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# SACROILIAC PAIN IN THOROUGHBRED RACEHORSES: CORRELATION BETWEEN CLINICAL FINDINGS, ULTRASONOGRAPHY, SCINTIGRAPHY, AND HISTOPATHOLOGY

By

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# ABSTRACT

## SACROILIAC PAIN IN THOROUGHBRED RACEHORSES: CORRELATION BETWEEN CLINICAL FINDINGS, ULTRASONOGRAPHY, SCINTIGRAPHY, AND HISTOPATHOLOGY.

By

Ayman H. Mahdaly

The purpose of this preliminary investigation was to investigate the relationship between clinical signs of pain, ultrasonographic findings, scintigraphy, and histopathological lesions in the dorsal sacroiliac ligament and pelvic region of Thoroughbred racehorses. The pelvic region of five racehorses was examined bilaterally and three were determined to have signs of pain and two did not. After ultrasonographic and scintigraphic examination, horses underwent euthanasia, the pelvic region was dissected and examined histologically. Clinical signs were unrelated to ultrasonographic findings but signs of pain in the pelvis were correlated with increased activity on scintigraphic examination. Histopathological observations also were correlated with the results of scintigraphic examination. Particularly evident was the retention of the growth plate of the tuber sacrale in horses showing signs of sacroiliac pain.

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## List of Abbreviations

TB-Thoroughbred

DSIL-dorsal sacroiliac ligament

SI-sacroiliac

TS-tuber sacrale

S2-sacral vertebrae 2

Tc-MDP- technetium-99m- labeled methylene diphosphonate

HDP-hydroxymethylene diphosphonate

RU-radiopharmaceutical uptake

NSAID-non-steroidal anti-inflammatory drug

SID-sacroiliac disease

TC- Tuber coxae

LEAP-low energy all purpose collimator

L6-lumbar vertebrae 6

H & E-hematoxylin and eosin stain

TL-Thoracolamber

# Chapter I: Literature Review

## Overview of Equine Sacroiliac Disease:

Lameness is the most important performance limiting condition of Thoroughbred (TB) Racehorses (Dalin & Jeffcott, 1986). While distal limb conditions are reported to be most common (Reef, 1998), lameness and loss of performance can also be caused by primary back pathology including pain in the thoracolumbar and sacroiliac area (Haussler et al., 1999; Tomlinson et al., 2003).

Poor performance and hind limb lameness in horses have been associated with sacroiliac soft tissues and joint disease (Haussler et al., 1999; Tomlinson et al., 2003, Dyson and Murray, 2003, Jeffcott, 2009). However, currently, there are few studies on the correct diagnosis and treatment of this disorder. Diagnosis of sacroiliac soft tissue and joint disease is very challenging because of the horse's complex anatomy (Dalin & Jeffcott, 1986; Haussler, 2004). The first chapter of this thesis will provide a succinct background on equine sacroiliac disease to facilitate a better understanding of the disease and associated conditions. The second chapter will describe the study of sacroiliac pain in Thoroughbred Racehorses and the correlation between clinical findings such as physical exam score, ultrasonography, scintigraphy, and histopathology. The final chapter will draw conclusions from the research and recommend directions for future work.

**Current Prevalence Rate:**

Sacroiliac disease is a relatively common disorder diagnosed in sport horses that manifest poor performance. This disease is especially associated with horses engaging in high speeds and jumping such as horses in racing sports and other athletic competitions; however, definitive diagnoses involving specific structures are much less common (Dyson & Murray, 2004). Many affected horses are sports horses including hunters, steeplechasers, and jumpers (Dalin & Jeffcott, 1986). In Dyson and Murray's (2003) research paper entitled "Pain associated with the sacroiliac joint: a clinical study of 74 horses", a total of 74 cases of sacroiliac joint disease were recorded over a period of five years (1997-2002). The findings of this research study showed that the types of horses that are at most risk include dressage and show-jumping horses among the normal sample population in the study (Dyson & Murray, 2003).

**Clinical signs of sacroiliac disease:**

Clinical signs of sacroiliac disease are mainly nonspecific. According to previous authors, some of the common clinical signs that can be observed in horses with equine back pain and sacroiliac disease are poor performance, refusal to jump, decreased impulsion of the hind limb, soreness of the back, hesitation to run at a fast pace, alternating lameness of the hind limbs and behavioral response (Jeffcott, 1975, Rooney, 1977, 1979, Dyson & Murray, 2003, Haussler et al. 1999). Other clinical signs include overt lameness and reactive pain response upon palpation in the soft tissues in the area of the tuber sacral, which present as a cute sacroiliac disease (Tomlinson, 2003, Jeffcott, 2009).

According to Jeffcott (2009), chronic sacroiliac disease can present as two major clinical forms. The first is less debilitating as horses respond to analgesics. Clinical signs associated with this form of sacroiliac disease include pain and poor performance. The specific pathophysiologic processes behind this symptomatology are unexplained, but authors have assumed that the pain comes from injury involving the periarticular structures. This assumption is based on the effectiveness, in some cases, of analgesics targeted to this area. As has been observed in 34 horses (Dyson & Murray, 2003), a response showing alleviation of pain suggests that the affected structures are located in the periarticular region in addition to sacroiliac joint.

The second form of sacroiliac disease is associated with pathological joint alterations which are chronic in nature (Jeffcott, 2009). This form is more debilitating because it leads to a more prominent change in gait, in addition to poor performance. Pathological joint changes are associated with asymmetrical muscles and bones of the sacroiliac joint, which can mainly be seen on ultrasound per rectum (Jeffcott, 2009). When given analgesics, horses affected with the second form of sacroiliac disease are found to be less responsive and show no alleviation of pain or very little improvement. These two forms of sacroiliac joint disease suggest the possibility of a disease severity continuum in horses (Jeffcott, 2009). This means that equine back pain associated with diseases is not strictly categorized and treated based on the disease type, but rather, it is treated and managed based on the severity. It is also suggested that the two forms of disease could both exist in the horse and progress from less debilitating to more debilitating as the disease progresses.

A study of 36 TB racehorses from two to nine years old has demonstrated that the incidence of osseous pathology in the SI region is high (Haussler et al. 1999). Mild changes were seen in 8% of cases while moderate changes were identified in 61% and severe pathology was present in 31% of the horses at the time of necropsy (Haussler et al. 1999). Similarly, Stubbs et al. (2010) found that 34/35 TB racehorses examined at necropsy had some degree of sacroiliac disease, with about equal numbers of horses exhibiting moderate and severe osseous pathology.

**Causes of Sacroiliac disease in the horse:**

There is little definitively known about the causes of sacroiliac disease in horses. However, authors have speculated about the causes of the disease based on the presence of lesions. Lesions reported in the sacroiliac area include arthrosis and instability of the sacroiliac joint, desmitis and strain of the sacroiliac ligament, pelvic stress fractures, sacroiliac joint stress and/or fractures, fracture of the ilium, and arthrosis of the lumbosacral joint (Jeffcott, 1975; Rooney, 1977, 1979; Marks, 1999; Dyson et al. 2001). Muscle and ligament damage account for much of the soft tissue injury in the equine back, with the DSIL commonly involved (Jeffcott, 1975; Rooney, 1977, 1979; Marks 1999; Dyson et al., 2001; Tomlinson et al., 2003). Based on these lesions, authors have speculated on possible causes. For example, it has been asserted that the DSIL can be injured by the high force exerted by the hind limbs on the ligament during acceleration, causing DSIL strain (Denoix, 1996), traumatic injury such as falling over backward

(Haussler et al. 1999), and/or repetitive cyclical loading from galloping at high speeds in training and racing.

**Sacroiliac Anatomy:**

The pelvic region of the horse has many complex anatomical features. The hind quarters of the horse have huge overlapping muscles that make most of the bony parts difficult to assess. Its depth makes it hard to palpate structures during clinical examination and difficult to view by use of diagnostic imaging. For example, it is difficult to obtain good images of the sacroiliac joint from radiographic examinations performed in this area. Consequently, it is difficult to arrive at a specific anatomical diagnosis of sacroiliac disease in the horse.

Pain in the SI region may arise from many structures including the sacroiliac joint and associated soft tissues, the dorsal sacroiliac ligament (DSIL), the tuber sacrale and associated epiphysis, the lumbosacral and facet joints, the lumbosacral intervertebral disc, the middle gluteal, longissimus dorsi muscle and associated thoracolumbar fascia. When studying sacroiliac pain in horses, it is important to understand the anatomy of the sacroiliac region. The bony structures involved in sacroiliac disease are pelvic bones, sacrum, and sacroiliac joints as Figure 1a illustrates.

The sacroiliac joint connects the ventral side of the ilium, the ilial wing, with the dorsal side of the sacral wing. The sacroiliac joint is classified as an amphiarthrodial joint. The sacral surface is lined by hyaline cartilage, while the ilial surface has fibrocartilage, thereby limiting motion (Engeli et al., 2006). The SI joint is exposed to high forces, particularly during jumping and galloping at high speed, which may predispose it to injury (Dyson & Murray, 2003). This joint is stabilized by soft tissues including the three ligaments in the sacroiliac region see (Figure 1b). These ligaments are the DSIL, the interosseous SI ligament, and the ventral sacroiliac ligament (Goff et al., 2008). The DSIL has two branches, a short and a long branch. The short branch inserts on the tuber sacrale and terminates on the lateral summit of the sacral spinous processes (S2-4). The long branch is a thin sheet, triangular in shape, that covers the sacrocaudal and multifidus muscles (Kersten & Edinger, 2004). The interosseous SI ligament, located between the ilium and the sacral wings, supports the sacrum (Kersten & Edinger, 2004). The ventral sacroiliac ligament runs between the sacrum and ilium and supports the joint capsule of the sacroiliac joint (Kersten & Edinger, 2004; Tomlinson et al., 2001; Engeli et al., 2006; Tomlinson et al., 2003, Van Wessum, 2009).

The sacroiliac joint is a fusion point for the sacrum and the ilium. Their junction is considered a synovial joint with unusual characteristics. This joint is unique because it is formed by a point of contact between two different surfaces - the sacral surface lined with a hyaline cartilage and the iliac surface with a fibrocartilagionous surface. In most synovial joints, both surfaces usually are lined with hyaline cartilages (Dalin & Jeffcott, 1986, Cassidy & Townsend, 1986; Haussler, 2004; Jeffcott, 2009).

The different muscles that support the pelvis are the middle gluteal muscle, superficial gluteal muscle, biceps femoris, semitendinosus, and semimembranosus (Figure 1c) (Haussler, 2003, Bainbridge, 2009). The middle gluteal muscle originates from the thoracolumbar fascia at the level of the first lumbar vertebrae and concavity of the dorsal aspect of the ilium and the lateral iliac wing up to the first sacral vertebra and it supports the cranial part of the underlying sacrosciatic ligament (Haussler, 2003, Bainbridge, 2009). The superficial gluteal muscle originates from the gluteal fasciae and the tuber coxae. The biceps femoris originates from the sacrum, ischial tuberosity and the lower half of the linea aspera of the femur and inserts on the crural fascia with its tarsal tendon (Henson, 2009). The biceps femoris supports the knee flexion, lateral rotation of the leg, and hip extension. The semitendinosus and semimembranosus originate from the ischial tuber (Haussler, 2003). The semitendinosus inserts on the tibia with its tarsal tendon on the calcanean tuber and the semimembranosus inserts on the medial condyle of femur and tibia (Haussler, 2003). The semitendinosus muscle and the semimembranosus muscle support knee flexion, hip extension, and medial rotation of the leg (Haussler, 2003).

The iliopsoas muscle is also an important structure in achieving stability of the sacroiliac joint stability and function. The iliopsoas muscle originates from the transverse processes and sides of the bodies of T12 and L1-L5 as well as the anterior aspect of the ilium (Watkins, 2009). Its point of insertion is at the lesser trochanter and it is involved in the flexion of the hip joint (Watkins, 2009). The iliopsoas muscle connects the dorsal portion to the ventral aspect of the body musculature to maintain vertebral stability and positioning of the back (Henson, 2009).

The middle gluteal muscle is an important of supporting the underlying bony and ligamentous structures in the sacroiliac area. Thus, it is highly possible that the alterations in the surrounding muscle tissue can cause the decreasing flexibility of the sacroiliac joint leading to pain and poor performance in horses. In relation to sacroiliac joint disease, functional instability of the sacroiliac joint occurs when the surrounding soft tissues and musculature are unable to provide resistance for movement in the joint (Goff et al., 2008). The alterations in the associated musculature in the sacroiliac area causing the disorder is more commonly categorized as the chronic type of sacroiliac joint disease (Goff et al., 2008).

**Function of the Sacroiliac Joint:**

The function of the sacroiliac joint was first studied in people. Goode et al. (2008) performed a systematic review of the published literature identifying the three-dimensional movements of the sacroiliac joint. Joint mobility was studied in different positions, both static and in motion. This was done in order to determine significance of positioning of the sacroiliac joint during assessment and examination. Results showed that rotation is possible between -1.1 to 2.2 degrees along the horizontal plane. Vertical movement ranged between -0.8 to 4 degrees and diagonal movement ranged between -0.5 to 8 degrees. Movement is also allowed between -0.3 to 8 mm (horizontal), -0.2 to 7 (vertical) and -0.3 to 6 (diagonal). These findings suggest minute movements of both rotation and translation. Clinically, this implies that position changes using rotational and translational movements of the sacroiliac joints, which have limited use because the movement allowed in this joint is very small (Goode et al., 2008).

