Applied Animal Behaviour Science 135 (2011) 252–258

Contents lists available at SciVerse ScienceDirect

Applied Animal Behaviour Science

journal homepage: www.elsevier.com/locate/applanim

Pain issues in poultry

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ARTICLE INFO

Article history:
Available online 17 November 2011

Keywords:
Chicken
Pain
Nociceptors
Beak trimming
Skeletal disorders
Shackling
Feather removal
Environmental pollution
Lameness

ABSTRACT

This review highlights the possible pain experienced by layer and broiler poultry in modern husbandry conditions. Receptors which respond to noxious stimulation (nociceptors) have been identified and physiologically characterised in many different part of the body of the chicken including the beak, mouth, nose, joint capsule and scaly skin. Stimulation of these nociceptors produces cardiovascular and behavioural changes consistent with those seen in mammals and are indicative of pain perception. Physiological and behavioural experiments have identified the problem of acute pain following beak trimming in chicks, shackling, and feather pecking and environmental pollution. Chronic pain is a much greater welfare problem because it can last for long periods of time from weeks to months. Evidence for possible chronic pain is presented from a variety of different conditions including beak trimming in older birds, orthopaedic disease in broiler and bone breakage in laying hens. Experiments on pain in the chicken have not only identified acute and chronically painful conditions but also have provided information on qualitative differences in the pain experienced as well as identifying a cognitive component providing evidence of conscious pain perception.

1. Introduction

Pain in humans is defined as an unpleasant sensory and emotional experience associated with actual or potential tissue damage (IASP, 1979). However, animals cannot be asked directly about the pain or suffering they may be enduring and even in humans, verbal assessment of pain is difficult, especially in children. Although the exact nature of the emotional component in animal pain is uncertain (Wall, 1992; Anil et al., 2002), and there is no universal indicator of pain (Rutherford, 2002), Zimmermann (1986) has proposed a working definition of pain in animals:

> "*Pain in animals is an aversive sensory experience caused by actual or potential injury that elicits protective motor and vegetative reactions, results in learned avoidance, and may modify species specific behaviour, including social behaviour*".

This may not help to determine whether or not an animal is in pain but it does provide a framework of physiological and behavioural indicators for experimental studies with which to detect pain. The presence of nociceptors which signal actual or potential tissue damage, the behavioural and physiological changes resulting from nociceptive stimulation together with the physiological and behavioural changes following trauma would amply satisfy Zimmermann's definition of pain applied to poultry (Gentle, 1992a).

Pain is usually divided into acute pain and chronic pain. The former lasts for second to days and follows nociceptive stimulation or minor trauma and goes following healing. Chronic pain however, lasts for weeks or even years and is seen in chronic disease states or after major trauma. As part of a framework for detecting acutely painful experiences it is important to determine firstly that the animal has the necessary sensory receptors to detect the actual or potential injury and secondly that activation of these nociceptors results in both behavioural and autonomic cardiovascular changes. Chronic pain on the other hand, is not simply a continuation of acute pain; with prolonged pain

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doi:10.1016/j.applanim.2011.10.023

new factors emerge following pathological changes in the peripheral nervous system and physiological changes in both the spinal cord and the brain. The behavioural changes seen in chronic pain in both humans and animals are often more global in nature with not only guarding of the injured structure but also reductions in a variety of behaviour patterns including overall activity, exploratory and grooming behaviour.

Poultry throughout their lives sometimes experience a variety of acute or chronic painful conditions which are either inflicted on the animal as a result of current husbandry practices (e.g. beak trimming, pre-slaughter shackling) or occur as a result of trauma (e.g. bone breakage resulting from osteoporosis in the laying hen) or disease (e.g. orthopaedic disease in broilers). This review aims to identify potentially painful conditions in poultry and use the current state of knowledge regarding each issue to allow a scientific evaluation of the resulting welfare compromises.

