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NEUROLOGIC RECOVERY FOLLOWING SURGERY FOR MALIGNANT DISEASE OF THE SPINE

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Introduction: Patients with malignant spinal disease who have neurologic symptoms are often considered poor surgical candidates. The aim of this paper is to review the effect on neurologic symptoms of surgical management of malignant spinal disease.

Methods: A retrospective review of patients treated from January 1993 to June 2003 was undertaken. Pain status was assessed using patient statements and recorded analgesic requirements. Neurologic symptoms were assessed using Frankel's grading.

Results: There were 95 patients (32 females aged 26-83; 63 males aged 15-89). No patients were asymptomatic. 61 of 109 presentations were with multiple symptoms. The most common symptom was pain (99) – either localised (8), non-specific back (56) and/or radicular (57). The next most frequent symptom was weakness (54). The time course of onset varied from acute ward deterioration, with urgent surgery, to slow progression over weeks, prior to elective surgery. 8 cases had sphincteric dysfunction.

There were 98 tumours treated. In females, the most common tumours were breast (8) and renal (4) and in males, prostate (13), multiple myeloma (12) and lung (10). The thoracic spine was involved in 62, the lumbar in 18, cervical in 16 and sacral in 2. The vertebral body was involved in 76.

There were 109 operations. An instrumented fusion was performed in 82. Surgical approach was anterior in 17 (9 cervical, 8 thoracic) and posterior in 80 (5 cervical, 56 thoracic and 17 lumbar). Six patients had combined approaches (2 cervical, 3 thoracic and 1 lumbar). Two patients were treated for metachronous tumours. One patient had non-contiguous metastases treated separately. One patient was treated for local recurrence. One patient had revision for implant failure (anterior thoracic). One patient was explored after deterioration due to loss of autoregulation. Thoraco-abdominal approaches (12) were associated with ileus (2) and pneumonia (3). Of four cases with deep wound infections, three had received prior local irradiation. Two patients died of pulmonary embolus. 83 patients survived beyond three months.

All patients demonstrated improvement in pain status. Thirteen of 29 non-ambulatory cases were able to mobilise postoperatively. There were 32 whose Frankel grades improved. Seventeen of these returned to normal (15 from Grade 4 and 2 from Grade 3). One patient with complete motor and sensory loss improved to useful but subnormal status, three others improved to residual motor function. 11 other patients improved one grade. Of those whose scores did not change (76), 53 remained normal, eight maintained useful but subnormal status, five were stabilised with residual motor function, three kept some sensory perception and two had complete motor and sensory loss. One patient deteriorated from residual motor function to complete motor loss. The outcome for sphincter dysfunction (8) was not clear from the notes. In no case was a specific change in function documented.

Discussion: Surgical treatment of malignant spinal tumours is worthwhile. Posterior approaches are versatile and should be considered. Surgery is effective in the management of pain and preserves or may significantly improve neurologic function.

PATIENT-SPECIFIC FINITE ELEMENT ANALYSIS OF SINGLE ROD ADOLESCENT IDIOPATHIC SCOLIOSIS SURGERY

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Introduction: Contemporary surgical interventions for adolescent idiopathic scoliosis (AIS) include both anterior and posterior rod systems, in which a single or double rod construct provides curve correction and stability. This paper presents a methodology for development of patient-specific finite element methods to predict the biomechanical outcomes of scoliosis surgery pre-operatively, with the aim of optimising the performance of instrumentation constructs for anterior single rod AIS surgery.

Methods: Geometry for each patient-specific finite element model is obtained from pre-operative thoracolumbar CT scans taken in the supine position using a low dose multi-slice imaging protocol. The finite element model incorporates vertebrae, intervertebral discs, and posterior processes with associated ligaments and zygapophysial joints. A custom pre-processor generates the entire model according to user-specified meshing parameters, providing rapid model generation once the geometric parameters have been extracted from each CT dataset. Material properties are currently based on published values. Simulated movements about axes corresponding to flexion/extension, left/right lateral bending, and trunk rotation are solved using the ABAQUS/Standard software, allowing assessment of predicted loads and stresses before and after addition of instrumentation.

