et al., 2009; Stafford and Mellor, 2011). Sporadically, wound healing after dehorning may last for a long time leading to a decrease in production indices.

Dehorning as stress causing factor

Farm animals are indispensably accompanied by stress. The methodologies used to measure stress include direct observations of the behaviours and an assessment of physiological reactions such as heart rate variability, blood pressure or the changes in stress hormones concentration (Ayala et al., 2012). Irrespective of the method, the procedure of dehorning is painful and stressful. Anxiety and muscle trembling are observed after dehorning; the animals shake their heads, try to hang their heads about pen equipment, they often behave in apathetic manner, lie with their heads at side and do not react to other individuals from the group (Stilwell et al., 2012).

Table 1. Description of calf behaviour during dehorning procedure (Graf and Senn, 1999)

Behaviour during procedure	
Tail wagging	Rapid tail movements from side to side, recorded as a new event after the tail was moving slowly or was still.
Head movement	Sharp head shaking, head movements at still standing, often due to lifting the front leg.
Treading	Rapid alternate raising of two or more front or hind legs.
Moving forward	Pushing against strongly forward, with the desire to escape.
Rearing	Forceful rise on hind legs, with the desire to escape.
Behaviour after procedure	
Locomotion backwards	Walking backwards for no apparent reason.
Head shaking	Shaking or turning head without any discernible reason, usually slowly and carefully (not violently).
Head pushing	Pushing/pressing head towards other individuals, of non-aggressive character.
Fodder intake	Fodder intake or desire of fodder intake without its consumption.

Behavioural research involves the methods used for stress assessment during dehorning. Table 1 presents the patterns of behaviours which may be used to create ethograms, involving an analysis of frequency or duration of predefined behaviours. Graf and Senn (1999) proposed the use a model of constant observation lasting up to 4 hours in an evaluation of behaviour patterns after dehorning procedure. Stewart et al. (2008) registered calf behaviour for 40 minutes digitally and proposed an ethogram composed of the following behaviours: prancing, raising limbs, rapid jumping forward, sitting, collapses, slides, vocalization. Playing is observed in young stress-free animals (Mintline et al., 2013). This behaviour is not noted in animals maintained in unprofitable conditions or after painful treatment (Boissy et al., 2007).

Other methods for stress assessment in the calves during dehorning procedure are measurement of physiological parameters such as heart rate (Grøndahl-Nielsen et al., 1999), respiration rate (Heinrich et al., 2009) and eye temperature measurement (Stewart et al., 2008). Heart rate is subject to a distinct increase directly after dehorning, especially without local anaesthesia application (Figure 1).

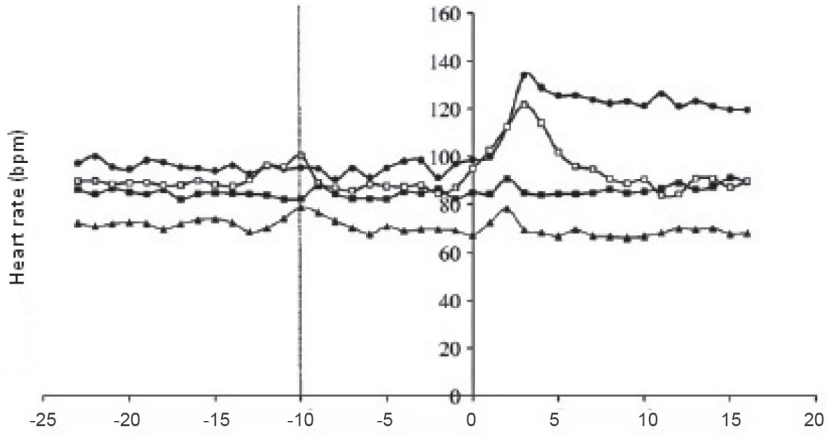

Figure 1. Mean heart rate (bpm) during 40 min for control group (■, n=8), control with local anaesthetic (▲, n=8), disbudded group with local anaesthetic (□, n=8), disbudded group without local anaesthetic (●, n=5); dashed line indicates the time of administration of local anaesthetic and time 0 min indicates the time of treatment (Stewart et al., 2008)