Studies of sacroiliac joint function in horses followed human studies. Because of the morphology of the sacroiliac joint, its movement is quite limited. This limitation in movement is unlike many other synovial joints. The sacroiliac joint is mainly used for gliding and not for weight-bearing. Accordingly, the sacroiliac joint is exposed to shearing forces instead of compressive forces (Ekman et al., 1986, Dalin & Jeffcott, 1986, Goff et al., 2008). Its main role is to transfer compressive forces from the hindquarters of the horse to the thoracolumbar vertebral column (Denoix, 1996). While subjected to these forces, biomechanical stability of the joint must be maintained. Joint stability is maintained by the use of strong ligaments, namely, the dorsal and ventral sacroiliac ligaments, and the interosseous sacroiliac ligaments. The sacroiliac joints of horses, especially racehorses, are subjected to large forces during athletic activities such as racing. This is one probable cause of low back pain in horses.

**Sacroiliac Range of Movement:**

The range of motion of the sacroiliac joint is not well studied. However, in relation to basic human anatomy, the sacroiliac joint is meant for gliding movements only. This is due to the anatomical position and composition of the bony structures connecting the joint as well as the surrounding supporting structures. These structures are closely linked together allowing minimal movement in the area to maintain balance. A study conducted by Degueurce, Chateau, and Denoix (2004) confirmed that the sacroiliac joint is capable of only small movements. This movement is accompanied by a flexion of the lumbosacral joint. This means that every time the sacroiliac joint moves, the angle of lumbosacral joint decreases. The ligaments surrounding the sacroiliac joint maintain the stability of this joint. This report also noted that studying the range of movement of the sacroiliac joint is difficult because of its limited movement (Degueurce et al., 2004).

Goff et al., (2006) measured "relative" sacroiliac joint motion with respect to the passive joints constraints by noting the change in the cross-section of the dorsal side of the dorsal sacroiliac ligament upon subjecting to manual forces. A comparison of the change in motion was performed between normal horses and those with diagnosed sacroiliac joint disease. The magnitude and direction of motion was measured before and after the DSI ligament was removed. It was found that the range of motion was greatly increased when the ligaments were removed. Thus the ligaments are an essential primary passive constraint that limits sacroiliac joint motion (Goff et al., 2006). The greatest range of motion was in the dorsal plane, however the range of motion increased the greatest in the sagittal plane after the dorsal sacroiliac ligament and sacrotuberous ligament were resected (Goff et al., 2006). It was shown that there is a decrease in the cross-sectional area of the dorsal sacroiliac ligaments when manual forces are applied to the tuber coxae and the tuber sacral, a provocation test often used by physiotherapist to assess the functional integrity of the ligament. These findings suggest that the main function of the dorsal sacroiliac ligament is to limit the sacroiliac joint motion along with being a primary proprioceptive structure, as is reported in the clinical literature (Henson, 2009).

**Clinical examination:**

This section provides a discussion on different physical assessment or examination techniques used to assess and aid in diagnosis of SI lameness in horses. Various techniques are available, with the possible responses of horses discussed in relation to the interpretation and meaning.

Physical examination of the sacroiliac region includes the subjective analysis of the horse's conformation and posture, palpation, provocation tests, and evaluation of the horse's motion via subjective gait analysis including; walking or trotting in a straight line (hard and soft), walking in serpentine, turning short, walking and trotting in circle (hard and soft), and cantering in circle in soft surfaces. Muscular and skeletal lumbosacral and pelvic symmetry including the position of the tuber sacrale, tuber coxae, ischium and sacrum in the sagittal (medial), transverse (axial) and the dorsal (coronal) planes are noted statically and during motion tests. Muscle development and wastage of the lumbosacral and hindquarter region including longissimus dorsi, middle gluteal and biceps femoris muscles are also evaluated. Possible observations will include elevation of the tuber sacral plus/minus muscle wastage, lowered tuber sacral plus/minus muscle wastage, lowered tuber coxae plus/minus muscle wastage, and lowered tuber ischii plus/minus muscle wastage (Haussler, 2003).

A full body palpation exam is performed to detect any abnormality such as heat, swelling/effusions, digital pulses, skin lesions, and superficial irritability of the myofascia. A lameness evaluation including hoof tester examination of the sole (body, branch, and angle), hoof wall (dorsal, collateral, heel and bar), and frog (apex, body, branch, central cuneal sulcus, and paracuneal culcus) is also applied. Provocation tests are also performed which include flexion tests of the right and left front limb isolating the (fetlock and carpus) and right and left isolating the (fetlock and hock/stifle), as well as abduction test of the hind legs isolating the (pelvic limbs, left sacral and sacroiliac joint). Full body soft tissue examination is applied with superficial, middle and deep palpation of the myofascia and ligamentus system. Soft tissue "rating" is done based on tissue irritability of the entire body and regions of pain and/or behavioral responses that occur with tissue provocation specific to the lumbopelvic region (Haussler, 2003).

Gradual compression of both tuber sacrale and dorsal sacroiliac ligament (DSIL) was applied simultaneously, then unilaterally. A positive response will be recorded if the horse demonstrated sudden limb flexion and inability to stand. The response could also be behavioral in nature in which there is a marked muscle fasciculation or spasm, which is also considered a positive response. The horse's response will be recorded as negative if there is only minimal fasciculation and slight extension of the lumbosacral joint with no behavioral response. Relative pain response was also assessed by putting rhythmic dorsal pressure over the dorsal spinous process of the $5^{th}$ and or $6^{th}$ lumbar and $2^{nd}$ sacral vertebrae. A negative response will be recorded if the dorsal ventral movement occurring at the lumbosacral joint is less than or equal to 1-2 cm with barely undetectable motion of the sacrum, no signs of pain and muscle spasm or behavioral responses. On the other hand, a positive response will be noted it there is noticeable pain and presence of movements and protective muscle spasms (Haussler, 2003).

Gradual manual pressure was applied with the heel of the examiner's one hand over the left or right (unilateral only) DSIL and the tuber sacrale (TS) with the force application directed to the ventrolateral plane. This action will elongate the DSIL relative to the S2 attachment. This test is called the DSIL provocation test. A positive response will be recorded if there is noticeable pain, presence of movement, and protective muscle spasms. The examiner should also be attentive in looking for relative laxity between the left and right. On the other hand, negative response will be recorded if there is no noticeable pain, absence of protective muscle spasm, and integrity/length of left and right is equal (Haussler, 2003).

**Diagnostic Imaging of the Sacroiliac region:**

Diagnostic imaging studies performed in the sacroiliac region of horses include scintigraphy, ultrasonography, and radiography. As discussed earlier, the assessment of the sacroiliac region is very difficult because of its complex anatomical structure and large tissue mass (Henson, 2009; Dyson, 2004). Nevertheless, diagnostic imaging helps in identifying alterations and abnormalities in the bone and soft tissue structures of the horse that may aid in the treatment and management of the sacroiliac disease.

**Scintigraphy:**

Scintigraphy is based on the functional distribution of radiopharmaceutical uptake in the body. Bone scintigraphy relies on the metabolism of the bone in order to be effective so that nuclear scntigraphic images reflect physiological function rather than anatomical structure (Weaver et al., 1999). In this diagnostic imaging technique, radioactive material, which is technetium-99m (99mTc) – binded with methylene diphosphonate (MDP) or hydrixymethylene diphosphonate (HDP), is injected intravenously. The agent is then distributed around the body via the circulatory system. The radioactive material attaches to exposed hydroxyaptite within osseous structures. The uptake of the radionuclide is relative to the osteoblastic activity and/or metabolism of the bone and the blood flow to the bone. The gamma camera responds to the radiation released by the radioactive material and shows regions of activity. When the radioactive material localizes in the bone, images are obtained due to the static nature of the radioactive material. Abnormalities in the bones such as tumors and fractures are seen as increased uptake (Martinelli & Chambers, 1995).

Nuclear scintigraphy is useful to identify sacroiliac joint disease. However, findings derived from this technique are nonspecific. Therefore, diagnosis is based on presenting symptoms in combination with the results of the scintigraphy (Goff et al., 2008). In a study conducted by (Dyson et al., 2003), radiopharmaceutical uptake (RU) obtained from the nuclear scintigraphy were compared between normal horses of varying age. The authors hypothesized that there is a difference in the RU with the age. It was observed that RU in the tuber sacrale decreases with increasing age. However, there is no change in RU in the sacroileal joint. These findings suggest that when interpreting a nuclear scintigraphic study, findings must be compared to those of age-matched control horses. Furthermore, evaluation of symmetry is also useful in the interpretation of scintigraphic studies. If a result shows significant asymmetry, it is likely that the examined horse has abnormal sacroiliac region (Dyson et al., 2003).

In another study, the relationship between radiopharmaceutical uptake and radiographic appearance was investigated through a retrospective approach. A total of 79 horses subjected to nuclear bone scintigraphy because of manifested lameness and poor performance were included in the study. Findings suggest that there is a significant relationship between RU and radiographic appearance of the examined horses. The study concluded that the sacral bones conformation is reflected in the radiographic appearance and may affect radiopharmaceutical uptake (Gorgas et al., 2009). The studies summarized above demonstrate that while scintigraphy has its limitations, it is potentially a useful technique in the diagnosis of sacroiliac disease in horses. One of the objectives of the study described in Chapter 2 is to determine the value of scintigraphy in the evaluation of sacroiliac disease of the horse.

**Ultrasonography:**

In a study conducted by Engeli, Yeager, Erb, & Haussler (2006), the normal ultrasonographic appearance of the sacroiliac region in horses was described. In order to do this, 10 normal adult horses underwent percutaneous ultrasonography in a cephalocaudal direction. The structures in the pelvic region including the tuber sacrale, ilial wings, dorsal sacroiliac ligaments were examined in detail. After the imaging study, the horses were euthanized in order to perform dissection. The lumbosacropelvic region was dissected in six horses. Gross findings upon examination were compared with ultrasonographic findings. Important findings of this study were that histologic findings of the portion of the dorsal sacroiliac ligament at the joint region and throracolumbar fascia correspond with the ultrasonographic findings (Engeli et al., 2006).

Tomlinson, Sage, Turner, and Feeney (2001) verified the ultrasonographic findings in detailed mapping of the equine anatomical sacroiliac region by comparing the images with computed tomography, magnetic resonance imaging, and measurement of frozen cadaver slices. Six normal horses were subjected to ultrasonography of the pelvis. Other confirmatory diagnostic imaging studies were performed after death of the animals. Correlation was done through linear regression. Results showed that there is a significant relationship between ultrasonography and the stated tests used to verify its findings. This implies that ultrasonography is a valid and accurate measure of the skeletal and muscular structures of the equine pelvis (Tomlinson et al., 2001). For this reason, ultrasonography as a diagnostic tool is used in the study described in Chapter II.

**Radiography:**

Radiography provides multiple positional views of the pelvic region of the horse. The ventrodorsal view of the sacroiliac joint can be viewed through this imaging study. The horse should be put under general anesthesia in order to perform this examination. Anesthesia reduces the blurring effect that would be present if the horse is not immobile under anesthesia. The radiographic appearance of the sacroiliac joint is well described. To perform the diagnostic procedure, the horse is placed in a dorsal recumbent or supine position. The beam of the radiograph is positioned at the center to ensure that it strikes the pelvis in a 90-degree angle or caudocranial (less than 10-degree angle) to the sacroiliac joint (Henson, 2009).

Radiographic images of the sacroiliac joint lack detail because of the complex anatomical structure, structure overlap, and the large tissue mass. The radiographic technique implemented in obtaining radiographs of horses has been described. The study selected 79 horses to undergo radiography (Gorgas et al., 2007). A technique employed in this study to create diagnostic quality images is the use of ventilation-induced blurring technique. This technique is done by performing active ventilation in the abdominal viscera during exposure to cause movement and radiographic blurring. Through this technique, radiographs obtained were in diagnostic quality and the structures of the sacroiliac region were distinct. This technique was used because the horses in this study were immobile because they were under anesthesia. In line with this, a trend in the width and size of the sacral wings was a correlated gender of the horse. Females have narrower sacral wings while males have broader sacral wings and bony prominences (Gorgas et al., 2007). This technique was not used in the current study because images produced from radiography are not very detailed. This diagnostic imaging would require active ventilation to increase chances of having good quality images.

**Treatment of Equine Sacroiliac Disease:**

There are many proposed treatments for sacroiliac disease because of the difficulty of arriving at a definitive diagnosis and the specific structures involved. A wide variety of procedures are available to provide pain and inflammatory relief in horses with sacroiliac disease. However, treatment efficacy is largely untested because few efficacy studies have been conducted. In equine veterinary medicine, evidence-based practice in the lumbopelvic and sacroiliac region is quite new, with treatment and management regimese mainly based on human studies of conditions that resemble sacroiliac disease in horses (Jeffcott, 2009).

In acute sacroiliac disease, the main goal of treatment is pain relief by alleviation of inflammation at the injured site. Prolonged rest is recommended that should last for 4-6 weeks and should be strictly maintained inside the horse's stall. Only hand walking is allowed as this level of exercise only involves minimal movement. Systemic nonsteroidal anti-inflammatory drugs (NSAIDs) are also given. The recovery and rehabilitation period is expected to last for 6-12 months (Jeffcott, 2009; McGowan et al., 2007).

In chronic sacroiliac disease, rest and use of NSAIDs are also recommended. However, complete rest is contraindicated in this condition because this may lead to deconditioning of the pelvic and hind limb musculature which will only worsen the condition. The most important goal of management in chronic sacroiliac disease is rehabilitation so that there would be no more worsening of the disease (Jeffcott, 2009).

Treatment and management options for horses are based on clinical manifestations. For instance, consider a horse which shows limited ability to move the affected side and a horse which shows only minor manifestations of the disease. The former would most likely be given the treatment which is appropriate for that degree of the effect of the disease. These treatments include rest, use of NSAIDs, prolotherapy (a method of injecting a solution to the body, usually at joints and tendons, to strengthen the tissue) and exercise. An important reminder in the alleviation of pain among horses is that while rest helps in reducing pain, complete rest is contraindicated. Complete rest will result in the reduced functionality of the hind limb which will only worsen the lameness and poor performance exhibited due to sacroiliac joint disease (Haussler, 2003).