2. Beak trimming

Beak trimming is recognised as an effective method of minimising feather pecking and cannibalism in layer flocks, but the procedure gives rise to welfare concerns due to its potential to cause short and/or long term pain and loss of function. An extensive review of pain resulting from beak trimming has been published by Cheng (2005). Recently, the more traditional method of applying a hot blade to remove the beak tip has been replaced by Infra-red (IR) beak treatment, in which a high intensity infra-red energy source is applied to the beak causing the tip to be lost after approximately 2 weeks (Marchant-Forde et al., 2008).

2.1. Young birds

The painful consequences of this procedure depend on the age at which it is performed. Beak trimming with a heated blade is likely to be acutely painful and increased heart rate associated with trimming may be related to short term pain (Glatz, 1987). Electrophysiological recordings from peripheral trigeminal afferent nerve fibres both during and after heated blade trimming showed a very large injury discharge which variable in duration but in some fibres lasted up to 48 s (Gentle, 1991). This injury discharge is likely to be felt as pain but of a relatively short duration because there was no abnormal neural activity recorded in the trigeminal nerve of the chicken for 4.5 h after the initial injury discharge, indicating a pain free period. Behavioural observations would support the absence of prolonged pain after trimming. In a study where birds where trimmed at one day of age, there were no significant effects on the behaviour of the chicks in the first hour after trimming or in the subsequent six weeks (Gentle and McKeegan, 2007). Behavioural effects which might reflect acute pain such as reduced feed intake, reduced activity and beak guarding have been reported in the first week after trimming day old birds in some studies (Gentle et al., 1997; Marchant-Forde et al., 2008) but not in others (Sandilands and Savory, 2002; Gentle and McKeegan, 2007) so there is currently no clear evidence of prolonged acute pain in birds beak trimmed at one day of age. The reason for the absence of any prolonged acute pain following beak trimming at a young age could be explained by the rapid regeneration of the beak in young birds. In the young birds there is an absence of scar tissue or neuroma formation following trimming and the beak rapidly regrows (Dubbeldam et al., 1995; Lunan et al., 1996; Gentle et al., 1997). The regrowing beak tissue allows the regenerating trigeminal sensory nerves to innervate normal beak tissue with free nerve endings and both Herbst and Grandry corpuscles have been observed in the regrown beaks at 10 and 70 weeks after trimming (Lunan et al., 1996; Lunam, 2005).

Recent work (McKeegan, unpublished) investigated the long term consequences of IR (infrared) beak treatment by examining changes in beak nerve function (neurophysiology) and anatomy over a range of ages. There was evidence for complete sensory regeneration in healed beaks and the results suggested that IR beak treatment of day old chicks does not result neither in chronic adverse consequences for sensory function, nor does it demonstrate evidence of chronic pain associated with the procedure.

2.2. Older birds

In older birds the trimmed beak rapidly heals but the beaks do not regenerate and the tip of the beak underlying the epidermis is composed of scar tissue (Breward and Gentle, 1985). At 10 days after trauma the damaged nerves show evidence of regrowth with some enlargement of the end of the nerve. This regeneration and regrowth of the nerve fibres continued so that by 15 days clear neuroma was present at the end of the nerve stump together with numerous bundles of regenerating fibres. These regenerating fibres continued to grow but, because of the adjacent scar tissue, were unable to innervate dermal structures and consequently the fibres grew back on themselves to form a complex mass of intertwining regenerating nerve fibres together with the surrounding tissue. In some nerves there was a simple terminal neuroma while in others a neuroma was formed at the original stump of the nerve in association with a large and complex neuroma formed adjacent to the scar tissue which forms the end of the beak. Some nerves did not appear to have a neuroma at the original stump but, instead, had a complex neuroma adjacent to the scar tissue. Subsequent electrophysiological recordings from the nerve fibres innervating these neuromas showed abnormal features not seen in normal trigeminal afferent fibres (Breward and Gentle, 1985). The most characteristic abnormality encountered in the stump was the presence of large numbers of spontaneously active nerve fibres with regular, irregular or bursting discharge patterns. This spontaneous activity seen in the amputated stump was similar to that observed in the experimental neuroma preparations developed initially by Devor, Wall and co-workers (Devor and Bernstein, 1982; Govrin-Lippmann and Devor, 1978; Wall and Gutnick, 1974) in the rat and later extended to the mouse (Scadding, 1981) and cat (Blumberg and Janig, 1984). This abnormal neural activity has been implicated in post-amputation stump pain in animals (Seltzer et al., 1991) and human amputees (Devor and Seltzer, 1999; Narsinghani and Anand, 2000).