An immediate reaction to painful stimuli is blood flow from the net of skin capillary vessels through sympathetic contraction of smooth muscles, which as a consequence lowers skin temperature (Blessing, 2003). The study demonstrated that the reaction of eye temperature measured thermographically is a non-invasive tool in stress assessment in the animals (Stewart et al., 2005). In cattle, this measurement is performed in the area of the medial edge of lower eyelid and lacrimal ducts, which are equipped with rich capillary nets innervated by the sympathetic system (Stewart et al., 2008). It was observed that eye temperature increases as a result of stress (Figure 2), which results from an activity of hypothalamic-pituitary-adrenal axis (Cook et al., 2001).

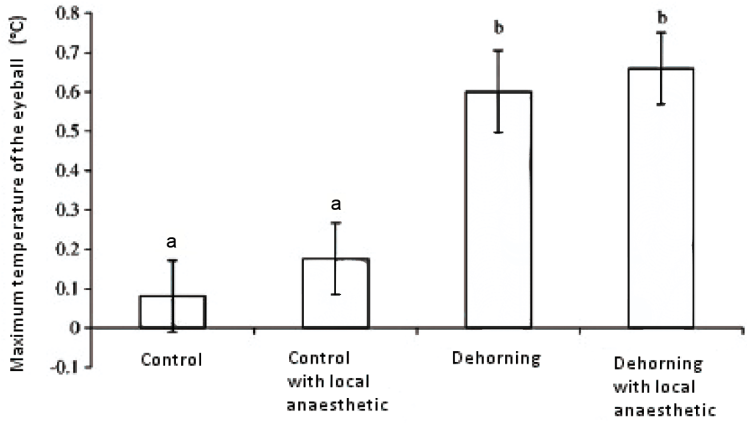

Figure 2. Change in maximum eye temperature (°C)±SEM, P<0.001 (Stewart et al., 2008)

Table 2. Effect of dehorning on plasma cortisol concentration (ng/mL) during treatment (Ballou et al., 2013)

Time (h)	Treatment			
	without anaesthesia/without analgesia		with anaesthesia/with analgesia	
	control*	dehorning	control*	dehorning
0	3.19	2.47	2.13	2.44
0.5	6.49 a	18.78 b	4.63 a	10.71 b
1.5	3.93 a	16.03 b	3.56	3.05
2.5	3.13 a	11.99 b	2.69	2.04
4	2.70 a	11.21 b	2.19	1.70
6	3.33 a	9.52 b	2.07	2.76
24	3.59	5.62	3.46	5.46
72	3.10	5.03	2.58	3.64

* The control group was subjected to a sham dehorning.
Means with different superscripts differ, P<0.05.

The result of an activation of hypothalamic-pituitary-adrenal axis (HPA) is an accelerated cortisol (Table 2) as well as corticosterone secretion. Cortisol causes various systemic effects which are helpful in stress attenuation (Hart, 2012). Since an activation of HPA axis and cortisol secretion are integral physiological reactions to stress, cortisol concentration in blood serum is one of the most often used stress markers (Hart, 2012). Graf and Senn (1999) claimed that measurement of three hormones, i.e. vasopressin, ACTH and cortisol, are significant. A strong stimulus for vasopressin secretion is physical stress or pain, and in the case of cortisol it is stress, including poly-etiological one. The highest concentration of cortisol is observed up to 1.5 hours after dehorning procedure. Regardless of whether anaesthesia will be used or not directly after dehorning, as well as irrespective of the age of calves, the cortisol eruption was observed and the values were above baseline concentrations for 30 min following dehorning (Allen et al., 2013; Mosher et al., 2013; Ballou et al.,

2013). The cortisol response suggests that amputation dehorning causes marked pain induced distress for at least 7–9 h and this conclusion is supported by the behaviour of calves (Stafford and Mellor, 2005). Administration of anaesthetic and analgesic agents distinctly lowers cortisol eruption after the treatment (Table 2). In another study, serum cortisol concentrations were lower in meloxicam-treated calves compared with control calves at 4 h postdehorning (Allen et al., 2013).

