RESEARCH REPORT
ANIMAL WELFARE

Title: A Comprehensive Literature Review on the Development, Treatment and Prevention of Shoulder Lesions in Sows – NPB #13-173 revised

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Industry Summary

Shoulder ulcers (shoulder lesions) in sows are most commonly observed in the first weeks of lactation, following farrowing. The prevalence of this problem varies greatly from herd to herd due to a range of contributing factors such as management, housing, genetics, health status, history of previous sores and body condition. Shoulder ulcers represent a significant welfare and economic concern to producers. These sores, much like human bedsores, are a form of pressure ulcer and are caused by persistent and constant compression of the blood vessels around the shoulder blade during prolonged periods of lying. The lack of blood flow to tissues results in localized cell death, tissue breakdown, and subsequent ulceration. The prevention of pressure ulcers is of great importance and although many factors have been implicated, maintaining sows in optimum body condition appears to be one of the most significant factors. While research on the occurrence of lesions is limited, their prevalence may be increased in hot climates as sows may spend more time lying, and the presence of moisture (eg. from drip cooling) is known to contribute to ulcer formation. Early signs of redness or irritation should be monitored closely in the farrowing room, as early detection and treatment are needed to prevent shoulder sores from progressing. Once the lesion has developed to include the superficial layers and underlying fat and muscle, the likelihood of recurrence increases greatly. When shoulder lesions appear, the sow should be immediately provided with a soft lying surface such as rubber flooring or deep straw. As the lesions typically occur in the weeks following farrowing, it is often necessary to provide rubber mats directly to sows in farrowing crates, or to wean early and transfer sows to a comfort pen. Measures are also needed to keep sows cool and to encourage movement. Lesions should be cleaned and treated with topical antibiotic. In severe instances, sows should be euthanized. Sows which have suffered from shoulder ulcers in a previous lactation are more likely to develop them in following parities. This is of particular importance when selecting gilt replacements as susceptibility is known to be a heritable trait. If ulcers are observed, then the incidence and animals involved should be recorded to monitor change and effectiveness of treatment, and as an indicator of sow welfare within the herd. The majority of recent research on shoulder lesions has been done in Europe. Further research is needed on risk factors, prevention and treatment under North American farm conditions and genetics.

Keywords

Lactating sows, decubital ulcers, shoulder lesions, review, needs assessment

Scientific Abstract

Shoulder ulcers (shoulder lesions) in sows are a common occurrence in commercial swine production, with lesions appearing most commonly in the first weeks of lactation, following farrowing. The prevalence of shoulder ulcers varies greatly due to a range of contributing factors such as management, housing, genetics, health status, history of previous sores, and body condition. Estimations of the occurrence of shoulder lesions within herds range between 4% and 48% of sows. This represents a significant welfare concern in sows and a significant economic cost to producers for reasons including drug use, premature culling, and carcass trim at slaughter. Aside from a small number of studies focusing largely on the prevalence in commercial swine herds, little research has been done on shoulder lesions in North America. To date, the majority of research on shoulder lesions and their prevention in commercial swine production has been carried out in Denmark. Shoulder ulcers result from persistent and prolonged compression of the blood vessels in the skin around the tuber of the scapular spine, causing insufficient blood circulation, tissue necrosis, and subsequent ulceration. The prevention of pressure ulcers is of great importance in controlling losses. Although several contributing factors have been identified, maintaining an optimum body condition score is critical for the prevention of shoulder sores. Sows must have sufficient backfat going into farrowing, and must be able to maintain sufficient fat covering throughout lactation. Early signs of redness or irritation should be monitored regularly, as early detection and treatment are critical for preventing the progressive development of shoulder sores. When shoulder lesions occur producers are advised to house the affected sow in a pen with a soft lying surface. Recent research has shown that placing rubber mats in farrowing crates in combination with zinc ointment resulted in improved healing in affected sows. Sores should be cleaned and treated with a topical antibiotic, and in more severe instances, sows should be euthanized. Susceptible sows should also be identified and monitored closely in future parities, as sows that develop shoulder ulcers in one lactation are more likely to develop sores in subsequent parities. This information is of particular importance when selecting gilt replacements, as susceptibility to shoulder lesions is known to be heritable. The presence of lesions should therefore be recorded in farrowing in order to monitor prevalence and improve management of the herd. There are many gaps in scientific knowledge related to shoulder lesions. Further study is needed to better understand their development, the healing process, pain associated with different stages of lesion, and effective treatment and prevention methods.