There are a number of behaviour studies indicative of pain for at least six weeks after beak trimming using a heated blade. In the immediate period after beak trimming electrophysiological evidence suggests a pain-free period (Gentle, 1991) and this was verified behaviourally (Gentle et al., 1991). In this experiment the number of pecks delivered by birds to an attractive visual stimulus were measured before, and again 6, 26 and 32 h after beak trimming. There was a significant reduction in the number of pecks 26 h after amputation but not at 6 h after and this reduction in the number of pecks was considered a quantitative measure of pain-related guarding behaviour. A similar initial pain-free period has been observed in human patients following full-thickness burns (Robertson et al., 1985; Stein and Stein, 1983). Twenty-four hours after amputation the birds were unwilling to peck at the environment but they also showed reduced food and water intake together with long periods of sitting and dozing (Duncan et al., 1989). The behaviour of the bird changed over the next six weeks with food and water intakes returning to preoperative levels but preening and pecking were still significantly reduced. A more detailed study of beak usage after amputation (Gentle et al., 1990) demonstrated significant reductions in environmental pecking, beak wiping and head shaking which persisted for six weeks after surgery and have been interpreted as instances of guarding behaviour and hyperalgesia.

In conclusion beak trimming in day old or very young birds is likely to be acutely painful at the time of the procedure and in the immediate post-surgical period but there is very little evidence for any prolonged pain. In older birds however, there is evidence of prolonged chronic pain following beak trimming. However, only a proportion of human patients experience chronic long-term pain following amputation (Wall, 1981, 1991; Angrill and Koster, 2000) and most phantom limb patients have a positive correlation with preamputation pain (Jensen et al., 1983, 1984; Jensen and Rasmussen, 1994). If similar considerations apply to the chicken then we would expect relatively few birds to show long-term chronic pain following trimming. However, the results of Eskeland (1981) showed that dozing and general inactivity were observed in beak trimmed birds for as long as 56 week after surgery and decreased activity is common in humans suffering from chronically painful conditions (Wall, 1979). At present therefore there is evidence for prolonged chronic pain only in birds beak trimmed at an older age. It remains to be determined at what age the beak does not regenerate following trimming and therefore the upper age limit for trimming without any painful consequences. There is also a need to determine the extent of the chronic pain developing from older birds where the beak does not regenerate.

3. Feather removal

Beak trimming is used to prevent feather pecking and cannibalism which is a significant welfare and economic problem in the egg industry (Glatz, 2005). During feather pecking it is commonly observed that the bird being pecked will show crouching immobility while the feathers are removed with no outward sign of pain.

In an experiment where feathers were removed from birds (Gentle and Hunter, 1990) the initial feather removal resulted in the birds becoming agitated with wing flapping and/or vocalisation and displayed associated increases in heart rate blood pressure and EEG arousal. These physiological and behavioural responses to feather removal would indicate that it was painful. Interestingly, the continual removal of feathers did not produce an exaggerated escape response; instead, birds were observed shortly after removal to crouch with the tail feathers and head lowered in an immobile state. The increase in heart rate was more variable during this period and only 62 per cent of feather removals showed a sustained increase, whereas feather removal resulted in an increase in blood pressure with each feather removed in all birds. During this period of immobility following feather removal the EEG showed a characteristic high amplitude low frequency activity similar to that seen in sleep (Tobler and Borbely, 1988; Van Luitelaar et al., 1987) or catatonic states such as tonic immobility (Klemm, 1966; Ookawa, 1972; Gentle et al., 1989). This immobility may be related to learned helplessness which develops when an animal experiences traumatic events which are aversive and which continue to occur independently of any attempts by the animal to reduce or eliminate them. It is not known if the birds feel pain during this crouching immobility but stress induced analgesia has been well documented in humans and mammals (Butler and Finn, 2009; Martenson et al., 2009) and the chicken has a remarkable ability to suppress even severe tonic pain (Gentle and Corr, 1995). Although the bird still shows changes in blood pressure and EEG arousal immediately after feather removal, the high amplitude slow wave EEG pattern has been associated in other species with analgesia (Bodnar, 1984) and it may be possible that an animal in the latter stages of feather pecking may not be experiencing pain even though it is subjected to considerable trauma. It is possible that the immobility seen following feather removal is similar to tonic immobility, which is an anti-predator strategy following capture to prevent further damage produced by struggling and to allow escape should the occasion arise. This strategy is however counterproductive in production systems where hens have no possibility to escape and are in effect making themselves available to be pecked, which may or may not be associated with long-term pain.

