

Hyperbaric Oxygen Therapy

The following information is from the Undersea and Hyperbaric Medical Society, Inc.

Rationale:

In an hypoxic environment, wound healing is halted by decreased fibroblast proliferation collagen production, and capillary angiogenesis (1). Hypoxia also allows growth of anaerobic organisms, further complicating wound healing. Hyperbaric oxygen therapy provides a significant increase in tissue oxygenation in the hypoperfused, infected wound. It influences the rate of collagen deposition, angiogenesis, and bacterial clearance in wounds. The greatest benefits are achieved in tissues with compromised blood flow and oxygen supply.

Diabetic Wounds:

The increased wound oxygen tension achieved with HBO promotes wound healing, increases the host antimicrobial defenses and has a direct bacteriostatic effect on anaerobic microorganisms.

Venous Stasis Ulcers:

HBO therapy has a very limited role. It is only indicated in highly selected patients in the preparation of a granulating bed over debrided venous ulcer for eventual skin grafting. (2)

Pressure Ulcers:

HBO therapy may be useful when underlying osteomyelitis is present or to improve the soft tissue envelope for reconstruction.

Arterial Insufficiency Ulcers:

HBO therapy may be of benefit in selected cases, especially when a wound fails to heal despite maximum revascularization.

Treatments:

HBO treatments are performed at 2.0 to 2.5 ATA for 90 to 120 minutes of oxygen breathing. The initial treatment schedule is dictated by the severity of the disease process. In the presence of limb-threatening infection after debridement or compromised surgical flaps following amputation the patient should be treated twice daily. When the infection is under control and the soft tissue envelope improves, once daily treatments are adequate.

Additive effects of hyperbaric oxygen and platelet-derived growth factor-BB in chondrocyte transplantation via up-regulation expression of platelet-derived growth factor- β receptor

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Abstract

The present study investigated the effects of hyperbaric oxygen (HBO) and platelet-derived growth factor-BB (PDGF-BB) in chondrocyte transplantation. In vitro, chondrocytes were treated with HBO, PDGF-BB, and HBO combined with PDGF-BB (H+P). Cell growth was analyzed using cell counting, MTT assay, and FACS analysis. mRNA expression of the PDGF- α receptor (PDGFR- α) and β receptor (PDGFR- β) was detected by RT-PCR. Protein expression of PDGFR- β was detected by

Western blotting. In vivo, chondrocytes and PDGF-BB were suspended in alginate as a transplantation system. Cartilage defects were grafted with this system and with or without HBO treatment. Released PDGF-BB concentration was quantified by ELISA. After 8 weeks, animals were sacrificed and the repaired tissues were examined. In vitro data suggested that each treatment increased cell growth via the up-regulated mRNA expression of PDGFR- α and increased cell accumulation in the S-phase. The H+P treatment was more additive in cell growth and in mRNA and protein expression of PDGFR- β than HBO or PDGF-BB. In vivo results suggested that PDGF-BB delivery lasted for more than 5 weeks. Scoring results showed that each treatment significantly increased the cartilage repair. Safranin-O and type II collagen staining confirmed the hyaline-like cartilage regeneration in the repaired tissues. In situ up-regulation of PDGFR- β expression partially explains the additive effect of H+P treatment in cartilage repair. Accordingly, H+P offers a potential treatment method for cartilage repair. © 2009 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. *J Orthop Res* 27:1439–1446, 2009

Effects of hyperbaric oxygen treatment on bone healing. An experimental study in the rat mandible and the rabbit tibia.

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Abstract

This study was undertaken in order to investigate some of the factors important for bone healing. A simple and reproducible experimental model was developed for study of tissue reactions following mandibular osteotomy in the rat. Osteotomies were performed proximal to the entry of the inferior alveolar artery, alone or combined with different degrees of mucoperiosteal reflections. The maximal damage that was seen 10 days after surgery was bone resorption in the central portion of the mandibular corpus. The incisors were found to be more sensitive to vascular disturbances than the molars. The tissue changes were most pronounced when the osteotomies were combined with mucoperiosteal reflections. In order to test different ways of reducing the damage induced and to initiate reparative events by altering local circulatory and metabolic parameters, hyperbaric oxygen (HBO), heparin, or dextran treatments were utilized. The HBO animals were placed in a pressure chamber and subjected to 2.8 ATA HBO, for 2 hours daily. The heparin was administered subcutaneously and dextran by i.v. infusion. Heparin treatment reduced morphologically determined tissue damage in the incisor pulp, odontoblasts and enamel organ. Dextran had no ameliorative effects. HBO treatment reduced tissue damage in a manner similar to heparin, and also induced reparative events, such as osteodentin formation in pulps and early chondroid reactions in bone. The vascular bed (86Rb) and blood flow [(125I]polyvinylpyrrolidone) in the mandible were determined at 10 and 30 days after surgery in animals with and without treatment with HBO. The operated right side was compared to the unoperated left side with respect to these two parameters. In HBO treated animals no difference could be seen between the operated and unoperated sides, whereas both a reduced blood flow and diminished vascular bed were seen in the operated side of the mandible in HBO-untreated animals. Alkaline phosphatase in serum (S-ALP) is considered to reflect the spillover of different isoenzymes from different tissues, and the activity of S-ALP is known to vary because of disease in the tissue from which it is derived. S-ALP was characterized biochemically. Separation and measurement of S-ALP isoenzymes was done using isoelectric focusing and optical densitometry. The S-ALP levels were determined before and after mandibular osteotomy and were compared in tissues of animals treated with HBO. A marked decrease in S-ALP was seen after osteotomy. HBO treatment, on the other hand, inhibited this S-ALP decrease, paralleling a reduced tissue damage in the mandible.

Bone healing of tibial lengthening is enhanced by hyperbaric oxygen therapy: a study of bone mineral density and torsional strength on rabbits.

Ueng SW, Lee SS, Lin SS, Wang CR, Liu SJ, Yang HF, Tai CL, Shih CH. Department of Orthopaedic Surgery of Chang Gung Memorial Hospital, Keelung, Taiwan.