Similar in humans, a specific rehabilitative program is important for recovery and achievement of optimal functionality in horses. The rehabilitative program should be constructed based on individual findings from the diagnostic procedures that will tell the existing bone abnormality in the horse (Dyson & Murray, 2003). Rehabilitation program will result in a long-term improvement and maintenance of the horse.

Localized periarticular anesthesia is an alternative medication treatment in horses with sacroiliac joint pain. This is because injection of analgesia in the intra-articular region is not recommended in horses because of the inaccessibility of the sacroiliac joint (Haussler, 2003). However, one of the possible side effects of regional anesthesia is reduced motor function. This means that paralysis will be manifested in the motor structures in the periarticular area. This area includes the supporting muscles, ligaments, and nerves of the sacroiliac joint. Thus, the innervation and neuromotor control of the joint will be compromised (Engeli et al., 2006). This will increase the likelihood that nerve transmissions and signals could be altered into producing negative effects such as adverse motor movements by way of the sacroiliac joint.

Exercises to strengthen the back and hindquarters' musculature are also recommended as appropriate management technique for equine sacroiliac joint pain (Jeffcott & Dalin, 1986). The limitation of this proposed exercise is that little is known about specific exercises that could build up muscle strength in the affected area. Exercises are limited to nonspecific exercises that do not mainly target the sacroiliac joint. This implies the need to further investigate muscle training specific to strengthening and optimizing motor and functional control of the sacroiliac joint area. This will eventually lead to maximum functioning which will improve performance of those horses that had manifested lameness and poor performance. Studies on specific muscle training of the human sacroiliac joint may be used as empirical basis in forming similar exercises that will target equine sacroiliac joint (Richardson et al., 2002).

## Chapter II: Sacroiliac Pain in Thoroughbred Racehorses: Correlation between Clinical Findings, Ultrasonography, Scintigraphy, and Histopathology.

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### Introduction:

Lameness is the most important performance limiting condition of Thoroughbred (TB) racehorses (Jeffcott et al., 1982; Rossdale et al., 1985; Robinson and Gordon, 1988; Wilsher et al., 2006; Parkin, 2009). While distal limb conditions are reported to be most common (Rossdale et al., 1985; Mohammed et al., 1991; Marr et al., 1993; Colbourn and Yovich, 1994; Reef, 1998; Ely et al., 2009) lameness and loss of performance can also be caused by primary back pathology including pain in the thoracolumbar and sacroiliac area (Jeffcott et al., 1982; Haussler et al., 1999; Tomlinson et al., 2003).

The diagnosis of diseases in the thoracolumbar and pelvic region is challenging because the anatomy is complex, large muscles overly the area, and clinical signs are often nonspecific (Jeffcott., 1985; Haussler, 2004). In most cases, the diagnosis is made by exclusion of other conditions, such as hindlimb lameness, thoracolumbar pathology, and metabolic and neurological disorders (Jeffcott and Dalin, 1985; Dyson, 2003; Tomlinson et al., 2003). Compared to distal limb pathology, there is relatively little known about lesions that cause pain and dysfunction in the sacroiliac region (SI) (Dyson and Murray, 2003; Tomlinson et al., 2003; Haussler, 2004; Goff et al., 2008). A study of 36 TB racehorses from 2-9 year-old has demonstrated that the incidence of osseous pathology in the SI region is high. Mild changes were seen in 8% of cases while moderate changes were identified in 61% and severe pathology was present in 31% of the horses at the time of necropsy. Similarly, Stubbs et al., (2010) found that 34/35 TB racehorses examined at necropsy had some degree of sacroiliac disease, with about equal numbers of horses exhibiting moderate and severe osseous pathology.

Pain in the SI region may arise from many structures including: the sacroiliac joint and associated soft tissues, the dorsal sacroilliac ligament (DSIL), the tuber sacrale, the lumbosacral joint, and the middle gluteal muscle. The middle gluteal muscle is very large in the horse, and covers a region from the first lumber vertebra cranially extending caudally to the second sacral vertebra and greater trochanter. The tuber sacral (TS) is the highest point of the SI region which may be traumatized during a fall. The sacroiliac joint is classified as an amphiarthrodial joint. The sacral surface is lined by hyaline cartilage, while the ilial surface has fibrocartilage, thereby limiting motion (Haussler 2004). The SI joint is exposed to high forces, particularly during jumping and galloping at high speed, which may predispose it to injury (Dyson and Murray, 2003). This joint is stabilized by soft tissues including the three ligaments in the sacroiliac region. These ligaments are the DSIL, the interosseous SI ligament, and the ventral sacroilliac ligament (Goff et al., 2008). The DSIL has 2 branches, a short and a long branch. The short branch inserts on the tuber sacrale and terminates on the lateral summit of the sacral spinous processes (S2-4) (figure 3a). The long branch is a thin sheet, triangular in shape, that covers the sacrocaudal muscles (Kersten and Edinger, 2004). The interosseous SI ligament, located between the ilium and the sacral wings, supports the sacrum (Kersten and Edinger, 2004). The ventral sacroiliac ligament runs between the sacrum and ilium and supports the joint capsule of the sacroiliac joint. Only the DSIL can be easily palpated and evaluated via transcutaneous ultrasonography (Kersten and Edinger, 2004; Tomlinson et al, 2001; Engeli et al, 2006; Tomlinson et al, 2003).

Lesions reported in the sacroiliac area include arthrosis and instability of the sacroiliac joint, desmitis and strain of the sacroiliac ligament, pelvic stress fractures, sacroiliac joint stress and/or fractures, fracture of the ilium, and arthrosis of the lumbosacral joint (Jeffcott 1975; Rooney 1977, 1979; Marks 1999; Dyson et al., 2001; Tomlison et al., 2003). Muscle and ligament damage account for much of the soft tissue injury encountered in the equine back, with the DSIL commonly involved (Jeffcott 1975; Rooney 1977, 1979; Marks 1999; Tomlison et al., 2003). The DSIL can be injured by the high force exerted by the hind limbs on the ligament during acceleration, causing DSIL strain (Denoix, 1996), traumatic injury such as falling over backward (Haussler, at al 1999) and/or repetitive cyclical loading from galloping at high speeds in training and racing.

Traditionally, a diagnosis of sacroiliac disease was made with a combination of clinical examination and radiography (Denoix 1996). Asymmetry of the tuber sacrale has been interpreted as a sign of sacroiliac disease but this finding is not specific (Turner

2001; Tomlinson 2003). Other nonspecific clinical signs attributed to SI disease include mild or chronic hind limb lameness, poor hindlimb impulsion, behavioral changes and poor performance (Jeffcott 1980; Dyson S, 2003; Goff et al., 2008).

Radiographic examination of the SI region is most effective with horses in dorsal recumbency under general anesthesia. However, anesthetic recovery of horses with SI disease is associated with additional risks. Chronic strain of soft tissues in the SI area causes pain; however there are minimal to no radiographic changes associated with these lesions, making radiographic diagnosis difficult (Jeffcott 1983). Nuclear scintigraphy is also used to diagnose sacroiliac remodeling in horse. However, increased radiopharmaceutical uptake using methylene diphosphonate in the sacroiliac region is not specific for soft tissue or bone injury (Tucker et al., 1998; Goff et al., 2008). Thermography can indirectly show active inflammation through increased heat generated by increased blood flow, but is also not specific in defining the cause. Ultrasonography provides specific diagnostic information about bone surfaces, such as fracture of the tuber coxae, wing and shaft of ilium as well as irregularities of the tuber sacrale (Pilsworth et al., 1994, Tucker et al., 1998, C. Erichsen, 2004), and also provides information about soft tissue abnormalities such as DSIL desmitis (Denoix, 1996; Tomlison et al., 2003; C. Erichsen, 2004).

The relationships between ultrasonographic, scintigraphic, gross pathologic, and histopathologic findings of DSIL and tuber sarcal have not been described in detail. The purpose of the current study is to describe the findings from theses diagnosic modalities in 3 Thoroughbred race horses with clinical signs of musculoskeletal pain referable to the sacroiliac region compared to 2 horses without sacroiliac pain. Our hypothesis is that Thoroughbred race horses with sacroiliac pain have ultrasonographic and scintigraphic findings that correlate with gross pathology and histopathology. In addicton to that, pelvic lesions in horses with sacroiliac pain differ from those in non-painful Thoroughbred race horses.

**Material and methods:**

Five Thoroughbred race horses (4 mares, 1 gelding; mean age 5.8, age- range 3-9 years), weighing a mean of 1149.4 lbs (1013-1260 lbs) were used in this study. Three horses had clinical signs of pain/dysfunction in the sacroiliac region (affected), while 2 horses had no clinical signs of sacroiliac pain (control). All horses had raced within the past 2 years. In this study, the sacroiliac area was defined as the sacrum, tuber sacrale, sacroiliac joint and dorsal sacroiliac ligament. Horses were evaluated by use of clinical examination, ultrasonogry, scintigraphy, gross anatomy and histopathology. The study was approved by the institutional of Animal Care and Committee Use at Michigan State University.

**Clinical examination:**

The horses were examined by two veterinarians and a physiotherapist. A general clinical examination was performed in all horses. Respiratory rate, heart rate, rectal temperature, mucous membranes, body score, and muscle fitness score were noted. Horses were categorized into two groups, Group "A" (suspected SID; n=3) or Group "B" (no clinical signs of sacroiliac pain (control); n=2). Horses were included in the Group "A" when they had pain on palpation of DSIL and pain on a DSIL Provocation test. In the latter test, gradual manual pressure is applied with the heel of the examiners hand over one DSIL and tuber sacrale (TS) with the force being directed in the ventrolateral plane. Furthermore, group "A" horses had at least 3 out of the following 6 relevant findings related to SID: 1) asymmetry of TS; 2) atrophy of hindlimb muscles; 3) pain on palpation of middle gluteal muscle; 4) pain on dorso-ventrally direction pressure over the dorsal spinous processes of $6^{th}$ lumbar and $2^{nd}$ sacral vertebrae; 5) pain on dorso-ventrally direction pressure over TC; 6) positive respond of proximal limb flexion test; Horses in group "B" did not have had pain on palpation of DSIL or pain on a DSIL Provocation test. Furthermore, the side of the pain (left or right) was used to characterize abnormal DSIL compared to normal DSIL.

**Ultrasound examination:**

Horses were sedated with xylazine or dexmetatomidine (0.01 mg/kg IV). The hair on the skin overlying the sacroiliac region was clipped in an approximately 20 x 20 cm region centered on the TS. The exposed skin was cleaned and contact transmission gel was applied. The horse was placed to stand squarely on both hind limbs thereby reducing asymmetry and uneven tension on the sacroiliac ligament during the ultrasonographic examination. Sagittal and transverse images over the tuber sacrale were used to image the dorsal sacroiliac ligament, thoracolumbar fascia and bone margins. Percutaneous ultrasonographic evaluation was performed in a cranial to caudal direction. The probe was place on the dorsal midline over the lumbosacral junction, 5 cm cranial to both TS. The probe was then slowly moved caudally until the TS appeared in the image. Both TS then were evaluated for left and right symmetry, which include assessment of height and shape and TS bone surfaces. The DSIL was examined from its attachment on the TS to 2-3 cm caudal. The DSIL was evaluated for echogenicity and linear fiber (Figure 2b). At least three images were analyzed per area. All images were made and analysed by 2 people including board certified radiologist (Dr. Anthony Pease). Ultrasound analysis included measurements of the thoracolumbar fascia and DSIL as well as fiber pattern and echogenicity. The fiber pattern and echogenicity was graded on a scale of 0-3 as described below.

**Fiber pattern**

- 0 = 76-100% parallel fiber alignment
- 1 = 51-75% parallel fiber alignment
- 2 = 26-50% parallel fiber alignment
- 3 = 0-25% parallel fiber alignment

**Echogenicity**

- 0 = none present
- 1 = mild (slightly hypoechoic area)
- 2 = moderate (50% anechoic)
- 3 = marked (more than 50% anechoic Echogenicity)

**Scintigraphy:**

The horse was injected intravenously with the radiolabeled pharmaceutical 150 mCi (99m Tc-MDP). After the injection, the horse was placed in a secure stall for two hours and bone phase images were acquired. Immediately prior to the study, the horse was tranquilize with xylazine or dexmetatomidine (0.01 mg/kg IV), and imaged with rectangular 60 cm/ 38 cm LEAP gamma camera, with a low energy general purpose collimator. The horse was placed to stand squarely on both hind limbs for imaging the pelvis. A dorsal view of the TS, oblique images of the ilial wings and lateral images of the pelvis were obtained as close as possible to the horse. A 91 sec acquisition was acquired using a 256 x 256 matrix. Regions of interest over the tuber sacrale and sacroiliac joints were analyzed. Specifically, scintigraphic activity of the region of interest was compared to the contralateral side. When activity on the region of interest differed by less than 10%, a score of 0 was assigned to this region. If the difference between regions was more than 10% a score of 1 was assigned to this region.

**Necropsy:**

Horses were euthanized by use of an IV injection of pentobarbital (86 mg/kg). The sacroiliac region was isolated by separating the lumbosacral junction (L6 and S1) and the sacroiliac joint (the junction between the dorsal sacral wing and the ventral pelvis ilium wing). The left and right DSIL were removed together. The cranial incision was made 5 cm from the cranial edge of the TS, while the caudal incision was 15 cm caudal to the first incision. The presence of lesions was recorded.

**Histopathology:**

The dorsal portion of the right and left dorsal sacroiliac ligaments (DSIL) was fixed in 10% neutral buffered formalin for at least 24 hours. Between 2-3mm thick cross and longitudinal sections were cut every 1cm of the length of the ligament. These sections were routinely processed and embedded in paraffin wax. Five micron (μm) serial sections were cut and stained with hematoxylin and eosin (H & E). Each histologic section of ligament was routinely examined via light microscopy by a board certified pathologist and assessed for the presence of the following lesions: 1) thinning or waviness of collagen fibers; 2) increased interstitial fibrosis; 3) interstitial edema; 4) increased interstitial vessels; 5) increased interstitial adipose tissue; 6) neural or perineural edema; 7) inflammation; 8) presence of fibrocartilage 9) bony metaplasia; 10) mineralization, and 11) degeneration or necrosis of the collagen fibers or the adjacent skeletal muscle. Each of these lesions was subjectively scored on a scale of 0-3 (0 = not present; 1 = mild; 2 = moderate; 3 = severe). In addition, the presence of hemosiderin pigment and hemorrhage was each indicated as present (score of 1) or absent (score of 0). Any additional lesions were recorded as well.

Both the right and left tuber sacrale growth plates were fixed in 10% neutral buffered formalin for at least 24 hours and then placed in Decal® for decalcification until the specimen was sectioned. Upon adequate decalcification, the specimen was sectioned so that a 3mm thick longitudinal section of the growth plate can be placed in a cassette for routine processing and embedded in paraffin wax. Five micron (μm) serial sections were cut and stained with hematoxylin and eosin (H & E). The histologic section was routinely examined via light microscopy by a board certified pathologist. The growth plate were assessed for inflammation and abnormal retention of the growth plate and scored on a scale of 0-3 (0 = no retention of the growth plate; 1 = mild retention and irregularity of growth plate; 2 = moderate retention and irregularity of growth plate; 3 = severe retention and irregularity of growth plate). The surface of the tuber sacrale where the DSIL attaches was also assessed for any irregularity in the transition from collagen to fibrocartilage to the bone of the tuber sacrale. Any additional findings were recorded as well.

**Data analyses/Results:**

Ultrasonographic, and histologic data were obtained from 30 regions (five horses, two sides, three regions per side). These findings, as well as clinical examination findings were scored based on normal =0; mild =1; moderate = 2; severe = 3. For the DSIL, the maximum score for each ligament was used in the analysis. Scintigraphic findings were scored normal =0; abnormal =1. For scores derived from the 0-3 scale, 0 or 1 was considered not clinically significant, and these scores were converted to 0. Scores 2 and 3 were considered clinically significant and these scores were converted to 1. The sensitivity and specificity of these scores in predicting pain in the affected side was determined with the following formulas:

*Sensitivity = number of true positive / (number of true positive + number of false negatives)*

*Specificity = number of true negatives / (number of true negative + number of false positives)*

Pain on palpation over the tuber sarcale was used as the true positive (TP) or gold standard to determine if SID is present. When determining the clinical relevance of the diagnostic modalities, all results were assessed against the TP. The DSIL thickness in the longitudinal view at three separate sites, and cross-sectional area in the cross-sectional view at two separate locations were recorded. Data reported are the average of these three and two measurements respectively in the cranial, middle and caudal regions when possible.

**Clinical examination**

TABLE 1: Summary of signalment and clinical signs of horses used in this study.

| Case | Age | Sex | Weight (lb.) | Clinical signs |
|---|---|---|---|---|
| 1 | 9 | M | 1260 | • Asymmetry of the pelvic L>R<br>• R middle gluteal, biceps femoral atrophy<br>• Pain on palpation of R DSIL(3/3)<br>• Pain on DSIL provocation test of R DSIL<br>• 3/5 LH lameness |
| 2 | 3 | F | 1114 | • Asymmetry of the pelvic R>L<br>• L biceps atrophy<br>• Pain on palpation of R DSIL(1/3) and L DSIL (2/3)<br>• Pain on DSIL provocation test of L DSIL<br>• 3/5 RH lameness |
| 3 | 5 | F | 1170 | • Asymmetry of the pelvic R>L<br>• R biceps atrophy<br>• Pain on palpation of R DSIL (2/3) and L DSIL (1/3)<br>• Pain on DSIL provocation test of L DSIL<br>• 3/5 RH lameness |
| 4 | 6 | F | 1013 | • No muscle atrophy<br>• No pain on palpation of TS and DSIL<br>• No pain on DSIL provocation test<br>• Bilateral stifle effusion R>L<br>• 1/5 LF lameness<br>• 1/5 LH lameness<br>• 2/5 RH lameness |
| 5 | 6 | F | 1190 | • Asymmetry of the pelvic R>L<br>• No pain on palpation of TS and DSIL<br>• No pain on DSIL provocation test<br>• Left carpus swelling<br>• 3/5 LF lameness |

F= female; Mc= castrated male; L= left; R= right; LH = left hindlimb; RH= right hindlimb; TS= tuber sacral; DSIL= dorsal sacroiliac ligament (short).

The signalment of the horses and their physical examination findings are summarized in table 1. In group "A" (horses 1-3), all horses had asymmetry of the pelvis, with the right side higher than the left side in horses two and three, while left side was higher than the right side in horse one. Horses one and three had atrophy of the right biceps muscle, while atrophy of left biceps muscle was seen in horse two. In addition to biceps muscle atrophy, horse one also had atrophy of the right middle gluteal muscle. All group "A" horses had pain on palpation of the right dorsal sacroiliac ligament, in horse one (3/3); horse two (1/3); and horse three (2/3). In addition to the pain on palpation of the right DSIL, horse two also had pain on palpation of the left DSIL (2/3). All group "A" horses had pain in response to the left DSIL provocation test. In group "A", horse one was 3/5 lame on the left rear limb, while horse two and three were 3/5 lame on the right rear limb. Group "B" (horses 4+5) horses did not have pain on palpation of TS and DSIL and also did not respond to the DSIL provocation test. Horse four was lame 1/5 on both left front and hind limb, and 2/5 on the right hind limb. In addition to the lameness, horse four had bilateral stifle effusion with the right side greater than the left side. Horse five had asymmetry of the pelvis, with the right side higher than the left side. Moreover, horse five had a swelling of his left carpus as well as 3/5 left front limb lameness.

**Ultrasound examination:**

TABLE 2: Summary of ultrasound scores.

| Horse | Side | Utrasound score | | |
|---|---|---|---|---|
| | | Echogenicity | Fiber pattern | ITS |
| 1 | Right | 3 | 2 | 3 |
| | Left | 2 | 2 | 1 |
| 2 | Right | 2 | 2 | 0 |
| | Left | 2 | 3 | 0 |
| 3 | Right | 2 | 1 | 1 |
| | Left | 2 | 2 | 2 |
| 4 | Right | 3 | 2 | 3 |
| | Left | 2 | 1 | 2 |
| 5 | Right | 2 | 2 | 2 |
| | Left | 2 | 2 | 1 |

ITS= irregularity of tuber sacral.

Ultrasound scores are summarized in table 2. In group "A", horse one had severe loss of echogenicity and moderate loss of linear fiber pattern in the right thoracolumber (TL) and DSIL, and also had moderate loss of the fiber pattern and echogenicity in the left TL and DSIL. In addition to that, severe irregularity of the right TS was seen (Figure 2a). Horse two had moderate loss of the echogenicity in the right and left TL and DSIL and severe loss of fiber pattern in the left TL and DSIL. This horse also had moderate loss of fiber pattern involving the right TL and DSIL. In horse three, moderate loss of echogenicity and fiber pattern of the left TL and DSIL were seen. This horse also had moderate loss of echogenicity and mild loss of fiber pattern of the right TL and DSIL. Moreover, moderate irregularity of the left TS was observed. In group "B" horses, horse four had severe loss of echogenicity and moderate loss of linear fiber pattern in the right TL and DSIL, and also moderate loss of echogenicity and mild loss of the linear fiber pattern involving the left TL and DSIL. The longitudinal transcutaneous scan of the TS showed severe irregularity of the right TS and also moderate irregularity of the left TS. Moreover, horse five had moderate loss of the echogenicity and linear fiber pattern in left and right TL and DSIL. Horse five also had moderate irregularity of the right TS.

**Scintigraphy examination:**

TABLE 3: Summary of clinical signs, scintigraphy, ultrasound and histopathology scores of the tuber sacral in 5 cases.

| Horse | Side | Physical | Scintigraphy | Ultrasound score | Histology | |
|---|---|---|---|---|---|---|
| | | | TS | ITS | Ossification | Inflammation |
| 1 | Right | 3 | 1 | 3 | 3 | 1 |
| 1 | Left | 1 | 0 | 1 | 3 | 0 |
| 2 | Right | 1 | 0 | 0 | 1 | 1 |
| 2 | Left | 2 | 1 | 0 | 2 | 1 |
| 3 | Right | 2 | 0 | 1 | 2 | 2 |
| 3 | Left | 1 | 0 | 2 | 2 | 2 |
| 4 | Right | 0 | 0 | 3 | 0 | 0 |
| 4 | Left | 0 | 0 | 2 | 0 | 0 |
| 5 | Right | 0 | 0 | 2 | 0 | 0 |
| 5 | Left | 0 | 0 | 1 | 0 | 0 |

TS= Tuber Sacral, ITS = irregularity of the tuber sacral.

Scintigraphic scores are summarized in table 3. In group "A", horse one had increased activity of the right TS compared to the left, and also had increased activity of the left SI joint compared to the right (Figure 3a). Horse two had increased activity of the left TS compared to the right. Horse three in group "A" and all horses in group "B" had no substantial increased activity of the SI joints and TS (Figure 3b).

**Histologic Examination:**

TABLE 4: Summary of DSIL ultrasound and histology scores.

| Side | DSIL Ultrasound echogenicity | DSIL Ultrasound fiber pattern | DSIL waviness of collagen fibers | DSIL Bony metaplasia | DSIL Loss of fiber density | DSIL Degeneration/ necrosis | DSIL Mineralization | DSIL Inflammation | DSIL Fatty infiltration | DSIL Fibrosis | DSIL Interstitial myxedema | DSIL Increased interstitial vessels | DSIL Hemosiderin | DSIL Perineural edema | DSIL Hemorrhage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Right | 3 | 3 | 2 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 2 | 1 | 0 | 0 |
| Left | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 1 | 0 | 0 |
| Right | 2 | 2 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 1 | 1 | 2 | 0 |
| Left | 2 | 3 | 1 | 0 | 0 | 1 | 1 | 1 | 2 | 1 | 1 | 0 | 1 | 1 | 0 |
| Right | 2 | 1 | 2 | 0 | 1 | 1 | 1 | 0 | 3 | 2 | 3 | 2 | 1 | 3 | 1 |
| Left | 2 | 2 | 2 | 0 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 |
| Right | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 1 | 1 | 2 | 0 |
| Left | 2 | 3 | 2 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 | 1 |
| Right | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 2 | 2 | 2 | 0 | 1 | 0 |
| Left | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 0 | 2 | 0 | 1 | 0 |

DSIL= dorsal sacroiliac ligament

**Ligament:**

Histology scores of the DSIL are summarized in table 4. The pathologist reported that "many sections of ligament from each horse, including the two control horses, contained variable amounts of fibrocartilage with or without associated foci of mineralization. The fibrocartilage was often present along the surface of the ligament sections, consistent with the normal attachment site of the ligament to the bone" see (Figure 4d). Active bony metaplasia was not noted in the right or left DSILs in any of the horses. Mild loss of fiber density was seen in horse number 3 in the right and left DSILs, and loss of fiber density was also observed in the left DSIL of the horse 4. Mild Skeletal muscle necroses was seen in all horses, except horse number 5. Mild inflammation of the right DSIL was seen in horse number 1, and in the left DSIL of horses number 2, 3 and 4. Present of fatty infiltration was seen as mild and moderate in most horses except for horse number 3 were the lesion in the right DSIL was considered to be severe. Mild to moderate fibrosis was seen in all horses. Presence of interstitial myxedema was seen as mild and moderate in all horses except for horse 3 where the lesion in the right DSIL was severe (Figure 4c). Mild to moderate increased interstitial vessels were seen in all horses. Present of hemosiderin was mild in all horses except horse number 5 where hemosiderin was not present. Severe perineural edema was seen in the right DSIL of horse number 3 (Figure 4b), and moderate perineural edema were seen in the left DSIL of the same horse. Moreover, moderate perineural edema were seen in right DSIL of horse number 2 and 4, and mild perineural edema was seen in the left DSIL of the same horses and both right and left DSIL of horse 5. Mild hemorrhage were seen in both side of right and left DSIL of horse number 3, and the left side of the DSIL of horse number 4.

**Bone:**

Histology scores of the tuber sacral are summarized in table 3. Horse one had a highly irregular retained growth plate involving the right and left TS with mild inflammation of the right TS (Figure 4e). In horse 2, mild retention of the right growth plate with mild inflammation was seen. Also in horse 2, the left TS had moderate retention of growth plate and mild inflammation. In horse three, moderate retention of the growth plate of the right and left TS with moderate inflammation were seen (Figure 4f). No retained growth plate or inflammation was seen in the TS of the 2 control horses.