4. Shackling

Shackling of commercial poultry involves the insertion of each leg into parallel metal slots and holding the bird inverted for a period of time before stunning and slaughter. To investigate the potential painful consequences of this procedure nociceptors signalling noxious stimulation of the scaly skin over the tarsometatarsus in the lower leg have been studied (Gentle and Tilston, 2000; Gentle et al., 2001) and their physiological properties determined. After comparing the stimulus threshold measurements and the stimulus response data of these leg nociceptors with previous measurements of the force applied to the leg during shackling it was clear that shackling was a suprathreshold stimulus for the cutaneous nociceptors in the leg. Shackling is therefore likely to be a very painful procedure.

This study on nociceptors in the scaly skin of the leg (Gentle et al., 2001) has also increased our general understanding of the nature of the pain experience in poultry. Previous detailed studies on the physiology of cutaneous nociceptors in birds have been largely confined to C-fibre polymodal nociceptors (Roumy and Leitner, 1973; Necker and Reiner, 1980; Breward, 1985; Gottschaldt, 1985; Gentle, 1989, 1991). A-delta fibres mechanothermal nociceptors were found in the chick embryo (Koltzenburg and Lewin, 1997) but in this study it was concluded that these fibres lost their heat sensitivity after hatching. However, A-delta mechanothermal nociceptors responding to both thermal and mechanical stimulation have been identified in the scaly skin of the adult chicken leg (Gentle et al., 2001) which indicates the chicken may experience a double pain sensation. In man, heat stimuli evoke a double pain sensation with the first sensation sharp pricking sensation and the second a burning feeling (Lewis and Pochin, 1937; Campbell and LaMotte, 1983). The latency to respond to first pain is too quick to be carried by slowly conducting C fibres and A-delta fibres are thought to signal first pain. It is likely that in the chicken leg, A-delta mechanothermal nociceptors are responsible for first pain which would initiate reflex leg withdrawal with its obvious protective function, maintaining the integrity of the leg and foot by responding rapidly to noxious stimulation. The physiological similarities between both the C and A-delta fibre nociceptors in birds and mammals demonstrate how closely the avian pain system parallels that of mammals.

5. Footpad dermatitis

Footpad dermatitis is relatively common in broiler chickens (Pagazaurtundua and Warriss, 2006; Haslam et al., 2007) and can result in severe lesions to the feet. The presence of nociceptors in the scaly skin of the feet (Gentle et al., 2001) would indicate that these lesions are likely to be painful and recent behavioural observations confirm this, at least for severe lesions (McKeegan, unpublished observations). Similar ulcerated epidermal erosions can occur in the mouth following feeding laying hens a very fine mash. Stimulating the birds with these lesions with substances known to cause pain in the human blister base test (Gentle and Hill, 1987) showed very clear pain related behaviours including periods of immobility.