Abstract

We investigated the effect of intermittent hyperbaric oxygen (HBO) therapy on the bone healing of tibial lengthening in rabbits. Twelve male rabbits were divided into two groups of six animals each. The first group went through 2.5 atmospheres absolute of hyperbaric oxygenation for 2 hours daily, and the second group did not go through hyperbaric

oxygenation. Each animal's right tibia was lengthened 5 mm using an uniplanar lengthening device. Bone mineral density (BMD) study was performed for all of the animals at 1 day before operation and at 3, 4, 5, and 6 weeks after operation. All of the animals were killed at 6 weeks postoperatively for biomechanical testing. Using the preoperative BMD as an internal control, we found that the BMD of the HBO group was increased significantly compared with the non HBO group. The mean %BMD at 3, 4, 5, and 6 weeks were 69.5%, 80.1%, 87.8%, and 96.9%, respectively, in HBO group, whereas the mean %BMD were 51.6%, 67.7%, 70.5%, and 79.2%, respectively, in non-HBO group (two tailed t test, $p < 0.01$, $p < 0.01$, $p < 0.01$, and $p < 0.01$ at 3, 4, 5, and 6 weeks, respectively). Using the contralateral nonoperated tibia as an internal control, we found that torsional strength of lengthened tibia of the HBO group was increased significantly compared with the non-HBO group. The mean percent of maximal torque was 88.6% in HBO group at 6 weeks, whereas the mean percent of maximal torque was 76.0% in non-HBO group (two-tailed t test, $p < 0.01$). The results of this study suggest that the bone healing of tibial lengthening is enhanced by intermittent hyperbaric oxygen therapy.

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Hyperbaric oxygen-stimulated proliferation and growth of osteoblasts may be mediated through the FGF-2/MEK/ERK 1/2/NF- κ B and PKC/JNK pathways.

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Abstract

We investigated whether the hyperbaric oxygen (O_2) could promote the proliferation of growth-arrested osteoblasts in vitro and the mechanisms involved in this process. Osteoblasts were exposed to different combinations of saturation and pressure of O_2 and evaluated at 3 and 7 days. Control cells were cultured under ambient O_2 and normal pressure [1 atmosphere (ATA)]; high-pressure group cells were treated with high pressure (2.5 ATA) twice daily; high- O_2 group cells were treated with a high concentration O_2 (50% O_2) twice daily; and high pressure plus high- O_2 group cells were treated with high pressure (2.5 ATA) and a high concentration O_2 (50% O_2) twice daily. Hyperbaric O_2 significantly promoted osteoblast proliferation and cell cycle progression after 3 days of treatment.

Hyperbaric O_2 treatment stimulated significantly increased mRNA expression of fibroblast growth factor (FGF)-2 as well as protein expression levels of Akt, p70(S6K), phosphorylated ERK, nuclear factor (NF)- κ B, protein kinase C (PKC) α , and phosphorylated c-Jun N-terminal kinase (JNK). Our findings indicate that high pressure and high O_2 saturation stimulates growth-arrested osteoblasts to proliferate. These findings suggest that the proliferative effects of hyperbaric O_2 on osteoblasts may contribute to the recruitment of osteoblasts at the fracture site. The FGF-2/MEK/ERK 1/2/Akt/p70(S6K)/NF- κ B and PKC/JNK pathways may be involved in mediating this process.

HBOT for Bone Regeneration & Healing Fractures: Effects of hyperbaric oxygen on proliferation and differentiation of osteoblasts from human alveolar bone

Wu D, Malda J, Crawford R, Xiao Y. Bone Tissue Engineering Lab, Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, Australia.

In view of the controversy of the clinical use of hyperbaric oxygen (HBO) treatment to stimulate fracture healing and bone regeneration, we have analyzed the effects of daily exposure to HBO on the proliferation and differentiation of human osteoblasts in vitro. HBO stimulated proliferation when osteoblasts were cultured in 10% fetal calf serum (FCS), whereas an inhibitory effect of HBO was observed when cultures were supplemented with 2% FCS. On the other hand, HBO enhanced biomineralization with an increase in bone nodule formation, calcium deposition, and alkaline phosphatase activity, whereas no cytotoxic effect was detected using a lactate dehydrogenase activity assay. The data suggest that the exposure of osteoblasts to HBO enhances differentiation toward the osteogenic phenotype, providing cellular evidence of the potential application of HBO in fracture healing and bone regeneration.

Stimulation of early bone formation by the combination of an osteopromotive membrane technique and hyperbaric oxygen.

Scand J Plast Reconstr Surg Hand Surg 1993;27(2):103-8 (ISSN: 0284-4311)

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Large bone defects often heal incompletely as a result of ingrowth of connective tissue. By using a mechanical hindrance, a porous expanded polytetrafluoroethylene (e-PTFE) membrane, it is possible to prevent fibroblasts and other soft connective tissue cells from entering the defect, thereby allowing osteogenesis to occur unhindered. As evidenced in several investigations, this osteopromotive membrane technique causes a strongly improved bone regeneration of well defined osseous lesions. Hyperbaric oxygen treatment has also been shown to accelerate bone healing. In this study the value of combining the two techniques was investigated. Through-and-through bone defects, 5 mm in diameter, were produced unilaterally in the angular region of the mandibles of adult rats (n = 60); the defects in half the number of animals were covered lingually and buccally with membranes. The animals were then divided into four groups: treatment with membrane alone, treatment with hyperbaric oxygen alone, combined treatment, and no treatment. Histological examination of the defects after 14 days showed that the combination of techniques had resulted in significant improvement in bone healing, compared with hyperbaric oxygen or the membrane technique alone. Synergistic effects can thus be achieved by the use of membranes and stimulatory factors for bone regeneration. Reprinted with Permission

Early administration of hyperbaric oxygen therapy in distraction osteogenesis--a quantitative study in New Zealand rabbits.

Wang IC, Wen-Neng Ueng S, Yuan LJ, Tu YK, Lin SS, Wang CR, Tai CL, Wang KC.

Department of Orthopaedic Surgery, Chang Gung Memorial Hospital, Chang Gung University, Taiwan.