**Ligament thickness:**

TABLE 5: Summary of TL/DSIL thickness (cm) (X+/-SD) and cross sectional area ($cm^2$) (X+/-SD).

| | | Longitudinal ligament thickness | | | Cross-sectional ligament thickness | |
|---|---|---|---|---|---|---|
| horse | side | Cranial | middle | caudal | middle | caudal |
| 1 | Right | 0.32 (+/-0.06) | 0.76 (+/-0.11) | 0.87 (+/- 0.06) | 1.31 (+/- 0.11) | 1.25 (+/- 0.09) |
| 1 | Left | 0.41 (+/-0.1) | 0.39 (+/- 0.06) | 0.79 (+/- 0.17) | 0.69 (+/- 0.02) | 1.07 (+/- 0.13) |
| 2 | Right | 0.49 (+/-0.04) | 0.21 (+/- 0.03) | 0.61 (+/- 0.04) | 0.75 (+/- 0.09) | 1.05 (+/- 0.12) |
| 2 | Left | 0.49 (+/-0.05) | 0.26 (+/- 0.05) | 0.46 (+/- 0.06) | 0.69 (+/- 0.21) | 1.13 (+/- 0.05) |
| 3 | Right | 0.57 (+/-0.11) | 0.22 (+/- 0.04) | 0.56 (+/- 0.07) | 0.65 (+/- 0.03) | 1.1 (+/- 0.07) |
| 3 | Left | 0.46 (+/-0.06) | 0.42 (+/- 0.08) | 0.62 (+/- 0.11) | 0.76 (+/- 0.02) | 1.18 (+/- 0.14) |
| 4 | Right | 0.51 (+/-0.61) | 0.27 (+/- 0.06) | 0.65 (+/- 0.85) | 0.64 (+/- 0.12) | 0.96 (+/- 0.06) |
| 4 | Left | 0.48 (+/-0.04) | 0.16 (+/- 0.01) | 0.63 (+/- 0.09) | 0.57 (+/-0.06) | 0.92 (+/- 0.03) |
| 5 | Right | 0.52 (+/-0.07) | 0.23 (+/- 0.06) | 0.60 (+/- 0.44) | 0.65 (+/- 0.16) | 0.88 (+/- 0.07) |
| 5 | Left | 0.52 (+/-0.09) | 0.28 (+/- 0.04) | 0.82 (+/- 0.10) | 0.59 (+/- 0.01) | 0.99 (+/- 0.12) |

Measurements of the cross-sectional area at a site, midway between the dorsal most aspect and the caudal edge of the TS, found that this cross-sectional area fell within the range of reported normals (0.9-2.4cm), and it was similar in affected and control horses. However, pathology of the DSIL is reported more frequently at its cranial attachment at the TS, rather than at the caudal attachment at the $S_2$ spinous process ranged from (0.6-1.0cm) (Denoix 1996). Therefore, the measurement of the ligament thickness at this site showed the thickness of the fused D-DSIL and TL fascia. In all horses the ligaments were within the normal range, except for horse number 1 were the thickness of the fused D-DSIL and TL fascia of the affected side was greater than the normal measurement 1.34 (+/- 0.11).

True positive (TP) values were determined based upon pain on palpation over the tuber sarcale. When determining the clinical relevance of the diagnostic modalities, all results were assessed against the true TP. Therefore, it appears that the lameness test does not predict the painful side of the horse in relation to the TP. In other words, the side of hind limb lameness does not necessarily predict side of DSIL and TS pain. Moreover, the sensitivity of the ultrasound test to predict the painful side of the horse in relation to the TP was high (83%), but the specificity of the test was (0%). This means that the ultrasound test predicted abnormality of the DSIL and the TS in all horses, the control and affected horses, painful and non painful sides. All histopathologic evaluations of the DSIL also showed low sensitivity and/or specificity in relation to the TP. Scintigraphy had high sensitivity (67%) and specificity (100%) in predicting the painful side of the horse in relation to the TP. TS ossification predicted the painful side of the horse in relation to the TP with relatively high sensitivity (100%) and specificity (71%).

**Sensitivity and specificity result:**

TABLE 6: Summary of sensitivity and specificity analysis using pain on palpation, (compression of TS), as the comparison group. HL = hind limb

| side | Right | Left | Right | Left | Right | Left | Right | Left | Right | Left | Sensitivity | Specificity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TS Compression of tuber sacrale | 3 | 1 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | **100** | **100** |
| lameness of HL | 1 | 3 | 3 | 1 | 3 | 1 | 2 | 1 | 0 | 0 | **33** | **57** |
| DSIL Ultrasound echogenicity | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | **100** | **0** |
| DSIL Ultrasound fiber pattern | 3 | 2 | 2 | 3 | 1 | 2 | 2 | 3 | 2 | 2 | **67** | **0** |
| TS Ultrasound score | 3 | 1 | 0 | 0 | 1 | 2 | 3 | 2 | 3 | 2 | **33** | **28** |
| TS Scintigraphy | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | **67** | **100** |
| DSIL waviness of collagen fibers | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | **67** | **0** |
| DSIL Bony metaplasia | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **100** |
| DSIL Loss of fiber density | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | **0** | **100** |
| DSIL Degeneration/ necrosis | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 0 | **0** | **100** |
| DSIL Mineralization | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | **0** | **100** |
| DSIL Inflammation | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | **0** | **100** |
| DSIL Fatty infiltration | 2 | 1 | 2 | 2 | 3 | 2 | 2 | 1 | 2 | 2 | **100** | **28** |
| DSIL Fibrosis | 1 | 0 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 1 | **33** | **57** |
| DSIL Interstitial myxedema | 1 | 2 | 2 | 1 | 3 | 2 | 0 | 1 | 2 | 0 | **33** | **43** |
| DSIL Increased interstitial vessels | 2 | 2 | 1 | 0 | 2 | 1 | 1 | 2 | 2 | 2 | **67** | **57** |
| DSIL Hemosiderin | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | **0** | **70** |
| DSIL Perineural edema | 0 | 0 | 2 | 1 | 3 | 2 | 2 | 2 | 1 | 1 | **33** | **43** |
| DSIL Hemorrhage | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | **0** | **100** |
| TS Ossification | 3 | 3 | 1 | 2 | 2 | 2 | 0 | 0 | 0 | 1 | **100** | **71** |
| TS Inflammation | 1 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 0 | 0 | **33** | **86** |

## Chapter III: Discussion:

In this study, I evaluated clinical exam features of horses with and without sacroiliac region pain and investigated the usefulness of ultrasound, histology, and nuclear scintegraphy for their ability to support the clinical diagnosis. Histological examinations of the DSIL and TS were performed and compared with the ultrasonographic and scintigraphic abnormalities as well as the abnormalities seen on physical examination. I made several observations. First, the side of the lameness generally did not match the side of the horse where pain was elicited by palpation of the DSIL. Also, ultrasonographic findings did not match the results of the histologic evaluation. Accordingly, sensitivity and/or specificity of histologic findings in predicting pain elicited by palpation of the DSIL were poor. In contrast, scintigraphy demonstrated abnormalities in two of the three affected horses on the same side that pain could be elicited by palpation of the DSIL.

Diagnosis of the ligament damage in equine practice can be very challenging. As with many conditions of back pathology, the causes and the clinical signs of the DSIL injury are variable and non-specific to the condition. Therefore, a good clinical exam with careful manipulation can give important information to the clinician regarding the severity or the side of the pain. In a previous study of 20 cases examined, all horses had pain on palpation over the TS on the lame side (Tomlinson, et al. 2003). In my study, 2 of the affected group horses had hind limb lameness at the opposite side of where pain was elicited by DSIL palpation. It is possible that in these horses, pain resulted from lower limb lameness. Because I did not perform nerve blocks, I cannot rule out this possibility. One horse head increased uptake of radioisotope over the SIJ on the affected side. Therefore, in this horse it is possible that lameness is the result of SIJ disease. In this horse, SIJ disease was confirmed at necropsy. All of the lame horses included in my study were chronic cases. Horses with chronic pain may try to compensate thereby induce lameness at another site (Landman et al. 2004). Therefore, it is possible that in horses used in this study, sacroiliac pain developed as part of compensation to pain in other regions. Horses used in my study did not have a good lameness history. Such a history may have helped me to determine if sacroiliac pain was caused as part of compensation to other lameness.

One of the surprising findings of my study was that ultrasonographic findings did not match histologic results. Interpretation of ultrasound findings requires an understanding of the anatomy of the region. Ultrasound examinations demonstrated, and post mortem examinations confirmed that the dorsal portion of the DSIL is fused with the medial or caudal extension of the thoracolamber fascia caudally to the TS (Figure 5). This finding supports previous reports were the fused dorsal portion of the dorsal sacroiliac ligament and thoracolambar fascia are described.(Sisson, 1975, Kresten, et al. 2004, Engel, et al. 2006). Separation between the caudal extension of the TL fascia and the dorsal portion of the DSIL was identified in one study (Kresten, et al. 2004), but not reliably identified in my study. My findings are supported by a similar study by Engeli, et al., 2006. Ultrasound examination of the sacroiliac region provided clear images of the DSIL and TS structures (Tomlinson, et al, 2003, Kresten, et al. 2004, Engel, et al. 2006). The transcutaneous technique is quick and can be performed easily in a clinical setting, but requires in-depth knowledge of the anatomy, and sufficient experience. Desmitis of the fused dorsal portion of the dorsal sacroiliac ligament and thoracolambar fascia was associated with loss of the echogenicity and linear fiber patterns (Tomlinson, et al, 2003, Kresten, et al. 2004, Engel, et al. 2006). In my study, ultrasonography of the sacroiliac area identified abnormalities of the short DSIL in all horses, which mild to severe loss of liner fiber pattern and decreased echogenicity. Because of the poor correlation between ultrasonographic findings and histologic results, the significance of ultrasonographic abnormalities must be questioned. This finding is very important, therefore must be confirmed in future studies with larger numbers of horses. There are few studies in the literature comparing ultrasonographic and histologic findings. In one study involving normal horses, bilateral hypoechonic area and decreased linear fiber pattern were seen in 4 of 10 normal horses, 3 of these 4 horses (4-6 years old) also had type 1-2 loss of the echogenicity and type 1 loss of fiber linear fiber pattern. Histopathology was performed on the fourth horse, a 24 year Quarter horse. Histological samples of this horse were judged to be within the normal limits (Engel, et al. 2006). Therefore this study also suggests a poor correlation between ultrasonographic and histologic findings.

Previous studies have reported that the thickness and cross-sectional area of the fused DSIL and the TL fascia measured at its insertion on the $S_2$ spinous process ranges 0.9 to 2.4 $cm^2$ (Tomlinson et al., 2001, Engeli et al., 2006). In my study, I measured the cross-sectional area at a similar site, mid way between the dorsal most aspect and the caudal edge of the TS. I found that this cross-sectional area fell within the range of reported normals, and was similar in affected and control horses. However, pathology of the DSIL is reported more frequently at its cranial attachment at the TS, rather than at the caudal attachment at the $S_2$ spinous process (Denoix 1996). Therefore in my study I also measured ligament thickness at this site. Here, the thickness of the fused D-DSIL and TL fascia ranged from (0.6-1.0) (Denoix 1996). In all horses the thickness of the fused D-DSIL and TS was within the normal range, except for horse number 1 were the thickness of the fused D-DSIL and TL fascia of the affected side was greater than the normal measurement 1.34 (+/- 0.11). The lack of correlation between abnormal ultrasound findings and histology results, combined with wide variability in ligament thickness measurements in normal horses makes it difficult to diagnose disamites of the fused dorsal portion of the DSIL and TL fascia by use of ultrasound. It is possible that left to right comparison of ligament thickness may be more helpful in identifying ligament lesions.

Mild, moderate, or severe irregularity of the TS was seen in all 5 horses except horse number 2 in the affected group. Mild to moderate irregularity of the TS has been reported in normal horses ranging in age from 4 to 24 years, and this should be considered normal in horses of any age (Engel, et al. 2006). Because categorizing TS lesions as mild moderate or severe is subjective, it is difficult to interpret the observation of severe irregularity in two of my horses. In the literatures authors have reported that some horses with sacroiliac pain have ultrasonographic abnormalities at the DSIL attached to the TS (Denox 1996, Grillis 1999, Tomlinson et al. 2003). In my study we found that there was no correlation between the irregularities of the TS, and pain elicited by DSIL palpation. Closure of the TS physis is reported to occur between 5-6 years of age (Haussler et al 1997). Therefore, irregular calcification is expected unilaterally or bilaterally at the TS in horses younger than 6 years of age. In my study, histological examination of the TS showed bilateral irregular calcification of the TS in all affected horses but not in control horses. My affected horses were three, five, and nine, years of age. Therefore TS irregularities can be explained by age in the three and five year old, but not in the 9 -year-old horse where the irregularity was probably pathologic. The 2 control horses were six years of age. This age, combined with no pathology is the most likely explanation for no TS irregularities in the control horses.

It has been reported that nuclear scintigraphy is a sensitive diagnostic tool in the evaluation of sacroiliac disease. (Steckel 1991, Tucker et al. 1998, Dyson and Murry 2003, Tomilnson et. al. 2003). In group "A", 2 chronic cases with 3/5 lameness and changes in the DSIL showed nuclear scintigraphy abnormalities in the sacroiliac area, while the other case showed no abnormalities in the sacroiliac area and hind limbs. Both chronic cases showed increased uptake of radioisotope over the tuber sacral on the affected side. In addition of the uptake of radioisotope over the tuber sacral, horse 1 had uptake of the radioisotope in the sacroiliac joint on the lame side. In a previous scintigraphic study hypothesize that injury of the DSIL ligament could explain the diffuse pattern of increased uptake in the sacroiliac area over the tuber sacral (Tucker et al. 1998). Post mortem examination was not performed in that study. In my study, post mortem examination was performed, and in the 2 horses with scintigraphic abnormalities we found irregularity of the SIJ 1 horse.

In summary, I started this investigation to determine the correlation between clinical findings, ultrasonography, scintigraphy and histopathology in horses with sacroiliac disease. Scintigraphy appeared to be most useful in identifying the site of pain. However, in my study there was no consistent correlation between diagnostic findings. Factors that may influence this observation include the age of the horse, and the chronicity of disease. Thus, it is important not to over interpret anyone finding, and it remains a challenge to specifically differentiate between sacroiliac joint osteoarthritis, sacroiliac ligament desmitis, and other causes of upper hind limb lameness and caudal back pain with the diagnostic tools currently available. Further studies with larger numbers of horses are needed to confirm my results.