Results: The total time per patient required for model generation is currently about six hours, with manual measurement of spine geometry from the CT stack accounting for most of this time. Actual solution time for each finite element model is expected to be around four hours, making patient-specific pre-operative planning for endoscopic scoliosis surgery a feasible option at least in terms of processing time per patient.

Discussion: A finite element methodology has been developed for patient-specific simulation of endoscopic scoliosis surgery. Issues to be addressed in future include prescription of patient-specific material properties, analysis of errors associated with geometry measurement from CT scans, and validation of the methodology by comparison of predicted and actual outcomes for scoliosis patients. Patient-specific simulation of scoliosis surgery has the potential to optimize surgical outcomes and reduce biomechanical complications associated with the use of endoscopic scoliosis instrumentation systems.

EFFECTS OF ADMINISTERED GROWTH HORMONE AND OESTROGEN ON THE DEVELOPMENT OF IDIOPATHIC SCOLIOSIS IN SHORT-STATURED CHILDREN.

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Introduction: Retrospective reports of adverse events following growth hormone administration to short-statured children indicate that the incidence of scoliosis is elevated, largely due to the higher incidence of scoliosis in Turner/ other syndromes within the group. The aims of this study are to analyse risk factors for scoliosis in these children.

Methods: Data on 184 of 267 (65%) current and recent Australian children from the Australian OZGROW program was collected in 2001/2002 (from three Australian States). This included medical records (including past history of known scoliosis), growth charts, timing of growth hormone and oestrogen administration and the presence and severity of scoliosis from clinical examination. Growth hormone dosage was controlled by Australian Health Department guidelines. Standard oestrogen dosage was similar for all pubertal girls. The cohort was noted to comprise many varying syndromes, some of whom were pituitary hormone deficient. Potential risk factors for the development of scoliosis were statistically analysed.

Results: Of 45 subjects with Turner Syndrome, 13 (30%) have idiopathic scoliosis and 2 have a hemi-vertebra. Of the other 139 subjects, 15 have scoliosis but 11 have syndromes which would normally be associated with scoliosis. Therefore, the incidence of idiopathic scoliosis in the remaining 128 subjects is 3.1% (4/128), which is within the normal population range. All 4 have mild scoliosis <20 degrees. For the 139 subjects with idiopathic short stature or a specific

syndrome, the age of commencement and total amount of growth hormone and/or oestrogen did not affect the degree of scoliosis.

Discussion: Having Turner Syndrome was the only variable identified as a risk factor for having scoliosis ($p < .001$). The incidence of scoliosis in growth hormone treated Turner Syndrome subjects is much larger than previously reported (11-12%)^{1,2}. To the authors' knowledge, this is the first report derived from non-retrospective data on the incidence of scoliosis in a growth hormone-treated Turner Syndrome population. This stimulated the next study looking at the incidence of scoliosis in growth hormone-treated and non-growth hormone-treated subjects with Turner Syndrome.

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THE INCIDENCE OF IDIOPATHIC SCOLIOSIS IN TURNER SYNDROME – GROWTH HORMONE TREATED AND NON-TREATED.

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Introduction: Following an Australian study on the incidence of scoliosis in a population of short-statured children treated with human growth hormone (conducted during 2001-2002), it was determined that the only risk factor for the presence of idiopathic scoliosis was having Turner / another syndrome. The 30% incidence in Turner syndrome was noted to be much higher than previously reported (11-12%). The aim of this study is to determine the incidence of scoliosis in a group of growth hormone-treated and non-treated Turner Syndrome subjects who attended the International Turner Syndrome Society meeting in Sydney, Australia in July 2003 and to correlate the results with the Australian 2001-2002 results.

Methods: 88 subjects were clinically examined for the presence and severity of idiopathic scoliosis. Their ages ranged from 11 to 60 years. All subjects provided information regarding previous growth hormone and/or oestrogen administration. Anthropometric data including sitting and standing height and arm span was also collated on this cohort.

Results: 13 of 46 (28.3%) subjects who had no growth hormone treatment were found to have scoliosis. Five of 42 (12%) subjects who were growth hormone treated were found to have scoliosis. 12 curves were thoracic, five were thoraco-lumbar and one was lumbar. The 13 subjects with scoliosis and no growth hormone treatment had curves between 10 and 20° Cobb angle. Three growth hormone-treated subjects had curves of 10°, one had a curve of 30° and the last subject had already undergone scoliosis surgery. Combining the results of this study with the three Australian States study from 2001-2002, 18 of 87 (21%) growth hormone-treated Turner syndrome subjects have idiopathic scoliosis. 13 of 46 (28%) non-growth hormone-treated Turner syndrome subjects also have idiopathic scoliosis. Of the total 133 subjects in this cohort, 31 (23%) have idiopathic scoliosis.