Pharmacological agents attenuating pain and stress

Stress in calves during dehorning is mainly related to the pain resulting from physical or chemical factors activity. To a lower degree it results from the immobilization of calves. This is confirmed by lower concentration of cortisol in blood of the control calves subjected to an apparent dehorning (Braz et al., 2012). Numerous studies point to the necessity of physical pain minimization by an application of pharmacological agents. The animals which were subjected to local anaesthesia and were administered an analgesic showed more proper behaviour patterns, and cortisol concentration in blood was lower (Graf and Senn, 1999; Stilwell et al., 2012). Successful is also the combination of anaesthetic and analgesic agents.

Numerous studies on an influence of pharmacological agents in order to minimize pain during the treatment and traumatic stress have been performed. These agents may be divided in a following manner:

– corneal nerve blockers – lidocaine (Duffield et al., 2010; Graf and Senn, 1999; Grøndahl-Nielsen et al., 1999; McMeekan et al., 1998, 1999), compression band on horns base (Duffield et al., 2010),

– non-steroidal anti-inflammatory drugs (NSAIDs) – flunixin meglumine (Duffield et al., 2010; Stilwell et al., 2009; Huber et al., 2013), ketoprofen (McMeekan et al., 1998, 1999; Stilwell et al., 2012), carprofen (Stilwell et al., 2012), acetylsalicylic acid (Duffield et al., 2010), meloxicam (Duffield et al., 2010; Heinrich et al., 2010; McMeekan et al., 1998, 1999; Stilwell et al., 2012), phenylbutazone (Duffield et al., 2010),

– sedatives – xylazine (Duffield et al., 2010; Mintline et al., 2013; Stafford and Mellor, 2011), butorphanol (Duffield et al., 2010; Grøndahl-Nielsen et al., 1999).

Dehorning procedure is not recommended in older animals (Graf and Senn, 1999), since the nociceptive system is not fully developed in animals in neonatal age (Taschke and Fölsch, 1997). Horn bud up to the 2nd month of life is freely embedded in skin layer above the skull. With age, the bud connects to periosteum of the frontal bone (Parsons and Jensen, 2006). At this stage, dehorning procedure is more painful, and also requires precise performance and application of both anaesthetic and analgesic agents.

Among prostanoids, prostaglandins E_2 (PGE_2) and presumably PGI_2 exhibit the highest influence on pain signals transformation. Non-steroidal anti-inflammatory drugs may decrease PGE_2 production. Oral administration of some NSAIDs (meloxicam, gabapentin) did not affect significantly PGE_2 concentration in blood of calves after dehorning (Fraccaro et al., 2013). Such influence was only observed in the case of intravenous administration of flunixin. The authors of this study conclude, however, that other mechanisms may be engaged in analgesic activity of these drugs.

Table 3 presents the changes in cortisol concentration in calves subjected to two methods of dehorning, after previous administration of various pharmacological agents. The calves subjected to thermal treatment were characterized by the highest concentration of cortisol in all the groups 10 minutes after the treatment. The highest cortisol concentration was noted in the groups which were given xylazine. Lower cortisol concentration was observed after lidocaine administration compared to the group where lidocaine and flunixin with meglumine was applied (Table 3).