Introduction

Shoulder lesions in sows are most commonly observed in the first weeks after farrowing (Herskin, 2011). The reduced body condition of sows during lactation, and prolonged periods of lying following farrowing increases the incidence of shoulder ulcers (Lundgren et al.). The consequence of continued pressure on the shoulder is to restrict blood flow, resulting in cell death and necrosis of the skin and/or underlying tissue. The severity of ulcers can vary greatly, ranging from superficial sores to deep, subcutaneous ulcers which can expose the underlying bone. Ulceration of the skin may appear in slightly different ways, but always includes necrosis of the epidermis, including the underlying basement membrane which may be sloughed off (Jensen).

There are many management and animal factors that contribute to the development of shoulder lesions. Key animal-related factors include size, age, health status, history of previous sores, genetics, and reduced body condition. While there are many contributing factors, Jensen (2009) suggests that it is the intensity and duration of the pressure at the point of contact between the shoulder and the floor that is the most important factor. Due to the complexity and multi-factorial nature of these wounds there is no simple prescriptive measure that can be taken to eliminate their occurrence, however risk factors should be assessed at herd level and, based on this information, targeted treatment and prevention plans can be implemented.

(Gjein and Larssen, 1995) have suggested that decubital shoulder ulcers are the largest welfare problem in sows confined during gestation. Knowledge of the pain related to decubital shoulder ulcers is limited. However, on the basis of the tissue structures involved in these injuries, we assume that the development and presence of shoulder ulcers is a prolonged and painful condition (Herskin, 2011). As well as affecting sow

welfare it results in significant economic losses to producers due to early culling, lost production, and purchase of replacement stock. This review summarises current scientific knowledge related to shoulder lesions in sows, including their development, treatment and prevention. We conclude by identifying gaps in knowledge related to this condition and potential areas of investigation.

Objectives

The objective of this review was to collect and assimilate the literature available on sow shoulder sores from a range of sources, and to highlight key concepts regarding the development, treatment and prevention of these injuries. Specifically the review discusses the causes of shoulder sores in sows; effective treatment options; methods for prevention, and potential areas for future research in this area. The occurrence of sow shoulder lesions poses a significant risk to both the economic success of producers and to the well-being of sows, and contributes to negative consumer attitudes toward the swine industry (Zurbrigg, 2006).

Efforts to improve the early identification and treatment of decubital ulcers have been undertaken in European countries and similar changes can be anticipated in the United States as producers seek to improve management and the demands of consumers and retailers for higher welfare standards continue to rise (Hazel, Wayne, and Morrison, 2014). This review will aid pork producers by assembling the existing knowledge on the subject, and outlining the most effective treatment and prevention measures for shoulder sores. It will also identify gaps in our current knowledge and research priorities to aid the direction of future research.

In addition to the current report, a more extensive review article is in final preparation for submission to the Journal of Animal Science, with a target submission date of Nov. 30, 2014. A fact sheet for producers has also been prepared, outlining relevant information on the causes, treatment and prevention of shoulder sores. Finally, a detailed future research needs assessment has been prepared, outlining specific areas which would benefit from research, prioritization of different research areas and key measures and methods to be followed.

Materials & Methods

The main databases used in the review were AGRICOLA, CAB International, Scopus, Science Direct and Google Scholar. Both peer reviewed and non-peer reviewed resources were utilized. Non-peer reviewed industry publications were used, including (but not exclusive to) publications by the British Pig Executive and the Danish Pig Research Centre.

The types of studies referenced include:

1. Peer-reviewed studies describing the pathology, and etiology of shoulder sores, many of which are in the veterinary research area.

2. Peer-reviewed studies that investigated the frequency of occurrence of shoulder sores on farms or from data on cull sows (from *post mortem* carcass inspection).

3. Peer-reviewed studies investigating the causes and treatments of shoulder sores, including management factors, the genetic heritability of sores, and traits of individuals predisposed to shoulder sores.

4. Human research on the etiology and treatment of bed sores, which share similar causes and resulting tissue damage to shoulder ulcers in sows.

5. Non-peer reviewed articles, including industry journals and factsheets, unpublished abstracts, reviews, and consulting reports.

The literature was summarized, highlighting where existing studies show agreement or contradiction. In cases where results were contradictory, the authors have speculated on why this may have occurred. After the initial collection of material was conducted, the literature selection was refined, and only the most relevant information has been included in this report. A more extensive review article is in final preparation for submission to the Journal of Animal Science.