Discussion: The incidence of idiopathic scoliosis in Turner syndrome appears to have been understated in previous studies. Data from this study would indicate that treating children who have Turner syndrome with adjuvant human growth hormone does not appear to result in a greater incidence or severity of idiopathic scoliosis. In this relatively small study, two of five children who had previous growth hormone treatment developed larger curves, one requiring corrective scoliosis surgery.

RESPIRATORY FUNCTION FOLLOWING ENDOSCOPIC SCOLIOSIS SURGERY.

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Introduction: Endoscopic techniques are an established method for anterior correction and instrumentation of thoracic scoliosis. Deterioration in respiratory function for up to two years following a thoracotomy¹ has been cited as a disadvantage of anterior approaches and has led certain authors to recommend posterior approaches.² This prospective study establishes the pattern of change in respiratory function in patients during the first 12 months following endoscopic scoliosis surgery.

Methods: 67 patients have undergone endoscopic scoliosis correction performed by the senior author (GNA). The patients were intubated with a double lumen tube. The lung was deflated on the ipsilateral side to the spinal correction and instrumentation throughout the procedure. A chest drain was inserted per operatively and removed on day two post-operation. All the patients underwent respiratory function tests (RFTs) as part of the preoperative workup. These included absolute and predicted FVC, as well as absolute and predicted FEV1. Thirty patients underwent postoperative RFTs for the purpose of this study. 10 patients had RFTs at 12 months following surgery. A further 20 patients had repeat RFTs scheduled at 3 months, 6 months and 12 months post operatively.

Results: The RFTs of all 10 patients within the initial group had returned to their preoperative level at twelve months. The RFTs of the further 20 patients showed a reduction in all parameters at the 3 month period post-operation but these had shown improvement at the 6 month period. The results are indicated for pre-op, 3 months, 6 months and 12 months respectively. FVC 2.82, 2.51, 2.84 and 3.10 FVC% predicted 82.2%, 70.6%, 79.0% and 89.4%. FEV1 2.48, 2.23, 2.49 and 2.67 FEV% predicted 75.3%, 67.3%, 75.1% and 79.6

Discussion: The provisional results have shown that there is a reduction in the respiratory function in the immediate post-operative period following endoscopic scoliosis correction, but this does not lead to serious respiratory compromise. The respiratory function returns to the preoperative level at 12 months, showing there is no long-term deterioration of respiratory function following endoscopic correction and instrumentation.

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PINEALECTOMY AND SCOLIOSIS IN THE CHICKEN: MORPHOLOGY AND RELATIONSHIP TO MELATONIN LEVELS

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Introduction: The development of scoliosis in pinealectomised chickens was first observed by Machida¹ and since reported by others. That melatonin deficiency following pinealectomy may be a factor in causing scoliosis has been postulated. The relationship between pinealectomy, scoliosis and serum melatonin levels has been subject to experimental investigations. This study reports the incidence and type of scoliosis in pinealectomised, sham operated and unoperated chickens, and related serum melatonin levels.

Methods: Serum melatonin levels were obtained at sacrifice up to six weeks postoperatively. Radiological and histological examination of the spine was performed.

Results: The vertebral motion segment comprises a synovial joint lacking any discs. 19% of the unoperated group had a sharp angular deformity in contrast to the smooth curve seen in adolescent idiopathic scoliosis (AIS). There was a 38% incidence of scoliosis after sham operation (mostly of the angular variety) and a 75% incidence in the pinealectomy group (of which half were smooth curves similar to those in human AIS). Melatonin was not abolished by pinealectomy or sham operation but was at significantly lower levels than in the unoperated group. There was no difference in Melatonin levels between birds with the two types of curves.

Discussion: The avian spine has fundamental structural differences with the human. There is a natural incidence of short angular scoliosis that increases with posterior fossa surgery in the chicken. We confirm that scoliosis similar to AIS forms after pinealectomy but it is not directly related to diminished melatonin levels.