Table 3. Cortisol concentration (nmol/L) in calves during dehorning (Stilwell et al., 2009, 2010)

Group	Time of dehorning			
	–5 min.	+10 min.	+25 min.	+40 min.
Thermal method				
CL (n=10)	16.85±9.54	18.54±9.54	16.17±9.54	10.84±9.54
CXL (n=10)	60.76 A±9.54	77.78 A±9.54	68.43±9.84	51.45 B±9.54
DXL (n=11)	43.26 A±9.10	86.34 B±9.10	80.79 BC±9.10	63.66 AC±9.10
DX (n=10)	53.04 A±9.54	94.82 B±9.54	76.89 B±9.54	54.22 A±9.54
Chemical method				
Group	–5 min.	+10 min.	+30 min.	+50 min.
PDA_2 (n=10)	11.16±7.90	19.11±11.40	16.71±10.69	14.73±8.80
$PDAF_2$ (n=10)	18.92±13.71	23.14±16.67	20.67±12.98	19.80±9.67
PD_2 (n=7)	17.49 aA±12.92	25.54 aAB±15.15	41.39 bBC±14.85	42.32 bC±14.47
SD_2 (n=8)	15.26±6.13	16.84±7.06	20.20±11.19	14.34±8.57

CL: control group subjected to a sham dehorning, with local administered lidocaine; CXL: control group subjected to a sham dehorning, application of xylazine and local lidocaine; DXL: dehorning – application of xylazine and local lidocaine; DX: dehorning – application of xylazine; PDA_2: dehorning – application of lidocaine; $PDAF_2$: dehorning – application of lidocaine and flunixin meglumine; PD_2: dehorning without use of pharmacological agents; SD_2: group subjected to a sham dehorning.

Different lower case letters indicate difference between groups for which $P<0.05$.

Different upper case letters indicate difference across time for which $P<0.05$.

In the case of chemical dehorning, Braz et al. (2012) used tramadol administered i.v. or in a form of suppositories. It was proved in that study that an application of caustic paste causes strong pain for the first 30 minutes after application, and tramadol does not exhibit an effective activity during that time. Intravenous administration of this drug may, however, help to reduce pain. Pharmacological control of cutting (sedation) is recommended in the case of this dehorning method. According to Vickers et al. (2005), local anaesthesia is not effective, while Stilwell et al. (2009) demonstrated that the pain may be controlled using local anaesthesia together with an application of flunixin with meglumine.

In the case of thermal method, Duffield et al. (2010) proposed an application of smaller device in order to minimize the injury and thus the pain. It is also recommended to use the local anaesthesia in this method (Stilwell et al., 2012). Doherty et al. (2007) applied various concentrations of lidocaine and proved, based on behaviour observations, that an application of 5% lidocaine solution does not assure higher comfort after dehorning, but reduces stress reactions during the procedure and thus dehorning becomes more safe. The study demonstrated that anaesthetic agents, together with their activity loss, cause an increase in cortisol concentration in blood,

and its level is then comparable to the concentration observed in calves not subjected to local anaesthesia (Graf and Senn, 1999; Grøndahl-Nielsen et al., 1999).

The results of oral meloxicam administration are similar to parenteral administration in following pain attenuation (Heinrich et al., 2010; Allen et al., 2013). Meloxicam is a NSAID that is considered to bind preferentially to cyclooxygenase-2 (COX-2) to inhibit prostaglandin synthesis. Oral meloxicam can provide effective analgesic concentrations for several days after surgery based on average elimination half-lives of approximately 38.6 hours (Allen et al., 2013). In the recent study, Allen et al. (2013) observed that irrespective of the time of oral meloxicam administration (1 mg/kg) in powdered milk replacer 12 h before cautery dehorning or oral bolus (1 mg/kg) at the time of dehorning suppresses a pain response. This research suggests that meloxicam reduced cortisol, SP, and PgE_2 after dehorning, but only PgE_2 production was significantly affected by the timing of meloxicam administration. Lidocaine blocking effect persists for 60–90 min after injection (Anderson and Muir, 2005), while NSAIDs act >34 h (Delatour et al., 1996). The application of meloxicam with lidocaine also caused a decrease in physiological reaction to stress during dehorning and 2 hours after the treatment (Heinrich et al., 2009). Cortisol concentration in blood decreased, similar to heart rate and respiration rate. Stilwell et al. (2012) claim that an association of regional anaesthesia with NSAID (carprofen) assures good welfare for 24 h after dehorning. The effectiveness of local anaesthesia and NSAIDs application during dehorning was confirmed in another study (Ballou et al., 2013). Also combined application of lidocaine with ketoprofen caused an attenuation of behavioural reactions to stress (McMeekan et al., 1998, 1999).

Numerous studies point out that an application of hot iron during dehorning is a source of pain (Stafford and Mellor, 2005; Doherty et al., 2007; Mosher et al., 2013), but its life-time is quite difficult to determine. However, behaviour analysis shows a high incidence of pain-related behaviours at 3 h, suggesting that, although not causing a noticeable rise in plasma cortisol, discomfort is present for longer time period (Stilwell et al., 2012). The study conducted by Stilwell et al. (2012) demonstrated that pain may persist up to 6 h after disbudding, and after regional anaesthesia and carprofen administration none of these calves showed any sign of pain at 24 h. According to Heinrich et al. (2010) the calves may experience the pain even up to 27 h after dehorning, but the authors highlight that there are differences in the time course and sensitivity of response variables. An application of NSAID did not affect significantly the play behaviour of calves (up to 27 h) and there was no difference between the treatments in head-related locomotor behaviours at either 3 or 27 h post disbudding (Mintline et al., 2013). Irrespective of pharmacological agents applications, the wounds around horn bud may remain sensitive for at least 75 h after the treatment (Mintline et al., 2013).

An increase in cortisol concentration after dehorning was quick and reached its maximum level 0.5 hour after the treatment (Ballou et al., 2013; Sutherland et al., 2013). During the next 30–60 min the concentrations decrease to a plateau and this persists for 5–6 h before decreasing to pre-treatment levels (Stafford and Mellor, 2005). The administration of local anaesthetic and a systemic analgesic attenuated ($P<0.001$) the cortisol response, both in the peak concentrations and the duration of

time greater than the sham dehorning (Ballou et al., 2013). Dehorning vs. delayed castration appeared to be more acutely stressful, which is proved by cortisol level and behavioural changes (Sutherland et al., 2013). Behavioural changes are higher when dehorning procedure is performed in older calves. Behavioural and physiological (cortisol eruption) changes caused by castration, dehorning, or both are indicative of calves experiencing pain for at least 6 h after application of these procedures, and these responses were additive when performed together (Sutherland et al., 2013). Cortisol eruption after dehorning may last 3 h longer than in the case of castration (Mosher et al., 2013). An application of local anaesthetic and the NSAID eliminates pain and cortisol reactions caused by dehorning (Sutherland et al., 2013).

The surgical method is recommended when the horns reach the length >10 mm. Horn amputation stimulates considerable cortisol secretion which lasts 7–9 hours (Figure 3). Serum cortisol concentration increased rapidly up to maximum value after about 30 minutes. The changes in blood cortisol concentration suggest that dehorning using surgical method causes a considerable pain (Stafford and Mellor, 2005). Anaesthesia with lidocaine application lasts up to 2 hours, and this time may be increased for the next 2 hours using bupivacaine (Stafford and Mellor, 2005). Local anaesthesia (bupivacaine) together with anti-inflammatory drugs (ketoprofen) practically eliminate cortisol eruption after dehorning (Figure 4).

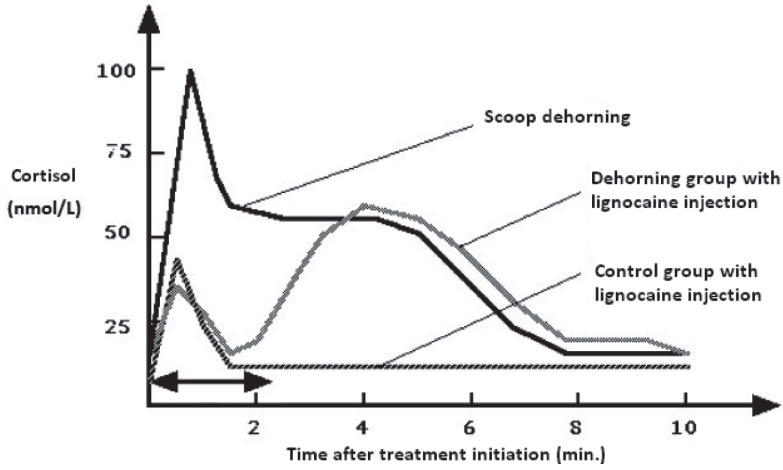

Figure 3. Plasma cortisol concentration of calves aged 20–24 weeks after scoop dehorning with lignocaine injection (Sylvester et al., 1998); arrow indicates the duration of corneal nerve blockade with lignocaine

Dehorning is also related to a distinct effect on the immune system. This procedure leads to leukocytosis and neutrophilia (Doherty et al., 2007; Ballou et al., 2013). Dehorning with hot iron provokes not only suppressive effect on leucocyte response, but is also connected to acute phase response via an increase in blood haptoglobin level (Ballou et al., 2013). The mechanism of suppressive activity on leucocytes is probably of multi-factorial character and does not result entirely from an increase

in cortisol level (Earley et al., 2010). Another study points out that the systemic immunosuppressive effect is also observed in the case of autonomic nervous system excitation (Chiu et al., 2012).

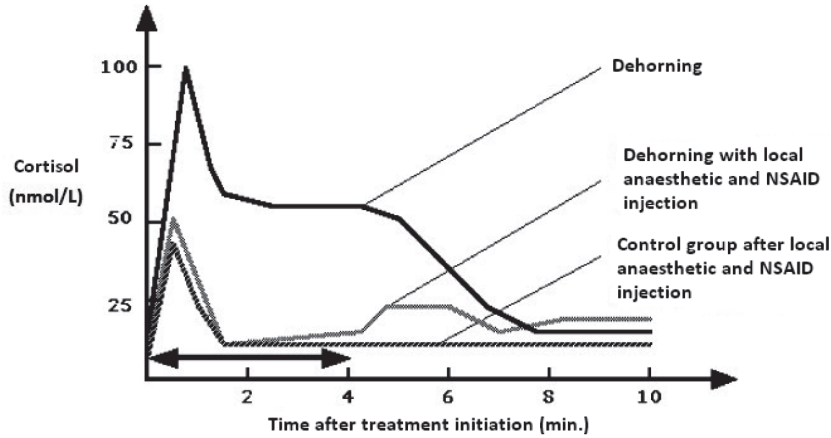

Figure 4. Plasma cortisol concentration of calves aged 12–16 week after scoop dehorning with local anaesthetic (bupivacaine) and NSAID (ketoprofen) injection (McMeekan et al., 1998); arrow indicates the duration of corneal nerve blockade with bupivacaine

It should be stated in the summary that calf dehorning causes a distinct neurohormonal response via an effect on the hypothalamic-pituitary-adrenal axis and autonomic nervous system. It is a painful procedure causing changes in behaviour, physiological parameters and an increase in stress hormones secretion (Grøndahl-Nielsen et al., 1999; Stewart et al., 2008; Heinrich et al., 2009; Ballou et al., 2013). Numerous studies have demonstrated the reduction of pain perceivable by the application of pharmacological agents. Beneficial effects were observed in the case of the combined application of anaesthetic and analgesic agents. Pharmacological activity, except for competency in its application, is of crucial significance in animal welfare assurance during dehorning.

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