Results & Discussion

Causes of Shoulder Ulcers

The most frequent sites for decubital ulcers are areas of skin overlying bony prominences (Edlich et al., 2004). The prominent tuber of the scapula is overlain by adipose tissue and skin, and has no overlying muscle tissue (Figure 1). When the sow lies laterally, the anatomy and location of the prominent tuber results in pressure being exerted on the overlying tissues, and predisposes this area to pressure ulcers (Figure 2).

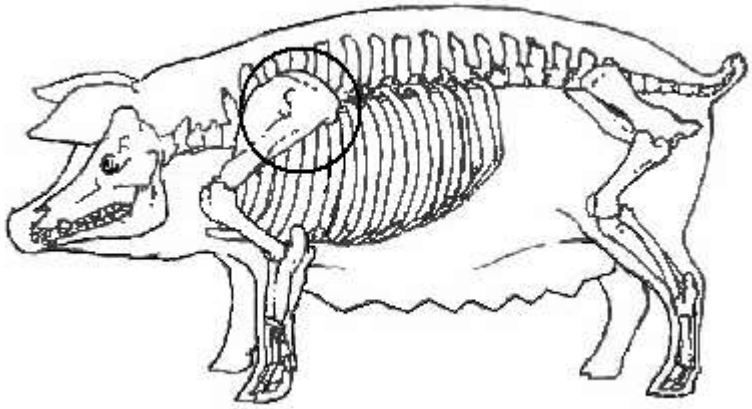

Figure 1. Diagram of the skeletal system of the sow, with circle highlighting the scapula and location of the prominent tuber of the scapula. (*Drawing: J. Brown)*

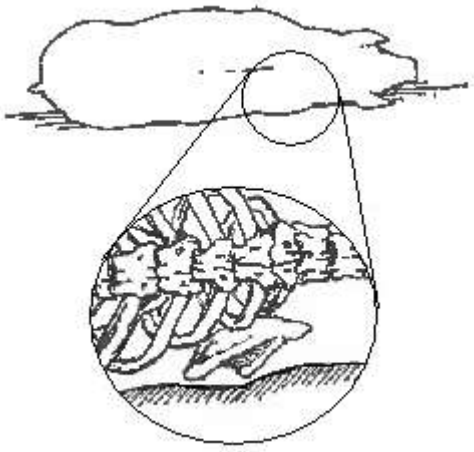

Figure 2. The sow in lateral recumbency, with detail showing the shoulder region and location of the scapular spine. (*Drawing: J. Brown)*

Pig related risk factors

There are numerous pig related factors that contribute to the development of shoulder lesions, including (but not limited to) body condition post-farrowing (Bonde et al., 2004; Havn and Poulsen, 2004); parity (Zurbrigg, 2006; Rosendal and Nielsen, 2005); health status (underlying diseases) (Zurbrigg, 2006); lameness (Rosendal and Nielsen, 2005; Anil, Anil, and Deen, 2014); previous history (Thorup, 2006); weaning weight of litter (Zurbrigg, 2006); lactation length (Anil, Anil, and Deen, 2014); sow behaviour (unrelieved pressure) (Rolansdotter, Westin, and Algers, 2009); breed (Zurbrigg, 2006); and genetics (Lundeheim et al., 2014; Lundgren et al., 2012).

The sows' behaviour has an important impact on the occurrence of shoulder lesions. Lateral recumbency, which is necessary for the formation of ulcers on the shoulders, is the predominant posture of postparturient sows, and is particularly common in sows during the early stages of lactation (Cronin and Smith, 1992). Authors have also found that shoulder ulcers are more common in sows with leg disorders (Bonde et al., 2004; Knauer et al., 2007), as being lame can impede the sows' ability to change position or to stand and relieve the pressure on the shoulder. A study by Kilbride et al. (2009) reported that the risk of new shoulder lesions increased as the responsiveness to human presence decreased, presumably due to the reduced likelihood of postural change occurring.

Several researchers have estimated the heritability of shoulder lesions (Hedebro Velander et al., 2011; Lundeheim et al., 2014; Lundgren et al., 2012). Lundgren et al. (2012) estimated the heritability of shoulder ulcers and the genetic correlation between shoulder ulcers, mean piglet weight and sow body condition. As shoulder ulcers are a heritable trait (Hedebro Velander et al., 2011; Lundeheim et al., 2014; Lundgren et al., 2012) it is therefore possible to reduce their prevalence by including this trait in selection and breeding programs.

Environmental risk factors

Besides the pig related risk factors there are several environmental risk factors that can contribute towards the occurrence of shoulder ulcers, including flooring (Mattson et al., 2009; Rosendal and Nielsen, 2005), feeding management (Bonde, 2009), area of farrowing room (Zurbrigg, 2006); temperature and humidity (Holmgren and Lundeheim, 2010; Kokate et al., 1995), type of sow housing (Reese, Straw, and Waddel, 2005) and friction (Lahmann and Kottner, 2011). Environmental risk factors can be described at both individual and at herd level.

Where housing is concerned, individual farrowing crate floors must, as far as possible, meet the sows' needs for a comfortable surface for lying, sufficient space and a non-slip surface for rising and standing, separation from excreta as well as being robust to her size and weight (Kilbride, Gillman, and Green, 2009). The same authors also found that there was an increased risk of new shoulder lesions occurring when the sow lying area was either damaged or had a covering of wet slurry when compared to clean, dry, and/or undamaged floors. Slippery floors impede postural changes. The ability to perform postural changes is believed to be very important as this will relieve pressure from the affected area, promote circulation and reduce discomfort.

Development of Ulcers

The precise mechanisms behind the development of shoulder lesions are not well known and there are several opinions as to how and why pressure leads to tissue breakdown (Rolansdotter, Westin, and Algers, 2009). It is generally believed that persistent and constant compression of the blood vessels in the skin around the tuber of the scapular spine results in insufficient blood circulation, ischemia, necrosis, and subsequent ulceration. It is assumed that the development of ulcers primarily depends on the force and the duration of the pressure, but is also affected by the robustness of the skin (e.g. texture) (Herskin, 2010). In terms of pathological findings, Jensen (2009) has described four stages of shoulder ulceration along with their histological characteristics. A description is provided of how the ulcerations develop progressively, starting on the skin surface and progressing through stages 2 and 3 to stage 4 (see Classification section below), in which the spinal tuber of the scapula is exposed (Jensen, 2009). It is estimated that the majority of decubital shoulder sores are present

for at least 2 to 3 weeks and that some of the lesions develop into ulcers during this period (Herskin et al., 2010).

Classification

To date, no international clinical classification system for decubital shoulder ulcers exists. In Denmark, shoulder ulcers have been classified using an officially accepted pathoanatomical scale since 2003 (Lund et al., 2003). This scale is based on a 1-4 grading system ranging from mild epidermal lesion (1) to deep ulcers penetrating to periosteal tissue (4), and is designed for use in *post mortem* evaluations. The Danish system for classifying *post mortem* ulcers is effective and several recent studies have been published using this system (Lund et al., 2003; Herskin et al., 2011a; Jensen, 2009; Kaiser et al., 2013; Rolansdotter et al., 2009. Thus use of this system is recommended in future studies of this nature to allow direct comparison of results and conclusions.

The evaluation of shoulder lesions in live animals is more difficult. Recently, a clinical scale for shoulder ulcers for use in *ante mortem* disease surveillance on-farm, has been developed in Denmark and consists of 3 categories, where 0 is no/negligible lesions (< 2 cm in diameter); category 1 describes minor ulcers (2 cm ≤ diameter < 5 cm); and category 2 describes severe lesions (diameter > 5 cm, surrounded by thickened edge) (Herskin et al., 2013). The aim of developing this *ante mortem* scale was to provide a simple scoring system for use in on-farm audit programs, and to aid agreement between packers and producers in terms of the severity of shoulder lesions at slaughter. In 2013, a large scale Danish study was conducted using the three point scale to determine its reliability and repeatability among different assessors. A shoulder ulcer measuring card was developed which can be placed over the sore to assess lesion size and severity according to the 3 point scale (VSP, 2013). While this classification is simple and results in good agreement across observers, it is potentially an oversimplification and not ideal for detailed research in live sows.

A variety of other classification systems have been used in studies on live sows. In an epidemiological study of decubital ulcers in sows by Davies et al. (1996), each shoulder was visually examined, and categorised as: normal, erythema (redness), callus, ulcer, scab or scar. Erythema was recorded when redness of the skin over the tuber was the only abnormality, and callus was recorded when the only abnormality was roughened or thickened appearance of the skin (Davies et al., 1996). The greatest width of the ulcer was also measured using calipers. Generally, only 1 lesion type was recorded per shoulder, using a hierarchy of ulcer, scab, scar, erythemas and callus (Davies et al., 1996). In a study of risk factors and treatments, Zurbrigg (2006) measured lesions using a 5 point scale (0 to 4), ranging from no lesion or scarring (0), to scarring (1), reddening (2), and broken skin over the scapular tuber (<2.3 cm: score 3, >2.3 cm: score 4). The adoption or development of a similar 4 or 5 point scale for use in research on live sows is recommended.

Pain Caused by Shoulder Ulcers

Despite the large number of pigs kept in production systems, little is known about nociceptive responses and sensitivity in this species (Herskin et al, 2009), therefore very little is understood regarding the pain caused by shoulder sores. Gorecki et al. (2010) and Rutherford (2002) have reported that human patients with a similar type of pressure ulcer (similar to those seen in sows) experienced pain, and based on analogous anatomy and physiology in pigs (Vardaxis et al., 1997) some degree of pain is expected. Currently the relationship between shoulder ulcerations and the degree of pain or discomfort experienced by sows has received limited attention (Dahl-Pedersen et al., 2013). Not only are ulcers believed to cause varying levels of pain at different stages of severity, but they also provide an entrance for pathogens which may cause infection (Herskin et al., 2011).

Human Pressure Ulcers

As mentioned previously, sow shoulder sores are comparable to a large extent with human pressure ulcers (Herskin, 2010). Human skin is reported to have histological and functional similarities to porcine skin

(Vardaxis et al., 1997). There is an abundance of peer reviewed articles relating to human pressure sores, and there are potentially valuable lessons that can be gained from this work and applied to the swine industry to reduce the occurrence, or aid in treatment, of decubital ulcers.

There are two main theories used to describe the development of two types of pressure ulcers commonly observed in human medicine: i) superficial, and ii) deep. It is believed that kinetic friction forces (rubbing the skin), possibly in combination with increased skin moisture, is primarily responsible for superficial skin lesions that resemble so-called category II pressure ulcers (Lahmann and Kottner, 2011). On the other hand, long enduring, unrelieved pressure leading to compression of all tissue layers is considered to be the main cause of breakdown of deeper tissues like muscle or subcutaneous fat (Lahmann and Kottner, 2011). A new body of evidence suggests that ischemia, rather than pressure, may be the principal culprit in decubitus ulcer formation (Campbell and Parish, 2010). Campbell and Parish (2010) also suggest that the evolving role of ischemia in ulcer formation deserves further assessment. Ischemia results when tissue pressures exceed capillary hydrostatic pressure for a prolonged period (Davies et al., 1996), and the lack of blood supply to any given tissue. Since cells depend on oxygen, heat, and nutrients transported by the blood, they become hypoxic and subsequently necrotic (Olesen et al., 2010). In humans, pressures greater than capillary filling pressure (32 mmHg) at the heels and sacrum on standard padding are enough to cause necrosis if the duration of pressure exceeds 2 hours (Witkowski and Parish, 1982).

Human medicine is in general agreement with the swine literature in showing that the risk factors for developing pressure sores are multifactorial, with immobility, underlying diseases, increased body temperatures, drugs, acute illness, age, nutritional status, mattress quality and moisture all being contributing factors (Leigh and Bennett, 1994).

In an effort to prevent decubital ulcer formation, risk assessment scales have been developed (Campbell and Parish, 2010). The most frequently cited and most commonly used of these scales include: the Braden scale, the Norton scale, the Douglas scale, and the Waterlow scale. These scales include factors such as (but not limited to): sensory perception, moisture, activity, mobility, nutrition, friction, shear, activity, mental status, body mass index, gender, age, and appetite. However, despite the availability of these risk assessment tools, a review of the Norton, Waterlow, and Braden scales (Papanikolaou et al., 2007) concluded that the scales had insufficient predictive validity and poor reliability. Campbell and Parish (2010) suggest that risk assessment scales may prove useful in situations where clinical experience is lacking or insufficient, however overall clinical judgement may serve as the most valid and effective means of predicting decubitus ulcer formation in human patients.

Human Treatments

Early recognition and intervention are vital to successful treatment of pressure ulcers (Brem and Lyder, 2004). Several peer reviewed articles report protocols for the treatment of pressure ulcers in humans (Basnal et al., 2005; Brem and Lyder, 2004; Campbell and Parish, 2010; Lyder, 2003). The protocols include factors such as identification of patients at risk, daily assessment of skin condition and measurement of wounds, promotion of a wound-healing environment, relief from pressure, and good nutrition. The main focus in treating human ulcer patients revolves around reducing or completely eliminating pressure on the site of injury. Todays treatment of decubitus ulcers is based on four primary modalities (Basnal et al., 2005):

i. Pressure reduction and prevention of additional ulcers
ii. Wound management
iii. Surgical interaction
iv. Nutrition

In managing sows, a producer would not resort to surgical intervention as animals with severe ulcers are generally euthanized, however the other three modalities are applicable to swine management. Pressure reduction can be achieved by the use of softer flooring surfaces and regular movement or position changes by the sow. When an open ulcer develops, wound management is critical (including cleaning, drainage, and absorption) to ensure optimal healing. Lastly, in terms of human patients problems of malnutrition must be addressed as these patients have delayed healing and are at a higher risk for ulcer formation (Basnal et al.,

2005). From the swine literature we also know that sows with a reduced BCS are at greater risk of developing ulcers.

Treatment

The treatment of decubital shoulder ulcers in sows is an under-researched and under-reported area. The magnitude and duration of the pressure are pivotal to the development of ulcers, and unrelieved pressure is particularly important, because short periods of pressure relief can enable tissues to recover from compression (Bader, 1990). In human medicine, zinc ointment is sometimes used prophylactically to protect the skin against moisture and urine, although there is little documentation on its effect (Kaiser et al., 2013).

One of the main treatments for sows is to provide them with a pen with softer flooring. This can be done by removing the sow to a comfort pen with early weaning, or adding softer flooring to the farrowing crate. Rubber mats are one of the best flooring alternatives. Their use has been studied in Danish herds where mats are provided in farrowing pens when signs of abrasion or reddening of the skin appear. From 2007 to 2010, a number of research studies were conducted in Denmark with the goal of reducing shoulder lesions (VSP, 2011). Studies on flooring included the use of rubber mats and in-floor cooling systems. Results from the mat studies indicated that a soft, perforated mat was more effective than a thicker, hard mat. The authors note that this result may have been due to the drier surface provided by the perforated mat (VSP, 2011). Studies on the use of in-floor cooling on two Danish farms were done to explore the hypothesis that shoulder lesions result from high temperatures in summer. In these trials, in-floor cooling showed no effect on the prevalence of shoulder lesions (VSP, 2011).

A recent study by Kaiser et al., (2013) studied the effects of providing rubber mats, zinc ointment and antibiotic spray on 304 sows on three farms with a history of shoulder lesion problems. The use of mats in combination with zinc ointment resulted in a significant reduction in ulcer size by day 14 after farrowing. Thin sows showed a faster response than fat sows, with measurable reductions in wound size by day 14 after farrowing. Straw bedding can also relieve pressure and improve comfort for lying sows, however, in many modern pig production facilities the use of straw is deemed unfeasible because of the potential to block liquid manure disposal systems, concerns over biosecurity, and increased labour and production costs (Calderon Diaz and Boyle, 2014).

The treatment of pain due to shoulder sores is another area which has received little (if any) research. When pain is suspected there are limited alternatives for analgesia for breeding swine (Deen, 2010). NSAID drugs such as Metacam are the most likely candidates for pain management, however their approval in food animals is lacking in some countries, and withdrawl periods must be carefully monitored in the eventuality that sows are culled. Providing pain relief to sows may result in greater comfort and more frequent postural adjustments, which could improve healing. Alternatively, sows may be more comfortable and show reduced movements, with little benefit to the healing process. Thus, it remains to be studied how much pain is present, and whether pain relief can be used effectively as an adjunct therapy.

In general, products used to treat decubital ulcers on sows (flooring, topical dressings, or pain relief) have not been well-evaluated (Hazel et al., 2014). However, to provide the most benefit future research should ideally focus more on prevention and early identification as this approach is far more effective than expensive treatments and ongoing care of affected sows after the fact.

Prevention

The prevention of pressure ulcers is of great importance, and an essential component of a preventive strategy is the assessment of risk of pressure ulcer development in the individual (Papanikolaou et al., 2007). From the human literature it is suggested that if pressure ulcers are to be prevented, risk assessments of an individual's chances of ulcer occurrence must be under taken before prevention plans are put in place (Papanikolaou et al., 2007). Prevention is always likely to be the most effective course of action, however, prevention methods are complex and multi-faceted. It must also be recognised that the wide range in both predisposing factors and ulcer prevention methods make recommendations for industry-wide prevention measures exceedingly difficult

(Hazel et al., 2014). Therefore, it may be most effective for individual herds to conduct monitoring and risk assessment, followed by an individually tailored prevention plan depending on their sow genetics, management, housing system, feeding system, etc.

Maintaining optimum body condition

Maintaining an optimum body condition score is critical for the prevention of shoulder sores. Sows must have sufficient backfat going into farrowing (ideally BCS 3 on a 1-5 scale), and must be able to maintain sufficient fat levels throughout lactation. This will be affected by a combination of sow genetics, sow comfort and meeting the sows' nutritional needs through diet. If the sows' nutritional needs are not met then body reserves will be used to meet reproduction and lactation requirements, with an accompaning loss of body condition. Loss of appetite and reduced activity in hot weather can exacerbate the problem. Regular assessment of body condition score can allow stockmen to quickly and easily identify any changes within individuals and take appropriate action. Condition scoring and the assessment of shoulder lesions should be a regular activity. It can be readily included in management procedures, for example at the time of farrowing or piglet processing, and recorded as part of production records.

Leg and hoof health

One reason that sows may be reluctant to stand or change position in farrowing (and thus not relieving pressure from the shoulder area) is due to locomotor problems. For example, lameness is a common problem among sows, and is one of the most common reasons for culling (Chagnon et al., 1991). High parity sows may also develop long hooves, dew claws or heel overgrowth that can compromise mobility and increase lying time. In a study evaluating sows at slaughter to determine the incidence of abnormalities (Stalder and Karriker, 2006) reported that open shoulder lesions were positively associated with rear foot abcesses. In addition to reducing the development of shoulder ulcers, the early detection and prevention of lameness can reduce veterinary costs, euthanasia costs and improve the productivity and profitability of pork production.

Flooring

In general, lactating sows are housed on partial or fully slatted floors in crates throughout the nursing period (Kaiser et al., 2013). It is assumed that fully slatted floors put more pressure on the shoulder than other types of floors, because the supporting surface area on which the sow lies is reduced (Kaiser et al., 2013; Davies et al., 1996). The use of alternative flooring, particularly in the farrowing room should be of benefit to the sow. Ideally floors should not be so rough as to cause skin abrasions, but must provide sufficient grip for the pigs to stand easily (I.J.Lean, 1999).

Flooring should allow sows to stand readily and make postural adjustments. Many producers will encourage sows in farrowing to stand once or twice per day. Although this is not likely to be sufficient to halt the development of shoulder sores, the practice may be beneficial for monitoring leg health, and the identification of flooring problems.

Soft flooring surfaces have been recommended to reduce or prevent the occurrence of shoulder ulcers, as described in the Treatment section above. Research and development of better flooring surfaces in farrowing are warranted. Flooring should be dry and non-slippery. In humans, prolonged exposure to moisture makes the skin more susceptible to injury and predisposes the development of decubital ulcers, especially when combined with other risk factors (Leigh and Bennett, 1994). Therefore, care should be taken when considering the location of drip coolers in farrowing rooms, and also the placement of water drinkers should be designed to limit moisture levels in the shoulder region.

The use of shoulder pads has also been studied in Denmark as preventative measure (Villadsen and Haland, 2012). The design includes a large round foam pad with canvas exterior that covers the shoulder region and is attached by two nylon straps around the sow's body with Velcro attachments. The pad was applied to sows

when redness was observed, and reduced the prevalence of sores during lactation compared to untreated control sows.

Susceptibility and previous history

It is widely acknowledged that sows which have a history of previous shoulder sores are more susceptible to recurring shoulder sores and should be given extra attention (e.g. provided with rubber floor mats in farrowing). Nielsen and Vestergaard (2003) suggest that sows that exhibit shoulder ulcers when exiting the farrowing room should be culled as these individuals will have a predisposition to developing ulcers. Some sows are also genetically susceptible to developing shoulder sores, and this is of added importance if producers are breeding their own replacement sows. If a sow has had a shoulder sore in her previous lactation, the chances of her developing sores in following pregnancies is greatly increased, and the trait is heritable to some extent. Selection for more robust pigs may therefore decrease the risk and prevalence of shoulder ulcers (Lundgren et al., 2012).

Conclusions

Overall, much of the evidence presented here suggests that sows in good body condition score, with good general health status, housed in an appropriate environment, and having appropriate genetics are at a low risk of developing shoulder sores. The presence of shoulder sores at either herd or sow level suggests that one or more of these factors should be addressed.

The period following farrowing results in prolonged, uninterrupted lying bouts in sows, and combined with reduced body condition, hard or damp flooring and other factors (both pig and environmental) increases sows susceptibility to developing shoulder lesions. The prevalence of sow shoulder sores varies greatly across herds, however some studies have reported levels as high as 50%. The incidence of sow shoulder sores may be underestimated due to their multifactorial nature and lack of monitoring for this condition. The presence of shoulder lesions are also not generally reported at culling.

As shoulder lesions are both complex and multi-factorial there is also no simple prescriptive measure that can be taken to eliminate their occurrence. However, there are a number of precautions and treatments that producers can implement to reduce their occurrence. Maintaining skin integrity and body condition throughout the first weeks of lactation is critical, as well as preventing extensive undisturbed lying bouts, maintaining clean/dry flooring, and early intervention when lesions appear. The effective treatment of shoulder lesions is dependent on early recognition and intervention. Following any early signs of redness or irritation, it is advised that stockmen house sows in a comfort pen and/or provide a soft lying surface such as rubber matting or deep straw. As some sows will have a history of shoulder sores they should be given extra attention, however these individuals are more likely to be predisposed to sores in the future, so depending on severity it may be advisable to cull sows to prevent recurrence and avoid propagation of this trait in replacement gilts.

Understanding the underlying causes and determining the correct preventative treatments for sow shoulder lesions is economical for producers (improving production and reducing veterinary treatment, and replacement costs for culled sows), but will also improve the welfare of sows. Improvement of this problem begins with regular monitoring of sows, especially in the farrowing period. Ongoing monitoring, combined with further research will result in improvements to productivity, and demonstrate the industry's commitment to animal care.

Research Needs

As noted in this review, there are many gaps in our knowledge related to the development, treatment and prevention of shoulder sores. Specific areas of interest include: risk assessment in North American herds, the mechanism of development and healing process, evaluation of prevention and treatment measures (flooring types, topical protection and antibiotics, pain mitigation, etc.), studies of pain experienced by sows (in different

lesion stages), the economics of the problem and different therapeutic approaches, and the effects on sow well-being. These studies have the potential to benefit sows and producers, and will demonstrate the industry's commitment to animal care.

Risk assessment: No data are available with regard to the effects of temperature, for example, flooring or skin on the occurrence of decubital shoulder ulcers in sows (Herskin, 2011a). Even though in many peer reviewed articles it is often cited that moisture, humidity and temperature are likely to play a role in the development of shoulder ulcers (Lahmann and Kottner, 2011; Leigh and Bennett, 1994; Parish and Witkowski, 2004), the exact role of these risk factors is poorly understood, and is of particular importance to North American pig producers where high summer temperatures are prevalent. The interaction of these factors with conditions in farrowing (esp. flooring) should be considered. Another area of risk concerns the relationship between shoulder lesions, lameness and hoof condition.

The use of the Danish 3 point clinical assessment scale could be included in on-farm assessment schemes. This would provide a simple tool for monitoring prevalence on-farm and at assembly yards or packers, and improve the understanding of risk factors.

Development and healing: Further investigation into the development and dating of shoulder ulcers would be beneficial to highlight the critical time-points for risk assessment and intervention, and the progression of healing under different treatment scenarios. Specifically, data are needed describing the rate of progression and the exact time of appearance after farrowing (Herskin, 2011a). For these studies, a more detailed clinical scale is needed, potentially a 5 point scale similar to that described by Zurbrigg (2006).

Prevention and treatment: Improvements to the farrowing environment, specifically provision of flooring types which promote sow movement (standing, postural adjustment) will aid in prevention. Methods for maintaining sow body condition will also be of benefit, including regular monitoring of BCS and feed systems that promote feed consumption during lactation. Further studies on the use of shoulder pads in preventing ulcers in at risk sows is also warranted. Studies are also needed on the heritability of shoulder ulcers and susceptibility of different North American genetic lines. Current treatments include the provision of soft flooring and application of topical disinfectants. These should be studied in greater depth, and alternative therapies developed and evaluated.

Pain assessment and management: The potential for pain related to shoulder ulcers is an important consideration for sow well-being, and may also benefit the healing process. Detailed studies would be useful to quantify the level of pain (eg. by pressure algometer) in relation to the stage of development of decubital shoulder ulcers. The use of analgesics (NSAIDs) could be examined as an adjunct therapy, and may also be an effective prophylactic treatment for sows at risk, as a preventative measure.

Financial implications: A financial analysis of the costs to industry associated with shoulder lesions will help to highlight the potential benefits to be gained from reducing the problem and assessment of the cost/benefit balance of any therapies proposed. An analysis of this type would aim to quantify such factors as impact of early culling and the sow replacement, medication costs, loss of production, additional labour, and loss of carcass value. Once a detailed economic weighting has to be calculated, shoulder ulcers can also be included in a genetic evaluation.

Sow well-being: Improving the well-being of sows is a central factor in all of the studies described above. In each of the study areas, measures of sow welfare can be included and compared among outcomes. Reducing the prevalence of shoulder lesions is expected to correlate with increased activity (standing, postural adjustment) and feed consumption in farrowing. Improving sow comfort may also be associated with improved gait scores and hoof condition, and could result in reduced piglet mortality by crushing in farrowing. Maintaining a stable body condition should also result in greater productivity and longevity in sows.

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