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AUDITING FUNCTIONAL IMPROVEMENTS FOLLOWING LUMBAR FUSION IN PRIVATE PRACTICE – A FIVE YEAR STUDY

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Introduction: This paper reports an audit of outcomes improvement in lumbar fusion patients in a private practice setting using routine application of a robust functional outcomes instrument – the Modified Roland Questionnaire (MRQ). The MRQ is a validated responsive disease specific functional questionnaire. It ranges from 23 points (maximum disability) to zero (no disability). Potential changes in score are 46 points (-23 to 23). A 4 point improvement is clinically significant.

Methods: 216 patients undergoing lumbar fusion procedures, over a 5 year period completed an MRQ prior to surgery and at the routine one-year follow-up. Changes to the score were documented and analysed in relation to diagnosis, ACC coverage, and revision procedures.

Results: Data completion was 88%. Median disability improvement was 10 points on the MRQ questionnaire. Benefit occurred in 80.0% of patients. Improvements were more marked in degenerative spondylolisthesis and isthmic spondylolisthesis than fusions for discogenic back pain although this was not statistically significant. There was a trend to lesser functional improvements in those on ACC and those who had undergone previous surgery.

Discussion: This study reports an attempt to audit outcomes in a spinal sub specialist private practice using an instrument that can be applied preoperatively and at one year follow up without undue additional work load for the patients or staff. The data completion was acceptable. Functional improvements were significant in all diagnostic groups. Outcomes in revision and ACC patients were not significantly inferior, as they have been described in similar overseas studies.

MECHANICAL STABILISATION OF THE DEGENERATIVE LUMBAR MOTION SEGMENT: THE WALLIS IMPLANT

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Introduction: The Wallis implant was developed as a minimally invasive and anatomically conserving method of addressing the various biomechanical derangements associated with lumbar

degenerative changes without recourse to rigid fixation.¹ The Wallis implant evolved from successful clinical experience in over 300 patients with a first generation implant, supported by detailed biomechanical and finite element studies. These demonstrated that the implant improves the stability of the degenerate motion segment, reduces loads transmitted through the intervertebral disc and facet joints and improves the dimensions of the spinal canal, lateral recesses and root foramina. The purpose of the present ongoing study is to demonstrate the tolerance of this implant and its efficacy against low back pain and functional disability in patients with degenerative disc disease.

Methods: A prospective multi-centre international observational study was commenced 2 years ago. The inclusion criteria were degenerative disc disease without disc herniation, recurrence of herniated disc, voluminous herniated disc (corresponding to a complete loss of the nucleus) and herniated disc accompanying the transitional anomaly, sacralisation of L5. Assessment includes SF-36, JOA, VAS and Oswestry Disability Index, and all patients undergo pre-operative radiographs and MRI scans with interval radiographs and scans post-operatively. The study will be continued for a minimum of five years.

Results: Thus far 210 patients have been recruited and 1-year review is available for 51. Preliminary 1-year results confirm the clinical efficacy of this procedure in the management of low back pain and as an adjunct in the treatment of radicular and stenotic symptoms. Furthermore, in some instances MRI evaluation has shown re-hydration of the disc nucleus.

Discussion: The procedure involves no additional exposure or muscle dissection compared with simple flavectomy decompression. The supraspinous ligament and facet joints are preserved and no bony fixation is required. As such the procedure can potentially be reversed and all options for future procedures, if required, are preserved. There is no adverse effect on adjacent segments.

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RADIOFREQUENCY HEATING OF PAINFUL ANNULAR DISRUPTIONS WITH THE discTRODE: 18-MONTH OUTCOMES

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Introduction: Although several studies have reported on outcomes following heating of annular tears with a thermo-resistive catheter (SpineCATH), little data is available on the efficacy of thermal treatment with a flexible radiofrequency electrode (discTRODE). The aim of this prospective case-control study was to determine the efficacy of radiofrequency heating of painful annular tears in the lumbar spine.