BACKGROUND: We investigated the effect of hyperbaric oxygen (HBO) therapy on the early phase of tibial lengthening in our established rabbit model. **METHODS:** Twenty-four male rabbits (six per group) underwent right tibial lengthening by 5 mm. Group 1 then underwent 2.5 atmospheres of absolute hyperbaric oxygenation for 2 hours daily for 6 weeks postoperatively; group 2, for early 5 weeks (weeks 1-5), group 3, for late 5 weeks (weeks 2-6), and group 4 had no HBO therapy. Bone mineral density (BMD) was measured before surgery and weekly thereafter from weeks 2 through 6. The mechanical strengths of the lengthened tibias were measured. **RESULTS:** Significantly higher mean %BMDs were obtained for groups 1 and 2 compared with groups 3 and 4. There was no difference in the mean %BMD between groups 1 and 2 ($p > 0.05$). The results were similar for mean percentage maximal torque; group 1 had the maximum torque, followed sequentially by groups 2 though 4.

CONCLUSION: The study results suggest that early and full-term administration of HBO therapy on tibial lengthening may achieve better benefits.

PMID: 15995475 [PubMed - indexed for MEDLINE]

Hyperbaric oxygen therapy facilitates surgery on complex open elbow injuries: Preliminary results

Complex open elbow injuries present a significant challenge to orthopaedic surgeons because of the poor potential for achieving a good functional level, even given good anatomic realignment. Associated massive soft-tissue damage impedes surgical fixation, delays rehabilitation, and therefore, further deteriorates the functional outcome. We studied a prospective, consecutive series of 16 patients with complex open elbow injuries who were treated with a combination of treatment modalities including early bony stabilization, debridement of soft tissue, and early coverage. The treatment protocol also used hyperbaric oxygen therapy to facilitate immediate internal fixation. The median value of the Mangled Extremity Severity Score was 5.5 (range, 3-10). Successful reconstruction was achieved in all 16 patients. No deep infection occurred, but there were 3 self-limited superficial infections. The average elbow functional result at 12 months

after surgery, based on the Mayo score system, was good (mean value, 80.9; range, 55-100). Of the patients, 75% achieved satisfactory functional results for the elbow. The results of this study demonstrate that the studied treatment protocol provides a promising alternative for managing these complex open elbow injuries.

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Effect of hyperbaric oxygen therapy on patellar tendinopathy in a rabbit model

Hsu RW, Hsu WH, Tai CL, Lee KF.

Source: Department of Orthopedic Surgery, Chang Gung Memorial Hospital at Chia-Yi, Chia-Yi, Taiwan.

Abstract

BACKGROUND: Hyperbaric oxygen therapy is a method for augmenting oxygen availability to tissues. This study investigated the effect of hyperbaric oxygen therapy on the collagenase-induced tendinopathy in the rabbit patellar tendon.

METHODS: In this study, 13 rabbits were treated by ultrasound-guided injection of 0.025 mL collagenase into the patellar tendon at the right knee, with the left knee serving as a control condition. The rabbits were randomly divided into two groups. After tendinopathy had been confirmed by histologic examination 3 weeks after treatment, hyperbaric oxygen therapy was initiated for group 1. The hyperbaric oxygen therapy involved 30 daily sessions of 2.5 ATA for 120 minutes starting 6 weeks after treatment. The rabbits in group 2 were put in normobaric room air. Both groups were killed 10 weeks after treatment. Histologic examinations as well as mechanical and biochemical tests were performed after the animals were killed.

RESULTS: The ultimate tensile load in the tendon that had hyperbaric oxygen therapy was 34.8% greater than that in the control tendon 10 weeks after treatment ($p < 0.05$). Hydroxyproline concentrations increased 82.2% simultaneously in the tendons that had hyperbaric oxygen therapy, as compared with the concentrations in the control tendons ($p < 0.05$). However, no statistical difference was found between the two groups in terms of pyridinoline concentration at the 10th week ($p > 0.05$). The histologic examination demonstrated an increase in blastlike tenocytes in group 1, with more mature phenotype, more organized collagen matrix, absence of myxoid degeneration, and increased vascularity at the 10th week, as compared with the control knee.

CONCLUSIONS: The results validate the effectiveness of hyperbaric oxygen therapy in the treatment of tendinopathy. Hyperbaric oxygen therapy may increase collagen synthesis and collagen cross-link formation during the early healing process.

Spinal cord infarction following endoscopic variceal ligation

Case Report

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Abstract

Study design: A case report of spinal cord infarction following endoscopic variceal ligation.

Objectives: To describe an exceedingly rare case of spinal cord infarction following endoscopic variceal ligation.

Setting: Department of Orthopaedic Surgery, Kagoshima, Japan.

Methods: A 75-year-old woman with cirrhosis caused by hepatitis C virus, who was admitted to our hospital for the treatment of esophageal varices, experienced numbness of the hands and lower extremities bilaterally following an endoscopic variceal ligation procedure. Sensory and motor dysfunction below C6 level progressed rapidly, resulting in inability to move the lower extremities the following day. Magnetic resonance imaging of the spine revealed abnormal spinal cord signal on T2-weighted images from approximately C6 through T5 levels, which was diagnosed as spinal cord infarction.

Results: The patient underwent hyperbaric oxygen treatment. Her symptoms and signs related to spinal cord infarction gradually remitted, and nearly complete disappearance of neurological deficits was noted within 3 months after the start of treatment.

Conclusion: We speculate that the pathogenesis of the present case may have involved congestion of the abdominal–epidural–spinal cord venous network owing to ligation of esophageal varices and increased thoracoabdominal cavity pressure.

Magnetic resonance imaging of hyperbaric oxygen treated rats with spinal cord injury: preliminary studies

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Magnetic resonance imaging (MRI) has been performed to assess the efficacy of hyperbaric oxygen (HBO) treatment on experimental spinal cord injury in a rat animal model. A moderately severe injury, similar to Type III injury seen in humans (Kulkarni et al. Radiology 164:837;1987) has been chosen for these studies. An improvement in the neurologic recovery (based on Tarlov scale) has been observed following HBO treatment over a period of 72 hr. Based on MRI, HBO treatment appears to arrest the spread of hemorrhage and resolve edema.

Hyperbaric oxygen (HBO) therapy for acute traumatic cervical spinal cord injury

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Abstract

Study design: A retrospective study of spinal cord injury (SCI) treated with and without hyperbaric oxygen (HBOT) therapy.

Objectives: To report on the use of HBO in spinal cord injury.

Setting: Neurosurgical Unit, Tokyo, Japan.

Methods: Thirty-four cases of hyperextension spinal cord injury without bone damage and previous history of surgical intervention were divided into two groups, with (HBO) or without (non-HBO) therapy. The neurological findings at admission and their outcomes were evaluated by means of Neurological Cervical Spine Scale (NCSS) and the average improvement rates in individual groups were compared.

Results: The improvement rate ranged from 100% to 27.3% with the mean value of 75.2% in the HBO group, while these values were 100%, 25.0% and 65.1% respectively in the non HBO group.

Conclusion: In the HBO group, the improvement rate indicated effectiveness in acute traumatic cervical spinal cord injury.

Hyperbaric Oxygen Therapy (HBOT) therapy for acute traumatic cervical spinal cord injury.

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STUDY DESIGN: A retrospective study of spinal cord injury (SCI) treated with and without hyperbaric oxygen (HBO) therapy.

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RESULTS: The improvement rate ranged from 100% to 27.3% with the mean value of 75. 2% in the HBOT group, while these values were 100%, 25.0% and 65.1% respectively in the non HBOT group.

CONCLUSION: In the HBO group, the improvement rate indicated effectiveness in acute traumatic cervical spinal cord injury.

Prediction of neurologic outcome in patients with spinal cord injury by using hyperbaric oxygen therapy

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Abstract

The effectiveness of hyperbaric oxygen therapy (HBO) in predicting neurological recovery in patients with spinal cord injury was evaluated. HBO has been used to treat spinal cord injury, but HBO does not appear to greatly alter the neurological outcome. This is the first report of the use of HBO as a diagnostic tool to evaluate neurological recovery after spinal cord injury. The study group consisted of 22 patients, aged 21-73 years, with spinal cord injuries. The effect of HBO was evaluated on admission and categorized as one of four grades (excellent, good, fair, or poor). The neurological status was evaluated on admission and at the time of follow-up, according to Frankel grade and the American Spinal Injury Association (ASIA) motor score. Correlations between the HBO effect and Frankel grade recovery and correlations between the HBO effect and recovery rate of the ASIA motor score were evaluated. The recovery in Frankel grade from admission to the final follow-up became better as the effectiveness of HBO increased ($r = 0.445$; $P = 0.0414$). The Frankel grade ($r = 0.036$; $P = 0.871$) and ASIA motor score ($r = 0.029$; $P = 0.893$) on admission did not correlate with the recovery in Frankel grade. There was a significant correlation between the HBO effect and the recovery rate of the ASIA motor score ($r = 0.586$; $P = 0.0072$), but this correlation was weaker than that for the ASIA motor score on admission ($r = 0.752$; $P = 0.0006$).

We conclude that HBO can be employed to assess the status of spinal cord function recovery after spinal cord injury.

Spinal Cord Injuries

WASHINGTON, MD -- May 11, 1998 -- High-pressure chambers used to treat deep sea divers for decompression sickness could play a key role in preventing permanent spinal cord damage and paralysis to many of the thousands of Americans who suffer spinal cord injuries every year, a doctor from Scotland reported today.

Dr. Philip James of the University of Dundee reported at a conference here that putting patients under high pressure forces more cell-resuscitating oxygen into damaged spinal nerves than is possible at normal atmospheric pressure.

"It may mean the difference between significant disability and no disability," James said.

James made his remarks at a meeting of the Space and Underwater Research Group of the World Federation of Neurology. The meeting is being coordinated by the Stroke Research Center of the Wake Forest University Baptist Medical Center.

James has been a consulting physician to North Sea diving operations for 25 years. Divers sometimes suffer from bubbles in their spinal cord, resulting in tissue damage that is similar to the bruising that spinal cords suffer from traumatic injury.

Typically, nerve tissue in the spinal cord is starved of oxygen because the small capillaries that carry blood to the tissue are damaged. If adequate blood flow is not restored within hours, the nerve cells in the spinal cord die from lack of oxygen. This can result in complete or partial paralysis.

Placing these divers in hyperbaric chambers and raising the pressure to 2.8 times the normal atmospheric pressure hastens their recovery, James said, because under high pressure the blood carries proportionally more oxygen. This raises the oxygen levels in the damaged nerve tissue toward normal levels to assist recovery. For spinal cord injury patients, raising the pressure to two times atmospheric pressure would be adequate, James said.

An estimated 250,000 Americans have spinal cord injuries, according to the American Paralysis Association. On average, 11,000 new injuries are reported every year. The cost of treating and caring for these individuals can range from \$600,000 US to \$1.3 million US over a lifetime, depending on age and the degree of injury.

James cautioned that hyperbaric oxygen therapy, as the high-pressure procedure is called, is useful only in cases where the spinal cord is bruised, but not in cases where it is physically severed. The National Spinal Cord Injury Statistical Center does not keep statistics on what proportion of spinal cord injuries are limited to bruising, but James said the vast majority fall into this category.

A number of very positive animal studies on the use of hyperbaric oxygen therapy in treating spinal cord injury have been published, James said. On humans, it has been used on a number of spinal cord injured patients over the past 20 years in the United States, Germany and Australia but no large scale studies have been conducted. One impediment was that until recently, there was no way to tell whether the spinal cord was bruised or severed, James said.

"If you go on the physical symptoms of the patient you can't tell," he said.

Recent improvements in magnetic resonance imaging, however, now make it possible to determine which spinal cord casualties should be treated with hyperbaric oxygen therapy.

Unfortunately, James said, most trauma centres do not have hyperbaric chambers, which is a tragedy, and most physicians don't understand the need to increase the dissolved oxygen in the plasma of the blood. They stop at hemoglobin saturation.

Spinal Case Studies

Mr. CD

Diagnosis : 34 year old male. L5/S1 herniation with sequestered fragment and thrombosis involving the arteriovenous plexus.

Clinical Symptoms : Long history of chronic low back and leg pains. Constant stiffness with episodes of acute debilitating back and sciatic pains. Condition had been progressively deteriorating with increased back stiffness and leg aches. During initial consultation, he complained of severe lower back pain with sharp shooting pains extending down his right thigh, leg and foot. He describes a heavy numbness sensation of his lower leg and foot. He complained of constant pins and needles extending down his legs and across his toes. He reported weakness of his right leg and when walking found that he often missed a rising step with his right foot. Review and treatment by his medical doctor, extensive physical therapies including chiropractic and physiotherapy failed to improve his condition. Review by an Orthopedic Surgeon recommended decompressive surgery and possible fusion.

Investigation : Cat Scan - Large right paramedian L5/S1 disc prolapse with right S1 nerve root compression. MRI - Small L4/5 disc protrusion affecting the right L4 nerve root. Large L5/S1 disc extrusion with mass effect and compression of the right S1 nerve root. Disc extends as far as the S1-2 with mass displacement of the S2 nerve root. Margins of the disc are ill defined with suspicion of haemorrhage associated with disc material. Endplate reactive changes Modic type II infiltration of the inferior L5 vertebral body. Desiccation both L4/5 and L5/S1 discs indicating continuing degenerative joint disease.

AFTER

Treatment : Daily Hyperbaric Oxygenation and assertive physical therapy program to reduce pain, disability and promote functional stabilisation. HBOT performed at 2.0 ATA 100% O₂ for 45-minute duration. Following clinical improvement patient treatments were reduced to 3 sessions per week. Physical therapy immediately following HBOT included electrically stimulated high frequency acupuncture, supportive chiropractic techniques and physiotherapy modalities including supportive taping, injectable vitamins. Medical review including muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : Substantial reduction of pains to both lower back and right leg. He reports no altered sensory function and the strength to his right leg had returned.

Investigations : Follow up MRI (3 months) after commencing with SRG confirmed substantial reduction of L5/S1 prolapse with reduction of the mass effect on both the theca (lower spinal cord structures) and exiting S1 and S2 nerve roots. Further follow up (6 months) confirms stable appearances of both L4/5 and L5/S1 discs with continuing reduction of residual effects of the L5/S1 extrusion.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Mr JB1

Diagnosis : 28-year-old male. L5/S1 herniation with large sequestered fragment.

Clinical Symptoms : History of chronic back pain with periodic episodes of acute back and right-sided sciatica. Original injury occurred whilst lifting a desk at work several years ago. Initially he experienced a 'tearing' sensation, which resulted in severe pain and stiffness the following day. Eventually his condition settled with a residual dull ache. He maintains a high level of fitness including skiing, snow boarding, surfing etc. During the 12 months prior to attending this clinic, his condition continued to deteriorate with increasing episodes of acute pain.

Day to day living became severely restricted requiring assistance to perform simple basic functions including getting in and out of bed and attending the shower or toilet. Unable to sit or stand, he had become stooped attempting to find relief. Extensive forms of treatments including physiotherapy, chiropractic, traction and hydrotherapy, all failed to alleviate his symptoms. His local doctor recommended a surgical opinion including discectomy and possible fusion.

Investigation : Retrolisthesis L5 on S1 measuring approximately 8.0mm. MRI investigation identified significant desiccation of the L5/S1 disc with mild narrowing and endplate degenerative changes. A large central and right posterolateral extrusion with sequestered fragment compressing both the thecal sac and obliterating the right S1 nerve root.

AFTER

Treatment : Daily HBOT and assertive physical therapy directed to reduce pain and promote stabilisation. HBOT performed at 2.0 ATA 100% O₂ for 90-minute duration usually several sessions per day. Physical therapy included electrically stimulated acupuncture, supportive chiropractic and physiotherapy modalities, supportive taping, injectable and oral vitamins. Medical review including antibiotic therapy, muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : Significant reduction of back and leg pain. Lifestyle and general sporting activities continue to require moderation. He remains prone to continuing bouts of episodic pain that are currently managed with continuing treatments and medication.

Investigation : Follow-up MRI (3 months) confirms substantial reduction of mass effect of the L5/S1 prolapse. Residual focal paracentral protrusion remains.

Ms. CJ

Diagnosis : 40-year female. Residual back and leg pain subsequent to back surgery of L5/S1 disc.

Clinical Symptoms : Back pain initially caused by 'tripping over a step', jerking her back. Apart from a dull awareness her back did not really bother her. Several months later she began to complain of a deep-seated stiffness and pain. She also noticed an increasing sensation of numbness across her right buttock and down into her thigh, leg, calf, foot and across the bottom of her toes. Her local chiropractor commenced a course of manipulation, however no X-rays were performed. Her condition progressively deteriorated, regardless of her treatments, ultimately forcing her to attend hospital casualty for assistance and investigation. She was immediately recommended bed rest and strong anti-inflammatory medication. Investigation including CT Scan and Myelogram revealed a large prolapsed L5/S1 disc compressing spinal cord structures.

Wide surgical decompression laminectomy and partial L5/S1 disc removal was performed 1 week later. Three months after the back operation, she began complaining of 'curling of the toes to her right foot' and a loss of sensation down the bottom of her leg and in her toes. She was walking with a distinct limp and described clawing of the toes that made her prone to tripping. Her surgeon stated that her 'foot condition was unrelated to her operation'.

Investigation : MRI-L5/S1 posterior laminectomy scar extending posterior and lateral to the thecal sac. The scar extends anteriorly to surround both the S1 nerve roots. The L5/S1 disc is narrowed with desiccation and substantial vertebral endplate degenerative changes (Modic type II). Minimal posterior disc bulging is seen deep to the scar. The L4/5 disc level reveals desiccation without significant narrowing. Prominent posterior annular tear and a further annular tear in a left posterolateral position in relation to the L4 foramina. Moderate L4 facet joint hypertrophy together with disc bulging causing moderate central canal stenosis at the L4/5 level. L2/3 level asymmetrical posterolateral disc bulge impinges on the point of origin of the left L3 nerve root.

AFTER

Treatment : Daily HBOT and assertive physical therapy to reduce pain, and promote stability. HBOT performed at 2.0 ATA 100% O2 for 90-minute duration, several sessions per day. Physical therapy included electrically stimulated high frequency acupuncture, supportive chiropractic techniques and physiotherapy modalities including supportive taping and injectable and oral administered vitamins. Medical review including antibiotic therapy, muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : Significant reduction of back and leg pain, increased sensation of the right leg and foot, regaining muscular strength and bulk of her lower leg and foot. Patient reports increased and improved lifestyle.

Investigations : Follow-up MRI (6 months) reduction of previously aggressive L5/S1 endplate degenerative changes. No recurrent or residual disc bulge is identified. L5/S1 disc space is generous compared to previous investigation. No abnormal enhancing soft tissue is identified at the laminectomy defect or within the epidural space to suggest scar formation. Ample CSF encases both S1 nerve roots with no identification of scar tissue surrounding.

Continuing Therapy : Patient continues with Stage 2 of treatment.

Mr. JB2

Diagnosis : 29-year-old male. L5/S1 disc prolapse with adjacent fragment.

Clinical Symptoms : Chronic history of low back and leg pain. Patient had received previous stabilisation treatment of his chronic back condition. Increased physical activities resulted in a slow deterioration of his lower back with a gradual increase in leg pains. Eventually his condition collapsed with intense crippling pain in his lower back extending into his right thigh and leg with intense pain at his right lower leg and ankle region.

Investigation : MRI demonstrated a 1-cm circumscribed T1 and T2 intermediate signal intensity lesion extending from the posterior aspect of the a L5/S1 disc protrusion/extrusion indenting the right anterolateral aspect of the thecal sac compromising the right S1 nerve root. This is associated with thickening of the posterior longitudinal ligament overlying the disc extrusion.

AFTER

Treatment : The patient was debilitated with severe pain. He was initially treated constantly receiving between 4-6 hours of treatment per day, including Hyperbaric Oxygenation. HBOT was performed at 2.0 ATA 100% O₂ for 90-minute periods with a minimum of 2-3 sessions per day. Physical therapy was intense with the patient receiving constant attention including high frequency electrically stimulated acupuncture and mechanical blocking of the pelvis. In addition supportive chiropractic techniques and physiotherapy modalities, structural tapping, injectable and oral vitamins and a firm back brace between treatments were applied. Medical supervision included cortisone injections, muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : Slow reduction of symptoms eventually stabilizing with a residual dull ache across the lower back and upper posterior right thigh.

Investigations : Follow up MRI (3 months) confirms that the previously identified 1cm mass is no longer evident. This lesion most likely represented a combination of inflammatory change and haemorrhage rather than sequestered fragment. The L5/S1 disc protrusion persists, however it is marginally smaller indenting the anterior and right aspects of the thecal sac contacting and displacing the right S1 nerve root. A small amount of fat persists between the right S1 nerve root and right-sided facet, and in addition the nerve root is not enlarged and although the nerve root is posteriorly displaced, no clear compression is evident. The disc extends to contact the left S1 nerve root as it emerges from the thecal sac, however no left sided neural compromise is evident.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy and medication continues. This patient has been instructed and continues to alter his lifestyle, which has included in excess of 7-kg weight loss. He continues to remain stable.

Mr. RC

Diagnosis : 45-year old male. Multi level degenerative instability due to a compression fracture of the L3 vertebra during 1976. Subsequent central canal stenosis L3/4 and L4/5.

Clinical Symptoms : Patient presents with a long history of chronic low back pain and right-sided sciatica. A heavy fall from a ladder during 1976 resulted in a compression fracture with subluxation. He is a commercial painter with heavy repetitive demands on his back. He complains of constant residual pain and disability. His condition has progressively deteriorated and suffers frequent episodes of acute attacks that force him to lie down between 4-7 days requiring heavy medication to provide some form of relief. He has consulted numerous medical doctors and treating practitioners. He has been recommended spinal fusion. He reports that manipulation definitely makes his condition worse.

Investigations : MRI - L5/S1 disc no abnormality. L4/5 disc narrowing, desiccation with prominent tear. Moderate central and right posterolateral protrusion compressing the theca and L5 nerve root. L4/5 level reveals moderate central canal stenosis with contribution from advancing posterior facet hypertrophy. L3/4 level reveals old wedge compression of the L3 vertebra. Substantial L3/4 disc degeneration with endplate degenerative changes, Modic type II. Moderate central canal stenosis with posterior facet joint arthropathy. Large central and right-sided posterolateral disc protrusion with L4 nerve root compression. L2/3 marked disc desiccation, narrowing with evidence of old herniation of the L2/3 disc into the L3 vertebral body. Degenerative endplate erosion again, at L2/3. Annular tear with moderate posterior bulging compressing theca and displacing the left L3 nerve root. Again, central canal stenosis is evident at the L2/3 level.

AFTER

Treatment : Daily Hyperbaric Oxygenation and assertive physical therapy program to reduce pain, disability and promote functional stabilisation. HBOT performed at 2.0 ATA 100% O₂ for 45-minute duration. Following clinical improvement patient treatments were reduced to 2 sessions per week. Physical therapy immediately following HBOT included electrically stimulated high frequency acupuncture, supportive chiropractic techniques and physiotherapy modalities including supportive taping, injectable vitamins. Medical review including muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : 6-month follow up, patient reports a significant reduction to his chronic and persisting condition. He reports a considerable reduction to both the frequency and intensity of acute episodes and his residual stiffness has also diminished. He reports improvement in his day to day activities stating that he though 'he had to live with it'. Follow up 12 month evaluation, he records no back or leg pain, experiencing a residual low back ache which disappears with simple stretching exercises.

Investigations : Follow-up MRI (6 months) reduction of the L3/4 prolapse with substantial improvement of the central canal stenosis. Improvements noted and recorded at other levels.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Mr. JF

Diagnosis : 23-year old male. Central canal stenosis due to large L4/5 disc protrusion.

Clinical Symptoms : Long history of chronic low back problems. Patient describes his condition as being 'on and off' over the years and directly aggravated by heavy physical work. He reports a number of impact falls, heavy farm related work including sheep shearing and numerous sporting related injuries. Patient reports acute lower back pains extending down the right thigh into his calf and foot area. Pain is predominately right sided but reports involvement of his entire left leg also. He describes his back as feeling 'extremely unstable'.

His condition is aggravated by prolonged sitting and standing. Basic lifting and even gently exercise movements significantly aggravate his condition. Acute sharp attacks are also triggered by 'sneezing and even coughing'. Recommended extended bed rest by his local doctor provided no relief. He has consulted numerous treating practitioners with therapies including chiropractic, physiotherapy, acupuncture and massage. He has maintained a reasonable exercise and stretching program where possible. Continuing instability resulted in him being referred by his local medical doctor to an Orthopedic Surgeon who recommended surgical decompression and stabilization.

Investigations : MRI - Large central L4/5 disc extrusion with high grade central canal compromise. Retrolisthesis L5 on S1 with small central disc protrusion. Posterior annular tear L5/S1 disc. Moderate bilateral L5 foraminal compromise. Desiccation at L4/5 and L5/S1 discs indicating continuing degenerative disc disease.

AFTER

Treatment : 12 month stabilization program recommended including Hyperbaric Oxygenation and assertive physical therapy to reduce pain, disability and promote functional stabilization. HBOT commenced daily between 45-90 minute sessions at 100% O₂, 2 ATA. Following clinical improvement patient treatments were reduced between 2-3 HBOT and physical therapy sessions per week. Physical therapy included electrically stimulated high frequency acupuncture, supportive chiropractic techniques and physiotherapy modalities including supportive taping, injectable vitamins. Medical review included muscle relaxants and anti-inflammatory medications.

Clinical Symptoms : Significant reduction of back and leg pain. Pain now described as a dull generalized ache across the lower back. No leg involvement.

Investigations : Follow up MRI (12 months) confirms clear and substantial reduction of the L4/5 prolapse with marked improvement of central canal compromise.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Mr. BB

Diagnosis : 34-year old male. L5/S1 herniation with left S1 nerve root compression

Clinical Symptoms : Chronic history of low back stiffness and pain associated with many former years of competitive sports. He states that his overall condition has been manageable with general physical treatments without any serious ongoing problems. Recent lifting injury resulted with immediate acute debilitating pain that continued to deteriorate with pains shooting down his left thigh, leg and into his foot. He describes pins and needles across his left foot extending into his outside toes. Coughing, sneezing and straining with bowel action aggravate his condition. He states that since his back has deteriorated, he now complains of increased urination frequency and incontinence. He cannot sit, stand or lie down for any length of time without increased pain. He had received numerous forms of physical therapy, medical treatments including reviewed by a prominent Neurosurgeon who recommended surgery.

Investigations : Functional loading X-rays revealed a 4.0mm Retrolisthesis of the L5 on S1. MRI confirms Retrolisthesis at L5 with moderately large left posterolateral L5/S1 disc prolapse with mass effect of the exiting S1 nerve root. Desiccation both L4/5 and L5/S1 discs indicating continuing degenerative joint disease.

AFTER

Treatment : This patient's home was approximately 2.5 hours away from our treatment facility. It was virtually impossible to provide an initial stabilisation period that is usually recommended to provide Oxygen saturation. Therapy sessions varied, occasionally daily if accommodation was provided, but often extended to beyond several weeks. HBOT was performed at either 45-minute or at 90-minute sessions at 2 ATA 100% O₂. Physical therapy following HBOT sessions included high frequency electrically stimulated acupuncture, supportive chiropractic techniques and physiotherapy taping, injectable vitamins, and medications including muscle relaxants and anti-inflammatory.

Clinical Symptoms : Significant reduction of initial presenting symptoms. Residual generalised dull low back pain without leg involvement. Activity levels have improved dramatically without disability. No bladder or bowel symptoms. No altered sensory dysfunction.

Investigations : Follow up MRI (12 months) confirmed a substantial reduction of the L5/S1 prolapse with marked improvement and reduction of the mass effect on both theca and exiting S1 nerve root.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Mr. HN

Diagnosis : 29 year old male. L5/S1 herniation with right S1 nerve involvement.

Clinical Symptoms : 2 year history of back related problems. Primarily low back with right leg involvement. Patient reports secondary pains involving neck and across both shoulders. Treatments prior to consulting SRG included massage, physiotherapy and chiropractic manipulations. Patient reports that his condition was slowly deteriorating and was not gaining relief from treatments.

Investigations : Functional loading X-rays revealed a 3-4mm Retrolisthesis of the L5 on S1 which increased upon extension and reduced on flexion. MRI investigation confirms a moderately large left postero-central L5/S1 disc herniation extending through the posterior longitudinal ligament contacting the exiting left S1 nerve root. Desiccation noted at L2/3 and L5/S1 discs indicating continuing degenerative disc disease.

AFTER

Treatment : Initial 4-6 month stabilization period which included assertive Hyperbaric Oxygenation coupled with physical therapy. HBOT initially commenced daily then reduced to between 2-3 sessions per week with clinical improvement. HBOT performed for 45-minutes at 2 ATA 100% O₂. Physical therapy following HBOT sessions included high frequency electrically stimulated acupuncture, supportive chiropractic techniques and physiotherapy taping, injectable vitamins and medications including muscle relaxants and anti-inflammatory.

Clinical Symptoms : Significant reduction of his initial presenting symptoms. No back pain other than a broad based dull muscular ache, no leg pains and no altered sensory dysfunction.

Investigations : Follow up MRI (3 months) confirms a substantial reduction of the L5/S1 prolapse with marked improvement and reduction of the mass effect on both theca (lower spinal cord) and exiting S1 or S2 nerve roots. Further follow up MRI (6 months) confirms stable appearances of both the L4/5 and L5/S1 discs with continuing reduction of residual effects of the L5/S1 disc extrusion.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Ms. GA

Diagnosis : 39 year old female. Multi disc degeneration with a large 1cm C6/7 right paracentral and foraminal disc prolapse.

Clinical Symptoms : History of neck and upper back problems which were 'generally kept at bay' with a maintenance approach of manipulations.. After a manipulation session, patient describes acute neck and shoulder blade pains with intense pains travelling down into right arm and hand. Hospital review with immediate pain medication including Pethidine injections had little or no effect. CT Scan and MRI performed confirmed large mass effect with cord compression due to C6/7 prolapse. Review by several Orthopedic Surgeons and a Neurosurgeon advised immediately surgical stabilisation given continuing deterioration, loss of strength of hands, pins and needles both upper and lower extremities.

Investigations : MRI investigation reveal large C6/7 right paracentral and foraminal prolapse (1cm) obliterating the exiting right C7 nerve root and resulting with significant cord compression (compressive myelomalacia) and rotation. Multi-level desiccation indicating degenerative joint disease.

AFTER

Treatment : Initial 3-month intensive treatment including high frequency electrically stimulated acupuncture, supportive chiropractic techniques and physiotherapy taping, injectable vitamins, and medications including muscle relaxants and anti-inflammatory.

Clinical Symptoms : Significant reduction of initial presenting symptoms. Post therapy 3-month assessment the patient now grades neck and arm pains at 4/10, previously 10/10. She continues to suffer dull neck and right arm involvement. She reports intermittent pins and needles across the palm of her right hand.

Investigations : Follow up MRI (3 months) confirmed a substantial reduction of the C6/7 prolapse with marked improvement and reduction of the mass effect and cord rotation. Significant reduction of the mass effect of the exiting C7 nerve root. Noted improvement of the multi-disc hydrated appearances.

Continuing Therapy : Patient transferred overseas for employment. Patient made contact with SRG approximately 6 months after cessation of treatment. She reports that overall she continues well, suffering intermittent dull neck pains with minimal pins and needles to her right arm and hand. Supportive treatment recommended.

Mrs. VS

Diagnosis : 65-year old woman. L5 spondylolisthesis with secondary post surgical degeneration with imposed central canal stenosis.

Clinical Symptoms : Chronic history of back problems extending over 25 years. She states that she had previous lower back surgery, approximately 22 years, with a double laminectomy decompression at her L5. She states that she has suffered constant back and leg pains which she had 'learnt to live with'. She states that her condition took a terrible turn for the worse when she fell on a slippery floor. Prior to this injury she states that she wore a back brace periodically, but

now she is totally dependent on the brace. She presents with acute low back pain with radiation extending down into both legs. She grades her pain as being 9 out of a possible 10. She reports cramping pains and pins and needles extending down both the front and backs of both her legs. She states that both legs are extremely weak. She reports secondary neck and upper back pains. Reviewed by a number of specialist, she has been recommended total block spinal fusion.

Investigations : MRI investigation identifies a 1cm anterior slippage of L5 on S1 with bilateral pars interarticulars defect (spondylolisthesis). Significant L5/S1 disc narrowing with evidence of post surgical fibrotic scarring. Small L4/5 disc bulge with a posterior annular disc tear. At the L3/4 disc level exists a degenerative bulge disc narrowing and desiccation with associated central canal stenosis.

AFTER

Treatment : 12-month stabilization including Hyperbaric Oxygenation coupled with physical therapy. HBOT initially recommended daily sessions for 45 minute intervals at 2 ATA 100% O₂. This frequency was reduced to 1-2 session per week with clinical stabilization. Physical therapy following HBOT sessions included high frequency electrically stimulated acupuncture, supportive chiropractic techniques and physiotherapy tapping, injectable vitamins, and medications including muscle relaxants and anti-inflammatory.

Clinical Symptoms : Significant reduction of back and leg pains. No longer dependent upon the back brace which is now used infrequently. Residual pains alleviated with heat, massage and mobility. She has returned to social activities, which previously she withdrew because of pain and disability. Overall, reduction of disability, improved mobility, residual pain managed with conservative care.

Investigations : Follow up MRI (9 months) confirms a reduction of central canal stenosis at L3/4. Reduction of the anterior slippage of L5 spondylolisthesis. Reduction of the posterior scar formation at L5/S1.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.

Ms. JT

Diagnosis : 42 year old female L5/S1 and L4/5 disc herniation with left S1 nerve involvement.

Clinical Symptoms : 2-year history of increasing back pain. Fell down stairs approximately 10 years earlier and 'bruised her tail bone'. Low back and left leg involvement has progressively increased during the previous 2 years. During the initial consultation she complains of acute low back pain with left sciatica. Patient walks with severe limitations, and complains of increased leg pain with attempted walking and when transferring weight onto her left leg. She reports pins and needles and cramping sensation in her lower thigh and left calf extending into the left foot. Pain is increased with prolonged sitting, standing, stooping and twisting. Straining with bowel and bladder action significantly increases the back and leg pain. She complains of increased urination frequency with incontinence. Medical management included pain killers and anti-inflammatories. She had been recommended decompression surgery and possible spinal fusion.

Investigations : MRI investigation - L5/S1 left posterolateral disc herniation displacing the left S1 nerve root. L4/5 disc reveals a posterior annular tear and focal disc protrusion indenting the theca. The L3/4 disc reveals disc bulging which again contacts the theca. Desiccation noted at the L3/4, L4/5 and L5/S1 levels indicating continuing degenerative joint disease. Inferior endplate L5 and L4 are consistent with reactive degenerative change and secondary to disc disease.

AFTER

Treatment : Initial 4-6 month stabilization period of intensive Hyperbaric Oxygenation saturation and physical therapy was recommended. HBOT commenced daily, initially performed at 90 minute sessions at 2 ATA 100% O₂ then reduced to 45-minute sessions with clinical stabilization. Physical therapy following HBOT sessions included high frequency electrically stimulated acupuncture, supportive chiropractic techniques and physiotherapy taping, injectable vitamins, and medications including muscle relaxants and anti-inflammatory.

Clinical Symptoms : Slow reduction of acute back and leg pain. Patient continued with residual symptoms that gradually improved with time and continuing conservative management. Frequency and intensity of acute relapses have significantly diminished and she continues to remain stable. No residual sensory dysfunction.

Investigations : Follow up MRI (3 months) confirms her clinical improvement with a clear reduction of the broad based L5/S1 prolapse.

Continuing Therapy : Hyperbaric Oxygenation coupled with physical therapy recommended on a supportive measure based upon the patient's continuing presentation. Additional limited MRIs to be performed on a biannual basis to monitor overall progress.