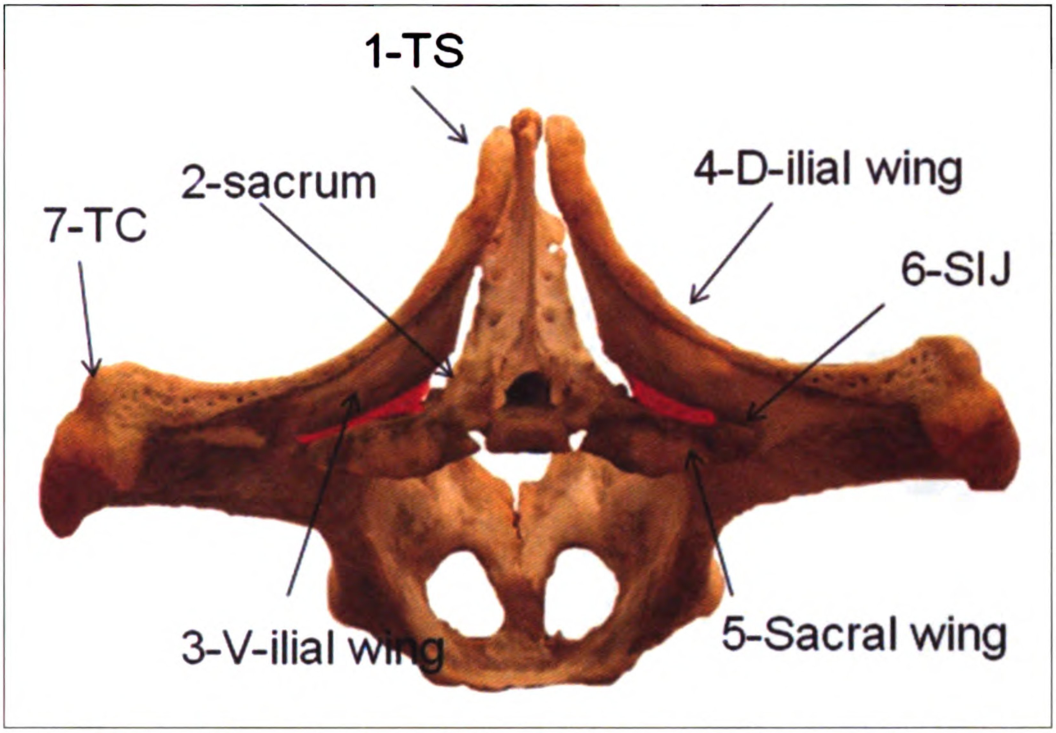



Figure 1a: Schematic bony structure of the sacroiliac region of the horse (viewed from the front of the horse). 1= Tuber sacral; 2=Sacrum; 3= ventral (V) serves of iliac wing; 4= dorsal serves of iliac wing; 5= ventral sacral wing; 6= sacroiliac joint (SIJ), located between the ventral serves of iliac wing and the dorsal serves of sacral wing.

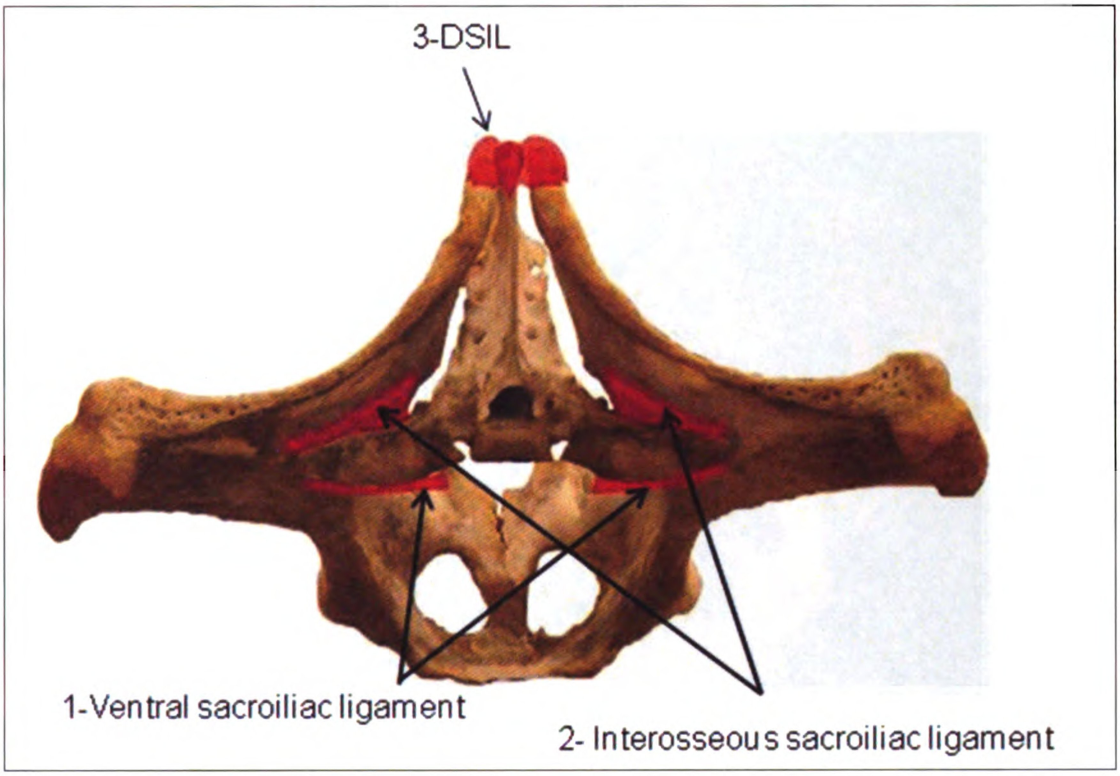



Figure 1b: Schematic ligament structure of the sacroiliac region of the horse (viewed from the front of the horse). 1= Ventral sacroiliac ligament; 2= Interosseous sacroiliac ligament; 3= Dorsal sacroiliac ligament (DSIL).

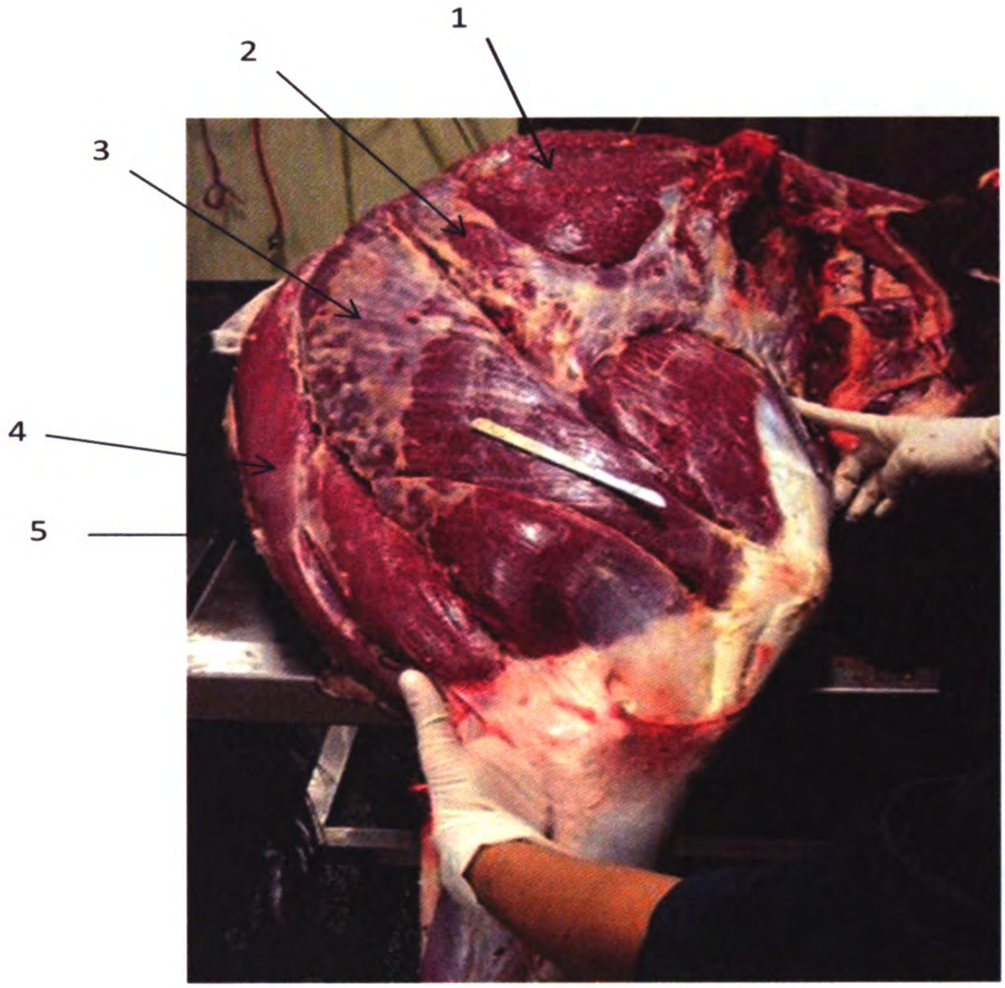



Figure 1c: Right lateral view of the outline of the rump muscles covering the equine pelvic region. 1=Middle gluteal ; 2= Superficial gluteal; 3=Biceps femoris ; 4= Semitendinosus; 5=semimembranosus.

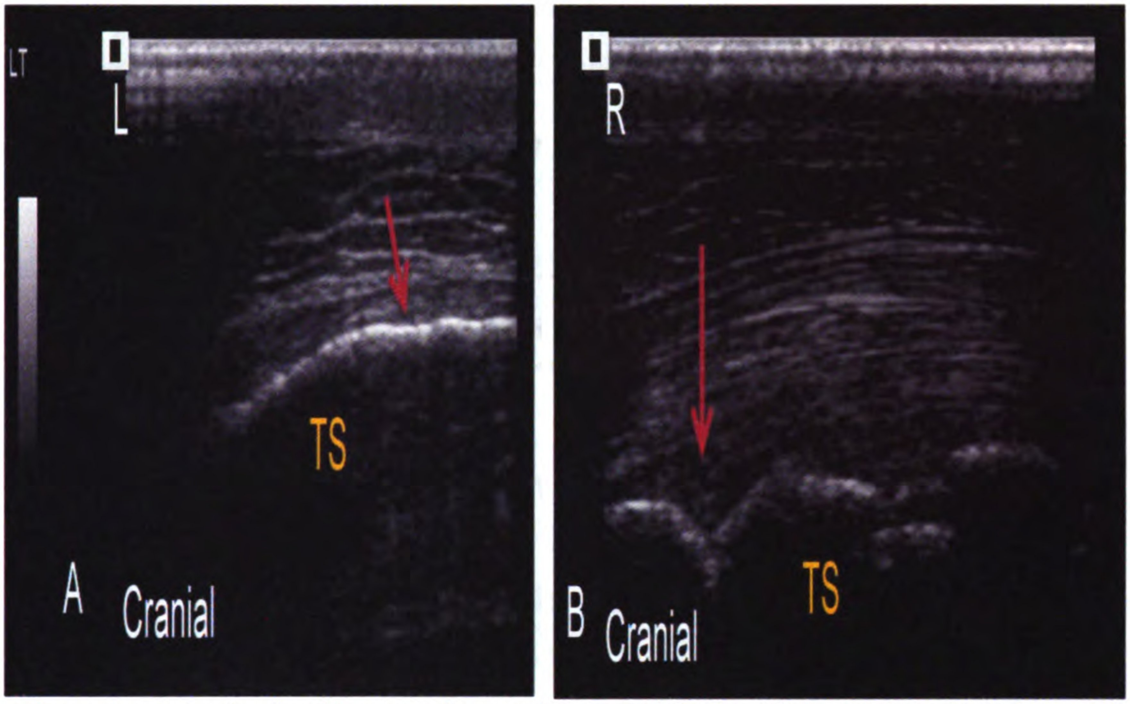



Figure 2a. Longitudinal image of tow tuber sacral (TS) with fused dorsal portion of the dorsal sacroiliac ligament and thoracolumbar fascia. Panel A, note the smooth bony surface of the TS. Panel B, note the severe irregularity of the bony surface of the TS.

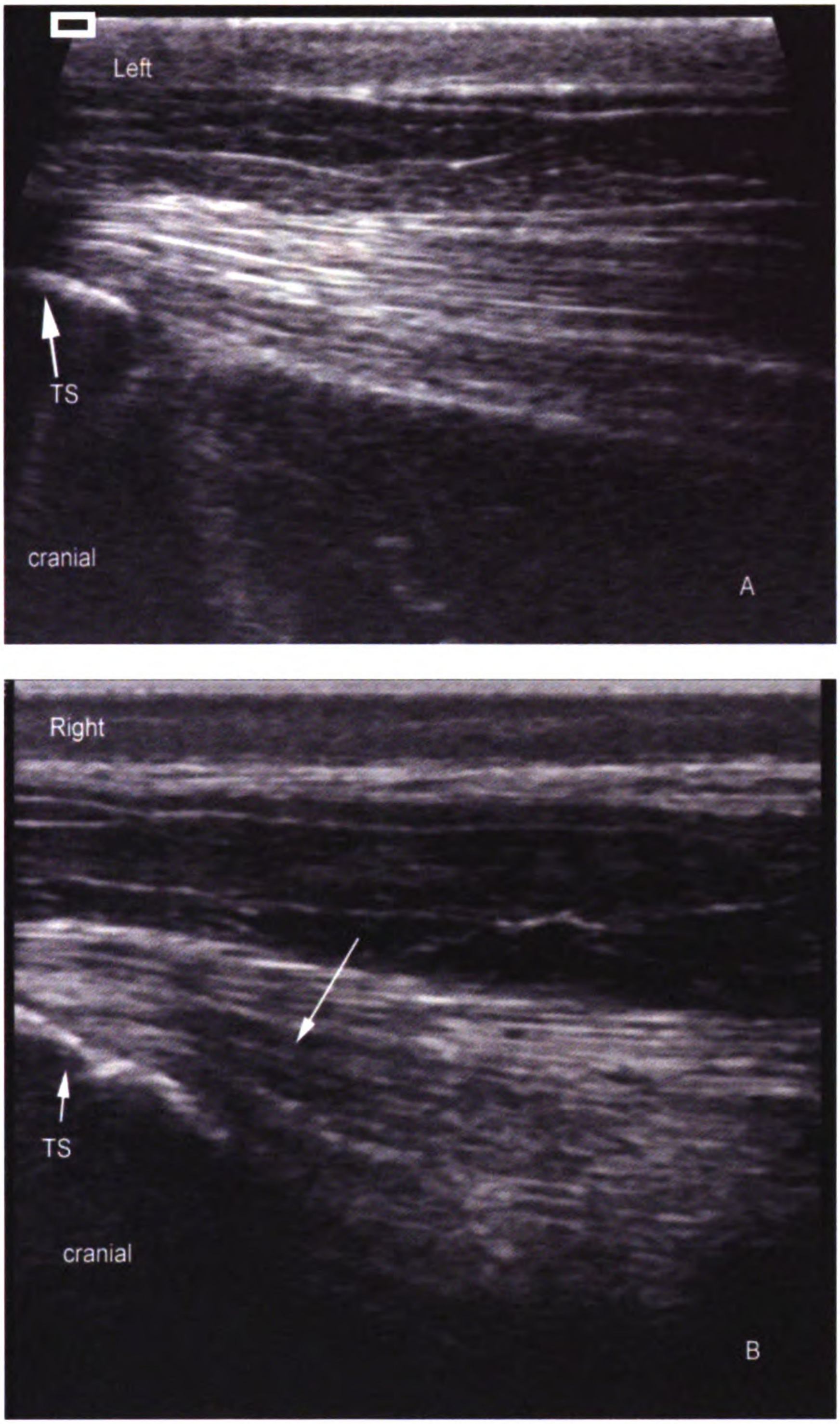
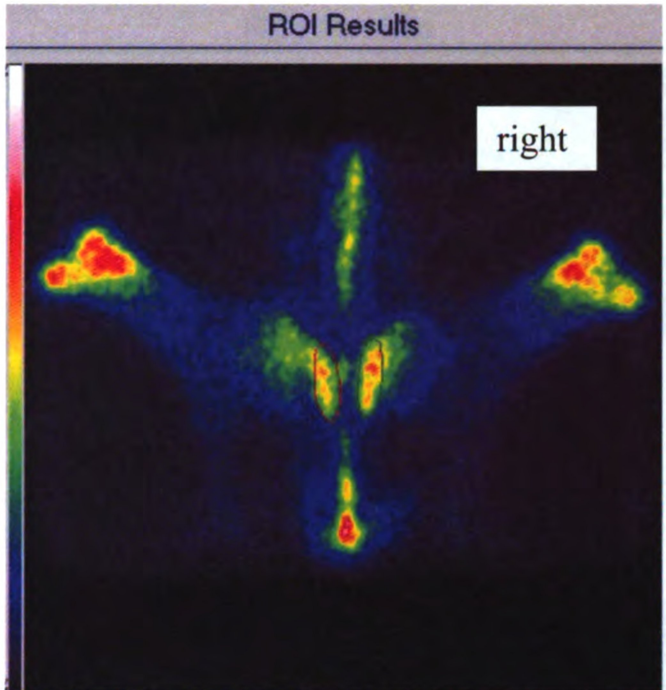


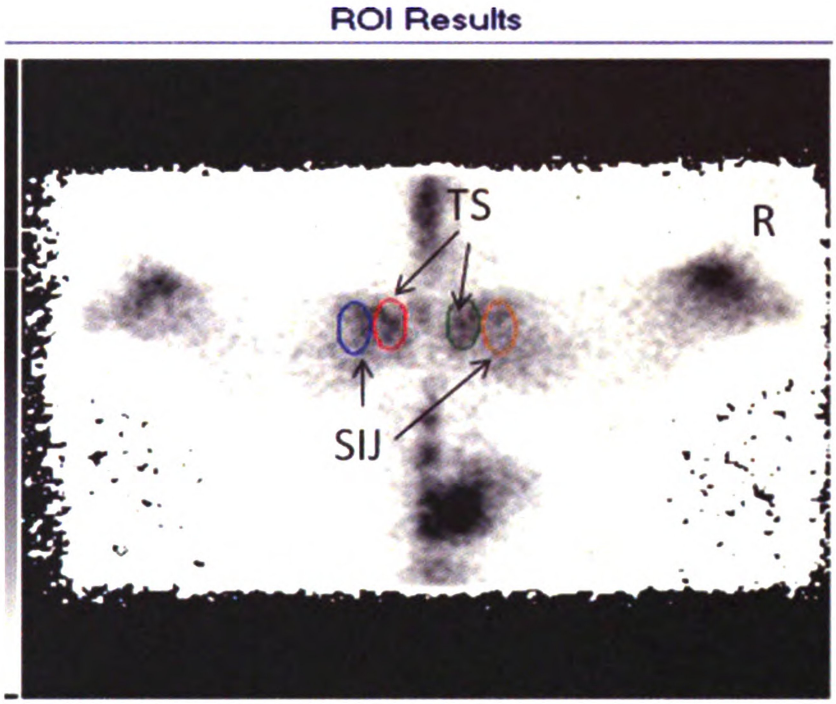

Figure 2b: Longitudinal ultrasonographic picture of the dorsal sacroiliac ligament (DSIL). (a) Normal appearance of the linear fiber pattern and echogenicity in caudal part of the left DSIL. (b) Pathology within the DSIL. There is loss of linear fiber pattern and echogenicity in right DSIL (arrow). TS= Tuber sacral.




| Name | Counts | Pixal | $cm^2$ | Counts/ Pixal | cmp | cmp $/cm^2$ |
|---|---|---|---|---|---|---|
| ROI 1 | 5979 | 252 | 143 | 23.7 | 3986 | 279 |
| ROI 2 | 6608 | 250 | 142 | 26.4 | 4405 | 310 |

| Name | ROI 1=100% | ROI 2=100% |
|---|---|---|
| ROI 1 | 100.00 | 90.0 |
| ROI 2 | 111.11 | 100.00 |

Figure 3a. Scintigraphic scan of the dorsal pelvis using Tc-MDP. The regions of interest are centered over the tuber sacrale. Note the right tuber sacrale has greater than 10% increased activity when compared to the left.




| Name | Counts | Pixal | $cm^2$ | Counts/ Pixal | cmp | cmp $/cm^2$ |
|---|---|---|---|---|---|---|
| ROI 1 | 2171 | 156 | 8.9 | 13.9 | 1447 | 163 |
| ROI 2 | 2169 | 156 | 8.9 | 13.9 | 1446 | 163 |
| ROI 3 | 1885 | 154 | 8.7 | 12.2 | 1257 | 144 |
| ROI 4 | 1851 | 154 | 8.7 | 12.0 | 1234 | 141 |

| Name | ROI 1 = 100% | R0I 2= 100% | ROI 3= 100% | ROI 4=100% |
|---|---|---|---|---|
| ROI 1 | 100.00 | 100.00 | 113.19 | 115.60 |
| ROI 2 | 100.00 | 100.00 | 113.19 | 115.60 |
| ROI 3 | 88.34 | 88.34 | 100.00 | 102.13 |
| ROI 4 | 86.50 | 86.50 | 97.92 | 100.00 |

Figure 3b. Scintigraphic scan of the dorsal pelvis using Tc-MDP. The regions of interest are centered over the tuber sacrale (TS) and the sacroiliac joint (SIJ). Note there is no increased activity over the TS and SIJ greater than 10%.

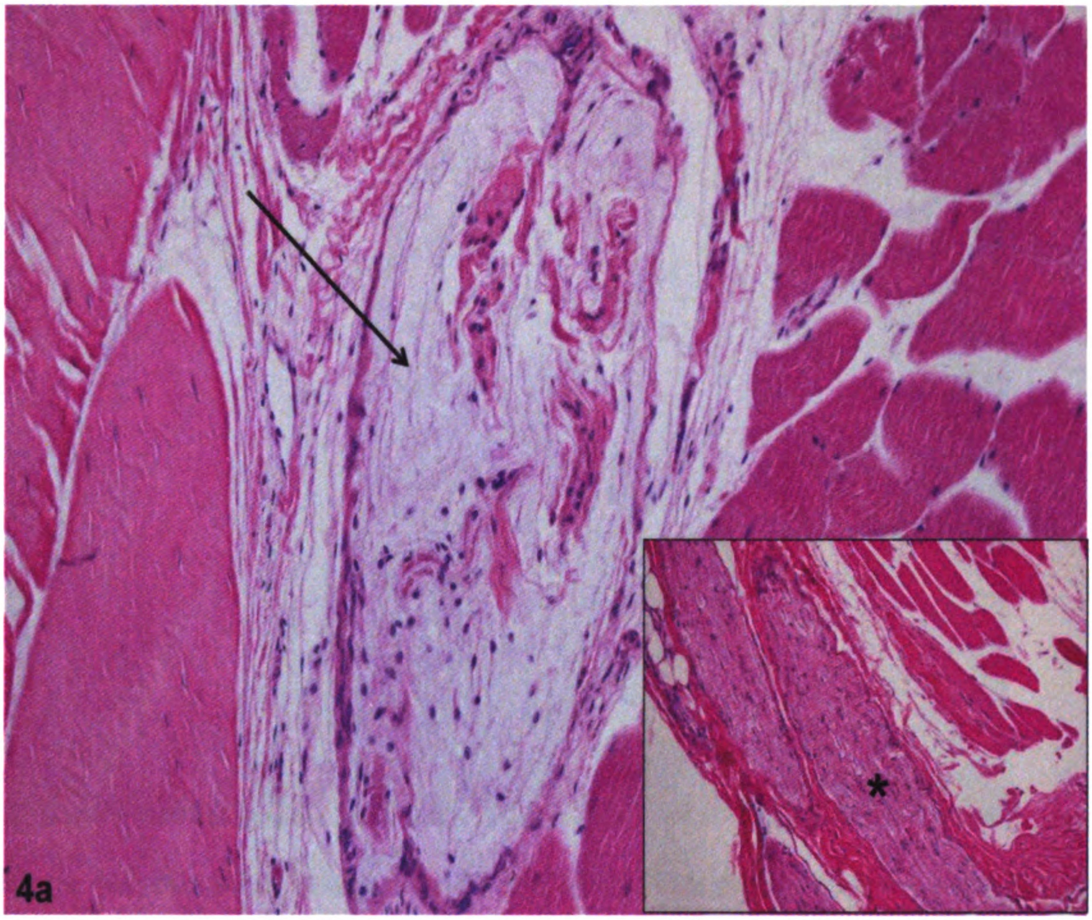



Figure 4a. H and E of right DSIL. This peripheral nerve exhibits marked edema and loss of nerve fibers. Inset: Normal peripheral nerve (*) from the DSIL.

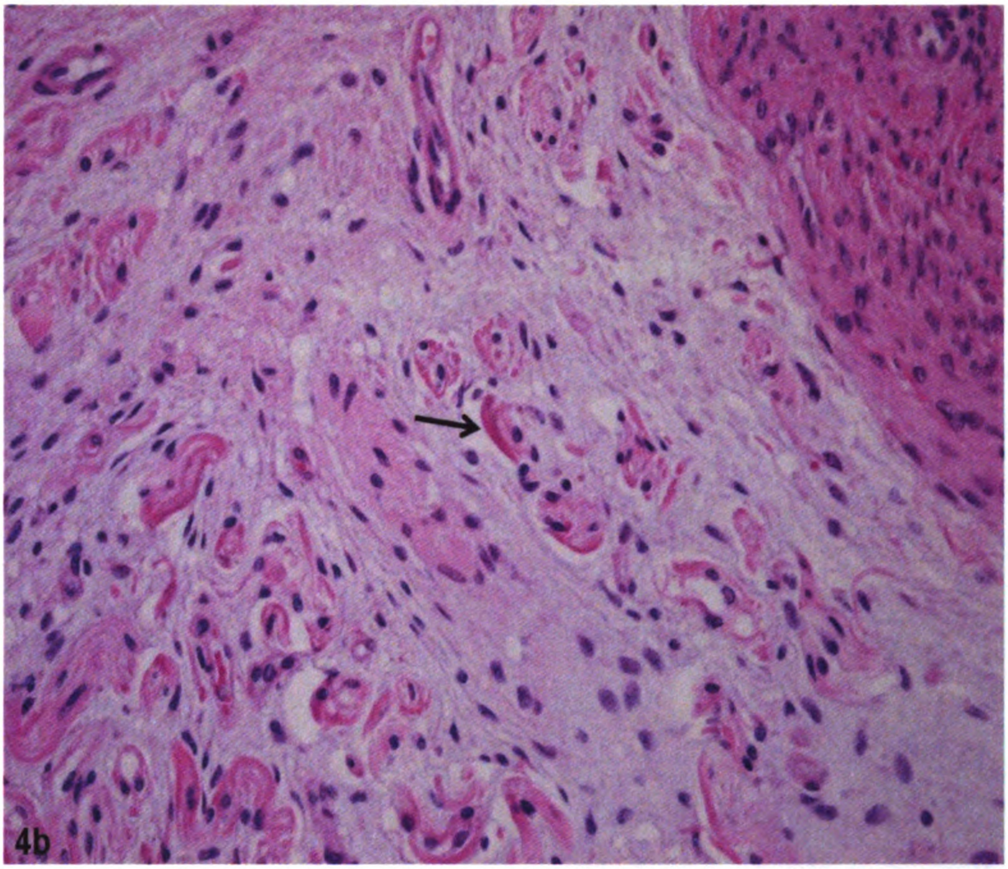



Figure 4b. Hematoxylin and eosin of right DSIL. This peripheral nerve exhibits a loss of nerve fibers with fragmentation of remaining fibers. Edema is also present.

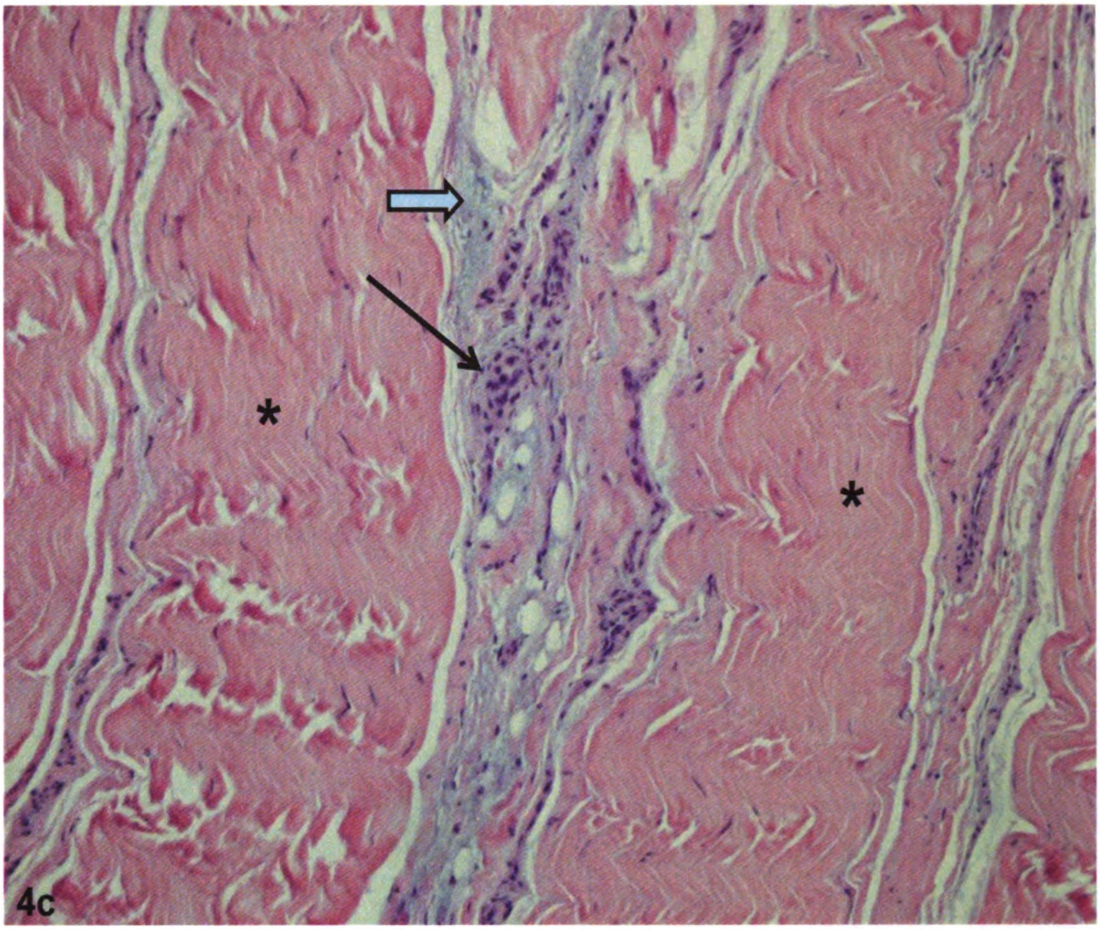



Figure 4c. Hematoxylin and eosin left DSIL. There are increased interstitial small arterioles (solid arrow) with surrounding pale basophilic myxedema (open arrow) between bundles of regularly arranged collagen(*).

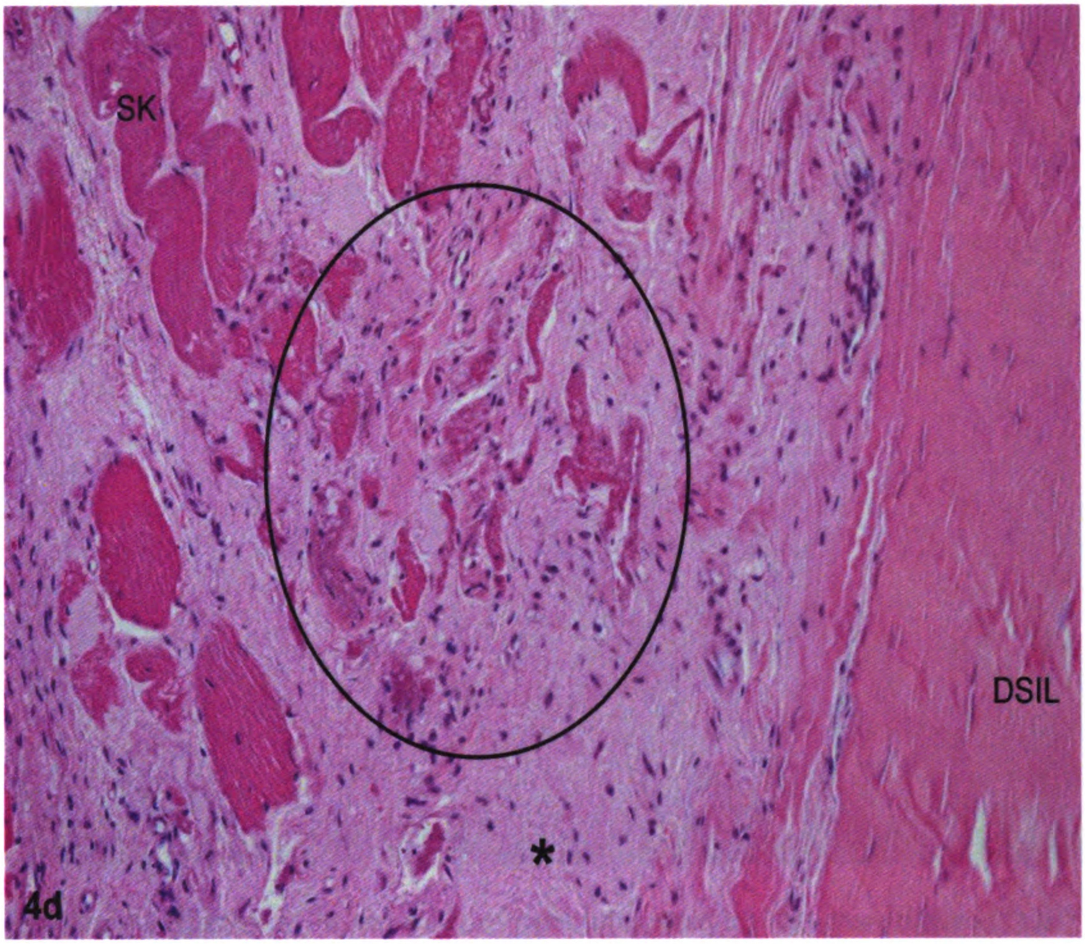



Figure 4d. Hematoxylin and eosin of left DSIL. There is increased fibrous connective tissue at the attachment site between the dorsal sacroiliac ligament (DSIL) and the skeletal muscle (SK). Skeletal muscle fibers in this area are multifocally hypereosinophilic, shrunken, variably sized and fragmented indicating necrosis (circle).

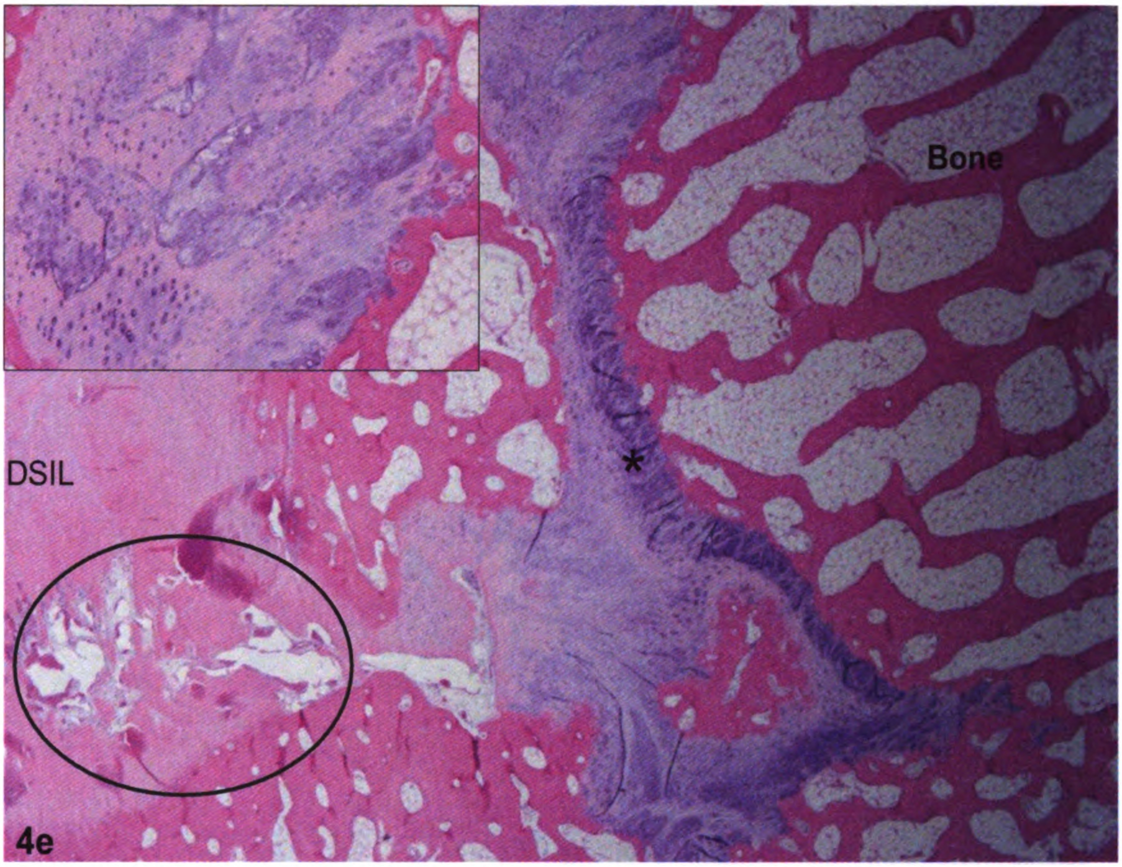



Figure 4e. Hematoxylin and eosin of right tuber sacrale. The growth plate (*) is retained and is highly irregular. The physeal cartilage extends at right angles in two foci to connect with the surface of the tuber sacrale where the DSIL attaches. In one of these foci, there is also a proliferation of blood vessels (circle) that extends from the physeal cartilage to the attachment site of the ligament. Inset: The retained growth plate consists of highly disorganized chondrocytes and the surrounding matrix is eosinophilic, indicating degeneration.


Figure 4f. Hematoxylin and eosin of right tuber sacrale. There is a small focus of inflammatory cells (A) consisting of macrophages and neutrophils as well as hematopoietic cells within the medullary spaces. Some macrophages contain red blood cells (erythrophagocytosis (B)). There are also small amounts of hemosiderin (circle). HE

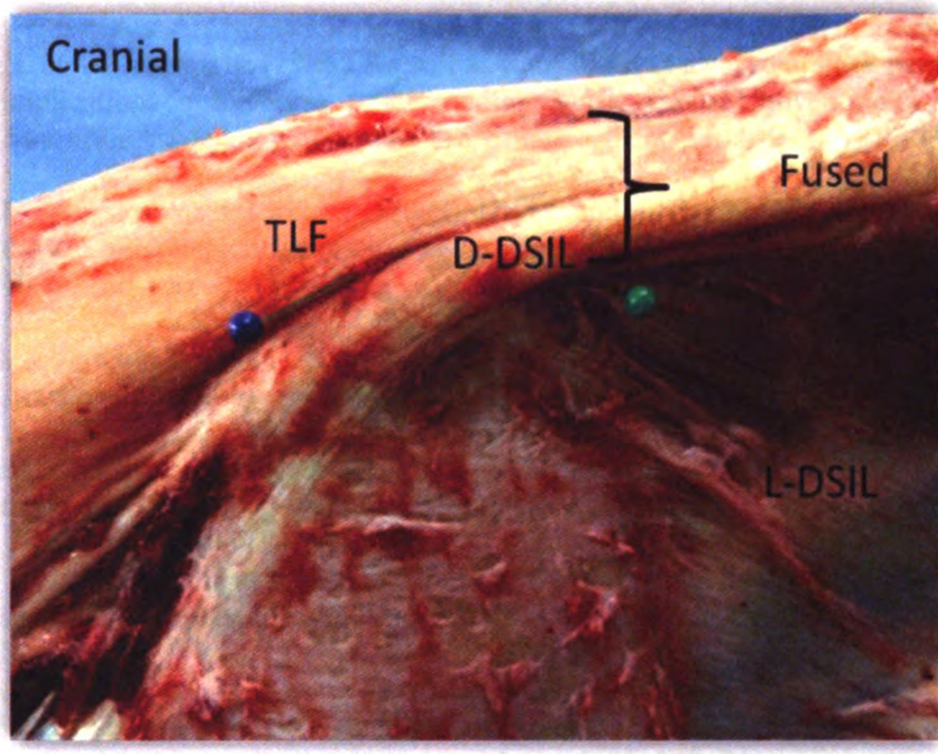



Figure. 5: Left dorsal view of lumbosacropelvic specimen at the level of the lumbosacral junction. The middle gluteal muscle has been removed to describe the deeper structures. TLF=thoracolamber fascia, D-DSIL= dorsal portion of the dorsal sacroiliac ligament, TS= tuber sacral, L-DSIL =lateral portion of the dorsal sacroiliac ligament.
In this picture you can see that the caudal portion of the thoracolamber fascia attached dorsally to the dorsal portion of the dorsal sacroiliac ligament at the level of the tuber sacral. The dorsal portion of the dorsal sacroiliac ligament and thoracolamber fascia fused caudal to the tuber sacral, which attaches on the sacral spinous processes.

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