Methods: After at least six months of conservative treatment, 46 patients were studied for the presence of single level painful annular tears with MRI and provocative discography. Thirty-one patients underwent heating of their annular tears with a flexible radiofrequency electrode placed across the posterior annulus. The remaining fifteen patients continued with conservative management and acted as a control group. At present, 22 patients have been studied at 18 months follow-up and the remainder including the control group for a minimum of one year. The Visual Analogue Scale (VAS), the Oswestry Disability Index (ODI) and the Medication Quantification Score (MQS) were obtained before and at three monthly intervals after treatment.

Results: VAS decreased significantly after the radiofrequency treatment, and this decrease persisted at 18 months follow-up. The VAS did not change over 18 months in untreated controls. The decrease in VAS was significantly greater in the treated patients than the controls. The ODI also decreased in treated patients but did not change in controls. The MQS did not change in either group over the 18-month follow-up period.

Discussion: Radiofrequency heating of annular tears can lead to an improvement in the pain and disability of internal disc disruption. The improvement gained by this treatment method is significantly better than conservative management.

PATIENT OUTCOME AFTER SPINAL CORTICOSTEROID INJECTION OR SURGICAL RESECTION OF LUMBAR JUXTAFACET CYSTS

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Introduction: This study is a retrospective review of patients who underwent corticosteroid spinal injections and/or surgery for lumbar juxtafacet cysts to determine the effectiveness of corticosteroid injection and/or surgery for the treatment of lumbar juxtafacet cysts.

Methods: The charts of 40 patients who underwent corticosteroid injection and/or surgery for the treatment of symptomatic juxtafacet cysts were reviewed and an outcome questionnaire was sent to each patient. All patients responded to the questionnaire (100%).

Results: Forty-four juxtafacet cysts were treated in 40 patients. 28 cysts were initially treated with corticosteroid injection. 18 facet joints adjacent to the cysts were injected (4 were injected on two or more occasions), 13 underwent epidural injection and 5 underwent nerve sheath exit foraminal blocks. 18 obtained no benefit from the use of corticosteroid injections and proceeded to surgical treatment. Of the 10 patients that did not undergo surgery, at follow-up 2 reported no clinical change and were considering surgical treatment. This represents a 71% failure rate for non-operative treatment with corticosteroid injections.

34 cysts were resected from 31 patients. Two (6%) were ligamental and 32 were facetal. 31 cysts were resected by laminectomy alone and 3 patients underwent laminectomy and bone only fusion. One cyst (3%) recurred and was managed by repeat laminectomy. One patient required instrumented lumbosacral fusion for increasing anterolisthesis. Incidental dural tear was the most common surgical complication occurring in two cases (6%). One patient demonstrated significant weakness of ankle and foot dorsiflexion which recovered incompletely. Average follow-up for the surgical group was 18 months (5-72 months). 27 scored an excellent or good outcome (79%), 3 scored a fair outcome, 3 were considered poor and one patient was worse. 30 (88%) patients were satisfied having complete improvement or improved with residual back or leg symptoms. Three responded as no change and one was worse.

Discussion: Juxtafacet cysts are an uncommon cause of radiculopathy. Corticosteroid injection into the adjacent facet joints, epidural space or exit foraminae of the spine produces disappointing results. Surgical resection is the treatment of choice with low rates of complications, recurrences and residual complaints.

HIGHLY SELECTIVE EPIDURAL STEROID INJECTION FOR THE TREATMENT OF RADICULAR PAIN ARISING FROM SPONDYLOLISTHESIS

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Introduction: The treatment with epidural steroids and local anaesthetic for radicular pain arising from nerve root compression is a commonly utilised and recognised treatment. The aim of this study is to determine the efficacy of CT-guided injection of epidural steroids without anaesthetic for radicular pain but without clinical neurology in the presence of a degenerative of lytic spondylolisthesis and concomitant foraminal narrowing.

Method: The study subjects, 21 in total, were selected over a 1-year period by the surgeon. All patients had either degenerative or lytic spondylolisthesis as determined by CT, MRI and plain film and were suffering from radicular pain – sharp, shooting and burning in the L5 or S1 dermatome. For inclusion, there had to be no associated evidence of nerve root compression. All patients completed, prior to epidural therapy, a pain diagram, visual analogue scale (VAS) of pain severity on a scale of 1 to 10 and Oswestry Disability Index (ODI). The MRI and clinical pain picture were correlated. The level of the spondylolisthesis was determined.

Highly selective CT-guided epidural steroid injection was then carried out at the level of spondylolisthesis by an experienced interventional radiologist. The pain diagram, VAS of pain severity and ODI were all completed again by the subjects themselves or by telephone at 1 and 3 months after injection in the presence of an independent assessor (nurse) and then reviewed and discussed with the treating doctor. All subjects were also asked to complete a functional questionnaire.

Results: One month after injection 86% of those treated had greater than 50% radicular pain relief and from this group 72% had radicular pain reduction of greater than 80%. All had improvement in function. All of the above, confirmed that their quality of life had certainly improved. Three months after injection 76% of those treated still had a reduction in their radicular pain of greater than 50% (92% of these still had pain reduction of over 80%). Again all reported continued functional improvement.

Discussion: Despite the small sample size, this study highlights the short-term benefit of CT-guided steroid epidural injections with symptomatic lumbosacral spondylolisthesis and spondylolysis with radicular pain. Pain can be relieved without anaesthesia. The mechanisms of pain relief are speculative.

ADCON-L CAN BE USED SAFELY IN ALL FORMS OF SURGERY FOR DEGENERATIVE LUMBAR DISEASE

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Introduction: Peridural fibrosis is a reaction that occurs outside the dura and occurs in the healing process following lumbar surgery¹. The fibrosis is recognised as one of the possible causes of the failed back syndrome following lumbar spinal surgery. ADCON-L Anti-Adhesion Barrier Gel has been shown to be of benefit in patients undergoing discectomy in reducing symptomatic fibrosis. The aim of this prospective study is to elicit the advantages and potential risks of using ADCON-L in more extensive decompression procedures and in instrumented spinal fusions.

Method: ADCON-L anti-adhesion barrier gel, has been used in 288 patients undergoing the following surgeries: posterior lumbar interbody fusion (PLIF) (49), decompression and instrumented fusion posterior interbody supplementary fixation (PISF) (96), decompression and Graf ligament stabilisation (31), decompression of stenosis (54), discectomy (41), and revision discectomy or decompression (17). Any adverse clinical events, including pseudarthrosis, new, recurrent or deteriorating leg pain, paraesthesia or neurological deficit, were documented. Patients with neurological symptoms suggestive of fibrosis including deteriorating leg pain were evaluated with an MRI scan with gadolinium enhancement. Fusion rates were evaluated where appropriate.

Results: Two patients developed significant early (<4 weeks) recurrent sciatica. MRI demonstrated a recurrent disc prolapse at the same level in one patient, who required re-operation, but no fibrosis was noted at the surgery. Late developing leg pain occurred in 16 patients. All these patients were evaluated with MRI with gadolinium enhancement. Independent radiological assessment indicated the principal cause of the leg pain to be peridural fibrosis in 9 patients (3.1%). Other causes included recurrent disc prolapse or lateral recess stenosis. Early post-operative wound seepage or superficial wound infections occurred in 5 (1.7%). There were no late infections. Two

patients developed a post-operative pseudomeningocele. One required re-exploration and repair, the other settled with conservative treatment. At review 1 to 4 years (mean 2.7 years) after undergoing PISF and PLIF fusion had achieved in 93.1% of cases.

Discussion: Previous prospective randomised multi-centre studies have shown the effectiveness of ADCON-L gel in reducing peridural fibrosis in patients following discectomy. Our study shows that there is low incidence of peridural fibrosis and associated leg pain when ADCON-L is used in all forms of degenerative lumbar spine surgery. There is a low complication rate and good fusion rate.

ASYMPTOMATIC VERTEBRAL OSTEOLYTIC LESION IN A CHILD – HAEMANGIOMA OR METASTATIC EWING’S TUMOUR?

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Introduction: The foot is an unusual site for presentation of Ewings tumour. Haemangioma of the vertebra is a common finding in adults, but is rarely reported in children.¹ Although rarely symptomatic, the lesion may cause diagnostic confusion particularly in the presence of comorbidity. A previous case report details an adult patient with a ‘pseudohaemangioma’ that was subsequently found to be an Ewings tumour.²

Methods: A review of the literature and a case report is presented of a boy with a Ewing’s sarcoma of the foot presenting with an asymptomatic lytic lesion in the spine.

Results: The 12-year-old male initially presented with pain and swelling in the right foot. Subsequent investigation and biopsy confirmed a diagnosis of Ewing's sarcoma in the second metatarsal. The child received 5 cycles of combined chemotherapy, and the primary tumour was excised from the metatarsal with fibular graft reconstruction.

Part of the clinical work up had included an isotope bone scan, which revealed a focal area of increased uptake in the L1 vertebra. On MRI, the vertebral lesion had a ‘halo’ of high intensity signal with infraction of the upper vertebral endplate. There were no clinical symptoms arising from the vertebral lesion. The differential diagnosis of the L1 lesion suggested was either a metastatic Ewing's tumour or an aggressive haemangioma. Given the possibility of a multifocal or metastatic lesion, a vertebrectomy and reconstruction with femoral allograft was performed. A second stage posterior stabilisation from T12 to L2 was performed. Histological examination of the resected vertebra revealed a benign capillary haemangioma. On recent review one year after treatment, the patient remains in remission from his tumour and has successful graft incorporation with minimal symptoms from his spine.

Discussion: Haemangioma is a benign tumour commonly found in the vertebral body.

Asymptomatic spinal haemangiomas do not require surgical excision. Clinico-pathological distinction between vertebral haemangioma and metastatic disease can be difficult, particularly in children where the haemangiomas may be in a ‘blastic’ phase. The combination of an extremely unusual age of presentation and the presence of a separate malignant primary bone tumour in this patient introduced a significant clinical dilemma in treatment.

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MASSIVE SPINAL EPIDURAL HAEMATOMA CAUSING NEUROLOGICAL DEFICIT IN AN ANTICOAGULATED PATIENT TREATED NON OPERATIVELY

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Introduction: Spontaneous spinal epidural haematoma is an uncommon clinical problem which may lead to severe and permanent neurological deficit. The treatment options for spinal cord compression by extradural haematoma in the anticoagulated patient are limited. The majority of cases reported have been treated surgically.¹ Operative intervention carries a potential risk of extending the haematoma with further deterioration of the neurological deficit.

Methods: A case of paraplegia following spontaneous epidural haemorrhage is reported with a review of the prognostic factors that determine likely improvement in neurological function post-surgery.

Case report: A 59-year old man was referred to the regional Spinal Trauma Centre with a 34-hour history of severe lower back pain of sudden onset and 14 hour history of neurological deficit in both legs and urinary overflow incontinence. He had undergone aortic valve replacement two years previously, with subsequent anticoagulation with Warfarin. Examination showed complete paraplegia below L3 with grade 1 power on hip flexion only. On catheterisation, the residual volume of urine was 1200mls. The INR was 3.5. An MRI of the spine showed epidural haematoma that extended from the level of T11 to L5.

The patient was treated non-operatively. On discharge at 10 weeks he had normal sensation to L3 and grade 5-power on left knee extension and grade 4-power on the right. There was no motor recovery distal to this. He had a hypotonic neurological bladder with sufficient resting tone in the sphincter to prevent incontinence.

Discussion: Although associated with a definite mortality, surgical decompression of the spinal cord and evacuation of the haematoma improves neurological outcome and is the treatment of choice.¹ The decision to treat non-operatively should be based on the duration and severity of the neurological deficit. A literature review identifies neurological deficit greater than 12 hours and severe neurological deficit on presentation are poor prognostic indicators.² The prognosis for neurological recovery in this case was poor. In a patient with severe coexisting medical problems these factors can assist when making the decision to operate on an individual patient with spinal epidural haematoma.

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EXTIRPATIVE TREATMENT OF RENAL METASTASES IN THE SPINE

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Introduction: There is increasing evidence that surgical treatment in tumour surgery can influence survival times. Renal cell carcinoma can lead to single or few sites of metastasis that are amenable to extirpative surgery with reconstruction in the spine¹. Such treatment can also be beneficial to improve quality of surviving years.

Methods: Retrospective cohort study of 10 consecutive patients treated for spinal metastatic renal cell carcinoma. Case note review and patient or general practitioner contact was used to ascertain

number of metastases, treatment given, survival time from diagnosis and survival time from surgery. All primary tumours were treated with nephrectomy.

Results: Of the 10 patients, 6 had extirpative treatment, while 4 had palliative surgery including decompression of the neural elements. