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The patient signed an informed consent allowing the use of medical information and video footage for this report and received information on the institution's policies regarding the Health Insurance Portability and Accountability Act.

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**Abstract:**

**Background and Purpose:** Bilateral pedicle stress fractures are extremely rare, with few cases reported in the literature. The pedicle is known to be the second weakest point of the vertebra, has a short moment arm from the vertebral body, and can resist a large amount of cyclic shear forces.[1] There have been several reports describing pedicle stress fracture in adolescent athletes.[1] However, in those reports the fracture was usually associated with contralateral spondylolysis, and isolated pedicle fractures are rarely found. [1]This case report details a conservative approach using manual therapy, Pilates exercises, and sport specific re-training in an adolescent sprinter with bilateral L4 pedicle stress fractures.

**Case description**: A fifteen year old male presented with low back pain due to bilateral L4 pedicle stress fractures; evaluation findings including weak hip flexors and extensors bilaterally, upper abdominals stronger than lower abdominals, quadriceps to hamstring ratio not adequate for a sprinter, and excessive active hip external rotation during running led therapists to believe that the fractures were the direct result of training errors, muscle imbalances, muscle weakness, and poor running biomechanics. The patient's pain level was assessed using the VAS pain scale and overall functional improvements were evaluated using a Functional Impairment Questionnaire specific to the clinic where treatment was provided.

**Outcomes**: Improvements were observed in overall muscular endurance, strength, joint symmetry, and running mechanics with manual therapy and Pilates exercise. He was able to return to sport.

**Discussion:** An improvement in joint symmetry, muscular endurance, strength, correction of training errors, and resolution of pain will improve the potential of an athlete to return to their desired sport without restriction, following pedicle stress fractures.

Manuscript word count: 2644

## Background and Purpose

The pedicle is known to be the second weakest point of the vertebra, following the pars interarticularis ("pars"), but has a significant amount of intrinsic strength, a shorter moment arm from the vertebral body compared to the pars, and can resist a large amount of cyclic shear forces.[1] As a result, fractures of the pedicles are much less common than those of the pars and do not routinely present bilaterally.[1]

There are few bilateral pedicle stress fractures recorded in evidence-based literature and there has been limited research conducted regarding conservative management of the young athlete with this type of injury.[1]Lumbar pedicle stress fractures occur mainly in individuals that perform loaded and repetitive activities that involve the spine, individuals with contralateral spondylolysis, or those that have had previous surgery of the lumbar vertebra.[1] The main causes of lumbar pedicle stress fractures are shear stress and twisting stressors, followed by sudden hyperflexion or hyperextension of the spine.[2]

Conventional X-ray examination does not routinely identify lumbar pedicle stress fractures and definitive diagnosis is confirmed through MRI, XCT, or bone scans.[3] Stress fractures are divided into four groups are per MRI findings: stress reaction, incomplete fracture, complete fracture, and pseudarthrosis.

The purpose of this case report is to demonstrate conservative management using manual

therapy, Pilates exercises, and sport specific re-training in an adolescent elite sprinter with bilateral L4 pedicle stress fractures. This case report may help clinicians incorporate injury prevention strategies into their plan of care involving young athletes with similar deficits.

## Case Description

### Patient History:

Both the patient and his mother provided consent to participation in this case report. The patient was a fifteen-year-old student who was an elite sprinter on his school's track and field team. He participated in the long jump, 100 meter, and 200 meter sprint. The patient was motivated and eager to return to sport in the fall and exercised six days per week prior to onset of low back pain. The patient reported pain with prolonged sitting, standing, ambulation on level surfaces, sleeping, and lifting loads larger than fifteen pounds. The patient was vitamin D deficient but all other aspects of his general health were unremarkable. The patient had previously received physical therapy services consisting of lower extremity strengthening and stretching for a left hamstring strain. The patient's father had a history of low back pain and has had one spinal surgery. No other significant family history was pertinent to this case. Surgical history included bilateral hearing loss that resulted in seven ear surgeries from age 3 to 7. Diagnostics included MRI and X-ray; X-ray was unremarkable, MRI displayed bilateral L4 pedicle stress fractures. The patient and family's goals involved returning to sport pain free.

### Systems Review:

Refer to Table 1

### Clinical Impression 1

The patient's primary problem was low back pain due to bilateral pedicle stress fractures. This resulted in his inability to participate in sport due to pain with running, jumping, and prolonged standing. Based on positive MRI imaging for the pedicle stress fractures, no other pathology was suspected. Video footage and photographs of the patient performing his sport were requested and acquired. This patient was a good candidate for a case report due to his unique pathology, not previously reported in the literature.

**Examination: Tests and Measures**

The plan for examination consisted of the following: palpation to the lumbar spine and pelvis, spinal range of motion, abdominal and lower extremity musculature strength assessments, passive intervertebral motion of thoracolumbosacral spine, soft tissue extensibility, and biomechanical analysis of patient during walking, running, and performing sport specific exercises. Pre-season training techniques, sport specific conditioning protocol, and biomechanical analysis of the patient performing his sport were also assessed. (Table 1,2)

**Clinical Impression 2**

The diagnosis of bilateral L4 pedicle stress fractures that resulted in low back pain was confirmed through initial examination data. The initial findings included muscle imbalances, decreased lower extremity soft tissue extensibility, spinal hypomobilities in both single and combined planes of motion, excessive active hip external rotation, and postural deficits. The patient presented with high soft tissue reactivity and easily provoked low back pain, which impeded his inability to return to sport. He required intensive further hip abductor and extensor strength and endurance training due to excessive hip external rotation during running. Premature spinal hyperextension during

the first 30 meters of the 100-meter sprint was also addressed through slow motion video analysis. Provided the patient's medical condition, *Lumbar Vertebral Stress Fracture,* ICD-9-CM code of 733.95 was the patient's physical therapy diagnosis. 4G: Impaired Joint Mobility, Muscle Performance, and Range of Motion Associated With Fracture was the most appropriate practice pattern for this patient. Based on known data regarding healing of spinal stress fractures, as well as the patients' high levels of motivation, it was anticipated that the patient could return to full activity at the start of his season two months after discharge from physical therapy services.

A follow-up evaluation, using the same tests and measures from initial evaluation, was completed after four weeks to assess the patient's progress and to ensure his plan of care remained appropriate. Assessments were completed every fourth week following the initial follow up and alterations to the plan of care were made as deemed necessary. During the initial acute phase of healing, the patient's plan of care focused on managing his pain level. After decreasing his pain to an average of 3/10 consistently at the three-week mark, and upon entering the sub-acute phase of healing, Pilates exercises were added to improve overall muscular symmetry, lumbo-pelvic stability, abdominal musculature strength, and endurance.[13] Once he entered the chronic phase of healing at the six week mark, and his pain continued to be well controlled, speed and agility drills involving sport-specific ballistic movements were added to ensure the patient had the necessary muscular control, strength, endurance, and flexibility to compete in his chosen track and field events without further injury.[14]

**Interventions**

The patient was seen twice a week, for 45 minutes sessions, over a period of ten weeks.

The plan of care included a home exercise program, therapeutic modalities and manual therapy techniques for pain management, abdominal stabilization exercises using Pilates, and a general sport-specific strengthening and stretching program. (Table 3) The purpose of these interventions was to manage the patient's pain, improve postural control and proprioceptive awareness during sport-specific activities, and advance biomechanical awareness during running and rapid position changes. The patient attended all scheduled appointments and was compliant with therapeutic exercise performed in the clinic as well as his daily home exercise program.

**Coordination, communication, and documentation**

Coordination and communication with the patient's mother was essential due to the fact that the patient was a minor. The patient did not drive and appointment times were coordinated around both the patient and his mother's schedule. The patient's mother was extremely supportive and a large facilitator in regards to obtaining MRI results from the patient's physician and ensuring proper communication between the physician's office and the physical therapist's office was present.

**Patient/client related instruction**

Patient instruction included education and training in the proper performance of a home exercise program that involved three different aspects of therapeutic exercise. The patient was instructed to alternate daily between the three groups of exercises, to assure regular performance of each exercise category. The first group of exercises was flexibility specific with the goal of increasing the patient's spinal range of motion by decreasing hamstring and hip flexor soft tissue restrictions. The second set of exercises was Pilates based with the goal of increasing lumbo-pelvic stability and abdominal strength.[18] The

Pilates component included both the essential and intermediate mat work series and was to be done for two sets of 8-10 repetitions.[15] The final set of exercises was focused solely on increasing lower extremity strength. The patient was instructed to perform two sets of 8-10 repetitions of each exercise. Exercises included straight leg raises, bridging on a physioball, single leg bridging on a physioball, standing squats, reverse lunges, and lateral lunges. This patient was also being recorded via slow-motion video camera every two weeks to assess his biomechanics during exercise. After recording the activities, the physical therapist analyzed the video and reviewed the findings with the patient and the patient's mother to ensure each person's understanding of where the remaining deficits were and what aspects of his mechanics required correction.

**Therapeutic Ultrasound (US)**

Therapeutic ultrasound, using a Therapeutic Ultrasound Tower[#], was applied over bilateral L1 to L5 paraspinals at the start of treatment for ten minutes at 1.0 MHz and 1.5 w/cm2 to elicit muscular relaxation prior to grade I and II posterior anterior mobilizations and was discontinued at week 6 due to a decrease in the patient's level of pain and anxiety. Although there is very limited current literature supporting the use of ultrasound for pain management, this intervention was deemed appropriate to aid in overall relaxation upon the patient entering our clinic, which tended to induce stress upon the patient.

**Soft tissue massage**

Soft tissue massage was performed to the thoracolumbar paraspinals and fascia, following therapeutic US, for ten minutes to increase circulation to the area and

[#] Therapeutic Ultrasound Tower, Chattanooga Group- A division of Encore Medical, 1430 Decision Street Vista, CA 9208

accelerate the healing process. [16] As per current literature, soft tissue massage increases blood flow to the area that is being treated, subsequently facilitating the healing process.[16]

**Manual traction and mobilization of spinal joints**

Following soft tissue massage, Grade I and II Posterior anterior glides were conducted in prone directly over L2, L3 and L5 spinous process for extension, and over the transverse process for rotation bilaterally for ten minutes. The goal of these mobilizations was to control pain. Manual lumbar traction was also performed in sidelying by providing a gentle distraction force between L3-4 and L4-5, with hand placement on the spinous processes to decrease muscle guarding and pain.[17] This intervention was discontinued at week six due to the elimination of muscle guarding and decrease in the patient's pain level to 0/10.

**Pilates Exercises**

The central construct of the patient's therapeutic exercise program involved Pilates abdominal stabilization principles, and was performed following manual therapy techniques each session starting the third week of treatment. Pilates abdominal stabilization exercises were performed for two to three sets of eight to ten repetitions and the patient's program consisted of the essential and intermediate mat work series, on a Pilates mat[##], as detailed in the Stott manual.[18] Essential mat work series exercises were incorporated at week three due to decreased pain at rest. Intermediate mat work exercises were integrated at week four when the patient showed no increase in pain following one week of the essential mat work series. Both sets of exercises were discontinued at week

[##] Stott Pilates, Express mat-dark blue, 2200 Yonge Street, Suite 500 Toronto, Ontario M4S 2C6 Canada

six due to the start of a sport-specific strengthening exercise program. The goal of these exercises was to improve sport specific postural control through abdominal stabilization.[19]

**Sport-specific Strengthening Exercises**

The first aspect of the patient's sport-specific exercise program involved body mechanics training using controlled quick changes in direction, acceleration, and deceleration. This was accomplished through propulsion onto and off a ten-inch Stott Pilates Reformer Box.[*]To ensure that the patient understood proper jumping mechanics, he was recorded via slow motion video analysis and the video was reviewed with the patient after each session. The purpose of this exercise was to develop the patient's ability to accelerate and decelerate with biomechanical efficiency during sport-specific conditioning involving jumping. [20] When the patient demonstrated proper form during jumping exercises and did not report increased pain at week seven, exercises were then advanced to higher intensity training. This included agility drills, such as lateral and forward foot fires, to prepare the body for rapid alternating movements and quick changes in position as well as running drills simulating 100 and 200-meter sprinting events. [20]

**Flexibility exercises**

The goal of the flexibility exercises was to increase the patient's hamstring and hip flexor tissue extensibility, allowing for improved biomechanics during running and jumping events.[21,22] All stretches were integrated at week two, continued until discharge, and held for three 30-second repetitions.[22] Stretching exercises for bilateral hip flexors were

[*] Stott Pilates, Stott Pilates Reformer Box 2200 Yonge Street, Suite 500 Toronto, Ontario M4S 2C6 Canada

performed in prone on a Metron® Plus Hi-Lo Mat Platform Table[**] with one foot planted on the floor in 90 degrees of knee flexion, and ten to 15 degrees of flexion in opposite knee. This method of stretching protected the lumbar spine by facilitating a neutral spine position throughout the stretch. Hip flexor stretching was followed by supine hamstring stretching that was performed with one lower extremity extended and the other lower extremity placed on a wall in front of the patient until a stretch was felt along the patient's hamstrings. This method of stretching allowed the patient to maintain a safe neutral spinal position through the entirety of the stretch.

**Outcomes:**

The patient progressed well with conservative management and his symptoms became less reactive each week. The same physical therapist performed tests and measures at initial evaluation and discharge to maximize test validity and reliability. After twenty sessions over ten weeks, the patient was able to meet his goal of returning to sport pain free. Gross abdominal muscular endurance in terms of tolerance to strength and endurance exercise time improved from eight minutes at week three to 21 minutes at discharge, with decreased overall rest time in between exercises. Table two reports the scores of the tests and measures at initial evaluation as well as discharge.

**Discussion:**

There is currently very limited literature regarding bilateral lumbar pedicle stress fractures and as a result it was difficult to develop an evidence-based prognosis[2]. It was apparent that the patient presented with unusual muscle weakness patterns for a sprinter that included weak hip flexors and bilaterally. [23] Current studies demonstrated the

[**] Metron® Plus Hi-Lo Mat Platform Table, Patterson Medical, 28100 Torch Parkway, Suite 700 Warrenville, IL 60555-3938

positive effect of hip flexor strength on the acceleration phase of sprint and attributed the majority of forward motion during running and sprinting to rapid hip flexion.[4] As a result of these muscle imbalances and poor biomechanics during sprinting, the patient compensated for his hip flexor weakness by using spinal hyperextension and hip external rotation while sprinting, which in turn may have led to lumbar stress fractures. Muscle weakness, limited soft tissue extensibility, and muscle imbalances were addressed through the following interventions: Pilates exercises, therapeutic modalities, manual therapy techniques, sport-specific training, and a home exercise program. These factors were addressed to facilitate the healing process, strengthen proper musculature required for sprinting, and reduce muscle imbalances that could lead to re-injury. The purpose of Pilates exercises was to improve abdominal stabilization as well as lower extremity strength through low impact exercises that would not further impact stress fractures. After sufficient abdominal strength was noted and pain had significantly decreased, a sport-specific exercise program was added to the patient's plan of care, with emphasis on proper running and jumping mechanics. This was done to prepare the patient for return to sport as well as teach him the correct running and jumping mechanics necessary for injury prevention. The patient was discharged from physical therapy services in ten weeks with no pain at rest, significant improvements in abdominal strength as well as hip musculature strength, no pain with passive intervertebral motion of T12 to L3, and significant improvements in spinal range of motion as well as posture. Improvement in running and jumping biomechanics were also noted at discharge due to overall improvement in postural control, proprioceptive awareness, and muscle imbalances. This case report details one possible intervention for individuals with pedicle stress fractures.

Future research is necessary to determine additional beneficial conservative physical therapy treatments for adolescent athletes who present with bilateral lumbar pedicle stress fractures.

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## Supporting Tables, Figures and Appendices

### Table 1

| | |
|---|---|
| **Cardiovascular/Pulmonary** | Normal; cardiopulmonary system was slow to fatigue. |
| **Musculoskeletal** | The patient demonstrated impaired abdominal and lower extremity strength, spinal hypomobility, bilateral hip hypermobility, and postural deficits. |
| **Neuromuscular** | Normal |
| **Integumentary** | Thickening upon palpation was noted bilaterally at the L4-L5 spinal level. No bruising, scarring, or erythema noted. The integumentary system was otherwise intact**.** |
| **Communication** | The patient had slight auditory deficits and wore bilateral hearing aids. As a result, the patient was spoken to directly with a slightly elevated tone. Communication was not impaired otherwise. |
| **Affect, Cognition, Language, Learning Style** | The patient learned best through visual representations and demonstrations. |

### Table 2

| **Tests and Measures** | **Initial Evaluation Results** | **Results at Discharge** | **Validity and Reliability** |
|---|---|---|---|
| **Spinal Range of Motion** | *40% spinal EXT<br>*30% spinal FLX<br>*25% B/L SB<br>*35% B/L ROT<br>*Unable to test combined motion<br>*All motion limited by pain | *85% spinal EXT<br>*85% spinal FLX<br>*80% B/L SB<br>*90% B/L ROT<br>*Combined EXT and B/L ROT non-reactive<br>*Pain free with all ROM | Good to high intrarater reliability for single plane motion[4] |
| **Soft tissue range of motion** | Passive SLR test: 40 degrees L and 35 degrees R; Thomas test: severe restriction | Passive SLR test: 45 degrees B/L; Thomas test: minimal restriction | Moderate reliability for Thomas Test using a goniometer to assess rectus femoris length.[5]Passive SLR test showed poor ability to detect changes in hamstring length. [6] |

| | | | |
|---|---|---|---|
| **Palpation** | Tender at B/L L4 transverse processes and B/L T12 to L5 paraspinal musculature.. | No tenderness | Pain provocation through palpation has proven to be the most reliable aspect of palpation.[7] Palpation of paraspinals musculature is not reliable in regards to diagnosing possible spinal pathology.[7] |
| **Strength** | *4+/5 B/L hip extensors,<br>*4/5 lower abdominals,<br>*4+/5 upper abdominals,<br>*4/5 bilateral hip flexors | *5/5 B/L hip extensors,<br>*4+/5 lower abdominals,<br>*5/5 upper abdominals,<br>*4+/5bilateral hip flexors | Good reliability and validity in the use of MMT for patients with neuromusculoskeletal dysfunction.[8] |
| **Joint Play Assessment** | PIVM:<br>T12-L3: 3/6, no pain<br>L4-5 2/6, painful<br>L5-S1 2/6 painful | PIVM:<br>of T12-L5 3/6, no pain | Low interrater reliability for PIVM assessments and diagnostic capabilities.[9] Further research required to determine pain provocation reliability and validity using PIVM[9]. |
| **Postural Analysis** | *Sitting uncorrectable posterior pelvic tilt<br>*Increased thoracic kyphosis<br>*Decreased lumbar lordosis | *Mild increase in thoracic kyphosis<br>*Decreased lumbar lordosis<br>*Normal sitting posture. | Good to excellent reliability was shown with postural analysis of spinal postures from a sagittal view.[10] |
| **Gait Analysis** | Decreased right-sided trunk rotation and hip EXT following toe off. | Abnormal gait pattern resolved | Low interrater reliability for observational gait analysis. [11] |
| **Functional Impairment Questionnaire** | 48/100 | 12/100 | The questionnaire was unique and individualized to the clinic. |

| | | | |
|---|---|---|---|
| **VAS Pain Scale[14] at rest** | 7/10 | 0/10 | High reliability for assessing acute pain[12] |
| **VAS Pain Scale[14] with prescribed therapeutic exercise** | 7/10 | 0/10 | High reliability for assessing acute pain[12] |

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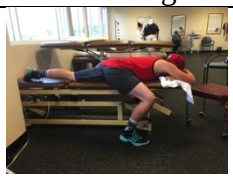
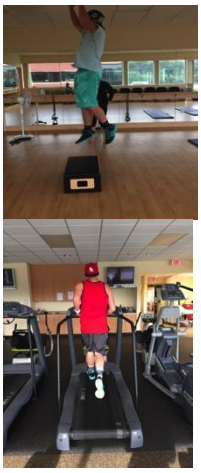
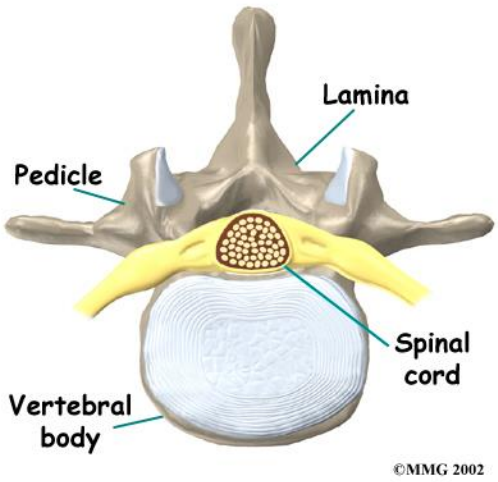
395
396 **Table 3**

| Progression of Therapeutic exercise from Initial evaluation to Discharge | | |
|---|---|---|
| | Strength and Endurance based therapeutic exercise | Flexibility based therapeutic exercise |
| Week 1 | Not prescribed at this point due to pain (7/10) | Not prescribed at this point due to pain (7/10) |
| Week 2 | Not prescribed secondary to pain, neutral spinal postures for sit and stand reviewed with the patient |  Initiated hamstring stretching |
| Week 3-4 | Essential mat work series Stott Pilates exercises    |  Stretching of hip flexors performed bilaterally  |
| Week 5 | Intermediate mat work Stott Pilates exercises  | Same as above |

| | | |
|---|---|---|
| |  | |
| Week 6-10 | Functional track and field specific training program  | Same as above |

397

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399 Figure 1; displaying anatomical structure of healthy lumbar vertebrae [24]

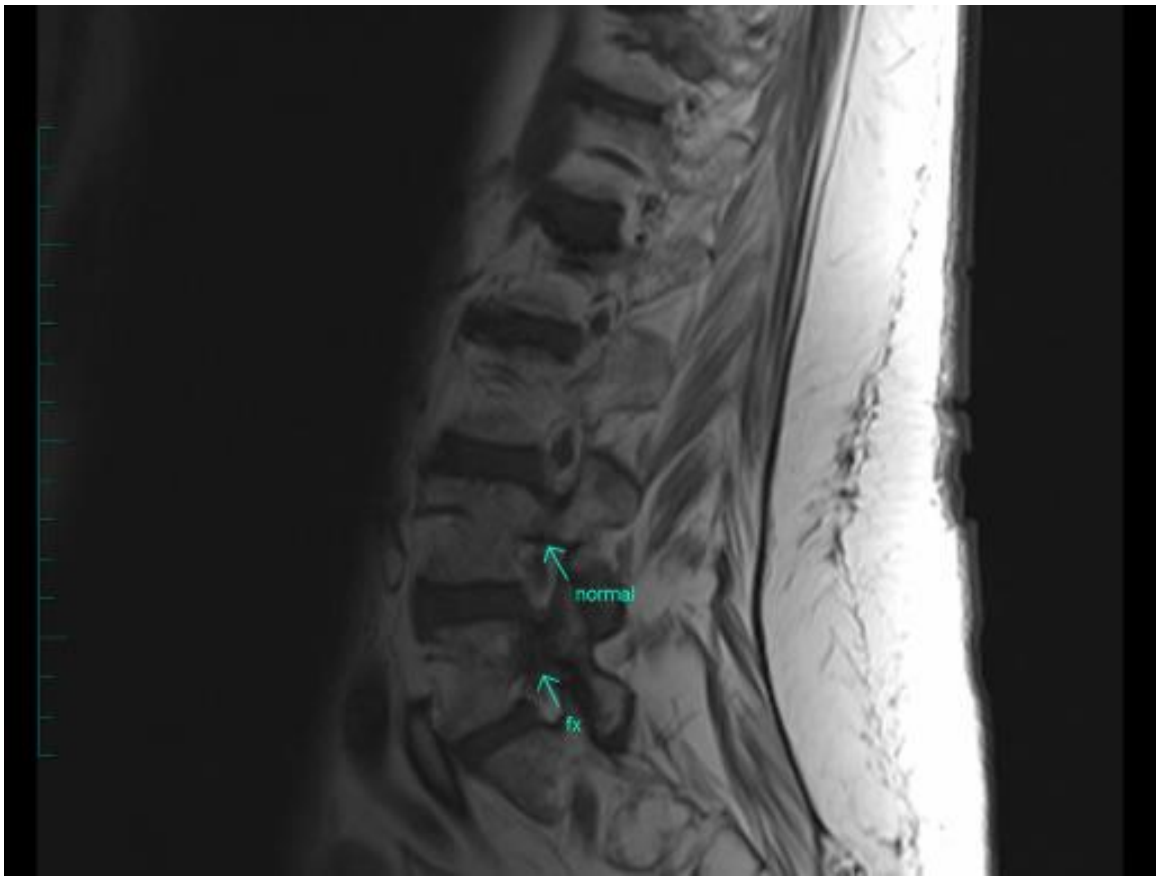


Figure 2; Acute pedicle stress fractures at the L4 and L5 levels without spondylolisthesis shown as per MRI[25].