6. Environmental pollution

In controlled environment rearing houses the problem of environmental pollution at noxious levels should not arise. Recent work by McKeegan (McKeegan et al., 2002, 2005; McKeegan, 2004) has demonstrated the presence of nasal and buccal trigeminal polymodal nociceptors which responded to ammonia, and some also responded to acetic acid vapour or carbon dioxide. It therefore follows that should these pollutants reach noxious levels they would be painful to the birds. However, available nociceptive thresholds suggest that ammonia pollution in poultry houses is unlikely to cause nasal pain (McKeegan, 2004).

7. Skeletal disorders

Skeletal disorder have been prevalent in the poultry industry for many years (Thorp, 1994) and selection pressure for production traits in modern lines of poultry has placed increasing demands on skeletal integrity. In laying hens the major problem is bone breakage usually resulting from osteoporosis (Webster, 2004; Fleming et al., 2006). In broilers there has been selection for rapid growth rate leading to pathologies in the growth plate and progressive degeneration of articular cartilage results in osteoarthosis and lameness.

7.1. Osteoporosis and bone fracture

There have been no studies on the painful consequences of broken bones in birds. The physiological, biochemical and anatomical mechanisms which are known to be correlated with painful experiences are very similar in both birds and humans and because broken bones are very painful in humans, it seems likely broken bones in birds will be also be very painful. Considering the extent of bone breakage in laying hens it constitutes an important welfare issue which merits further investigation, especially in the light of prevalence figure of up to 41% for keel bone fracture in laying hens (Sandilands et al., 2005).

7.2. Broiler lameness

Lameness is a major problem in the broiler industry and can arise from either infectious or non-infectious causes. Infectious causes would include bacteria, viral and mycoplasma infection and non-infectious causes would include developmental disorders (e.g. angular and torsional deformities and dyschondroplasia), degenerative disorders (e.g. osteochondrosis) and metabolic disorders (e.g. gout) (Thorp, 1994). Lameness can result from pain in the limb, or from pathological changes, which could alter mechanical function without necessarily being painful. Attempts to use analgesic to identify possible pain in lame broilers have shown an increase in activity following the administration of analgesia in some studies (McGeown et al., 1999) whereas others have not (Hocking, 1994). These contradictory results could be explained by the fact that the lameness in the different flocks of birds resulted from different pathological conditions but unfortunately in neither study was the underlying pathology investigated. Most joint disease is diagnosed post-mortem but Corr et al. (2003b) attempted to identify joint disease in the live animals by the analysis of synovial fluid from the hock joint. It was found that there was a high correlation between high heterophil counts and the extent of lameness in broilers indicating it could be probably caused by inflammatory rather than degenerative pathology. Another important finding was the presence of blood in the synovia of ad libitum fed broilers. In addition to the high heterophil counts a large number of synovial fluid samples had evidence of intra-articular haemorrhage which would suggest severe joint trauma and this trauma has implications for irreversible and painful joint damage.

Following on from this, there have been a number of studies investigating the painful consequences of inflammatory joint disease. Nociceptors have been identified in the joint capsule of the ankle of poultry (Gentle, 1992b) and following inflammation these nociceptors become sensitized and provide peripheral neural evidence of possible pain experienced during the disease. Injection of adjuvant into the joint to mimic bacterial infections produced significant changes in the response characteristics of the C and A-delta nociceptors (Gentle and Thorp, 1994). There was an increase in the receptive field size, a decrease in mechanical threshold and a high proportion responding to normal joint movement. These changes demonstrated sensitization of nociceptors and probable pain. A different inflammatory model using sodium urate arthritis (Gout) showed a similar sensitization of the C-fibres but no effect on the A-delta fibres and there was also a high level of spontaneous activity (Gentle, 1997). In a behavioural experiment it was found following the induction of sodium urate arthritis the birds showed pronounced pain-coping behaviour (one-legged standing, sitting) together with severe lameness (Gentle and Corr, 1995). This experiment confirmed that the sensitization of the C-fibres in sodium urate arthritis produced severe pain. In a third experiment a naturally occurring disease was induced by the injection of a mycoplasma culture into the ankle joint (Gentle et al., 2003). During the early stages of the disease sensitization was observed in both C and A-delta fibres with significantly increased receptive field size, decreased response thresholds, and increased response to joint movement; but it was only in the C-fibres where an increase in spontaneous activity was observed. Although all three arthritis models produced sensitization of the peripheral nociceptors the pattern of sensitization differed and this may provide evidence of qualitative difference in the pain experienced in the three different inflammatory conditions.

During the chronic stage of the mycoplasma arthritis (49–56 days after infection) there was pathological evidence of prolonged synovitis, the birds still showed some gait changes but not the pronounced unilateral lameness, antalgic gait (Corr, 1999), seen during the acute stage of the disease. The joint capsule nociceptors however responded normally to stimulation and there was no evidence of sensitization (Gentle et al., 2003). During this chronic stage of the disease there is therefore no evidence of pain which would suggest that mycoplasma infection in birds follows a similar pattern to human rheumatoid arthritis and mycoplasma infection in mammals (Cole, 1999). These results show the absence of any clear correlation between pathology and nociceptor activity also demonstrating the difficulty in trying to predict nociceptive consequences in animals on the basis of histopathology.

It is difficult to assess the possible pain associated with lameness resulting from morphological changes found in modern broilers. Walking difficulties in the modern broiler were highlighted by Kestin et al. (1992) and more recently by Knowles et al. (2008) using a system of subjective gait scoring a method which identified the extent of the problem in broiler flocks but did not provide any evidence for the underlying problems. By using a detailed objective analysis of gait however it is clear that the modern boiler walks very differently from the lightweight laying strains of birds (Corr et al., 1998, 2003a). Comparing a relaxed and selected strain of birds the ad libitum-fed selected broiler walked more slowly, with lower cadences and took shorter steps. The steps were wider, and the toes pointed outwards, resulting in a wider walking base. They kept their feet in contact with the ground for longer periods, having longer percentage stance times, shorter percentage swing times and increased double-contact times compared to the relaxed bird. These changes in gait serve to increase stability during walking and are likely consequences of the morphological changes in the selected broiler (Corr et al., 2003a) – in particular, the rapid growth of breast muscle moving the centre of gravity forward and the relatively short legs compared to their bodyweight. This altered gait would be very inefficient and would rapidly tire the birds, and could explain the low level of activity seen in the modern broiler. These gait changes seen in selected broilers can be explained on the basis of the morphological changes found in modern broilers and a similar conclusion was reached in a recent study comparing birds with gait score of 2 and 3 (Skinner-Noble and Teeter, 2009). Although these changes in morphological feature of the broiler compromise the walking ability of the birds they are unlikely to be painful.

In conclusion there are a range of different pathologies present in broiler flocks together with selective breeding for rapid growth rate all of which affects the walking ability of the animal. Inflammatory conditions are likely to be painful but the assessment of pain in other conditions relies on a deeper understanding of the underlying mechanisms giving rise to this lameness.

8. Conclusion

This brief review has highlighted the behavioural and physiological evidence of possible pain experienced by layer and broiler birds in modern husbandry conditions from the acute pain experienced by chicks following beak trimming to the pain of shackling on the killing line prior to slaughter. It is worth keeping in mind however that pain is a subjective experience and the subjective experience of the bird may be very different from mammals or humans. The chicken does however have a remarkable ability to suppress severe tonic pain by changes in motivation. Changes in motivation can reduce pain-related behaviours and it has been hypothesized these motivational changes act by way of altering the attention of the animal away from the pain (Gentle, 2001). The degree of pain suppression ranged from marked hypoalgesia to complete analgesia and these shifts in attention not only reduced pain but also significantly reduced peripheral inflammation (Gentle and Tilston, 1999). The fact that changes in attention modulate pain perception has far-reaching consequences for our understanding of avian pain implying a cognitive component. This cognitive component of pain also provides evidence of conscious pain perception which is likely to be experientially similar to mammalian pain and therefore equally ethically relevant.

Conflict of interest statement

I can confirm that there are no conflicts of interest in my manuscript. I have been retired for 8 years and the majority of the issues raised in the paper resulted from work undertaken by myself or co-workers at the BBSRC Roslin Institute.

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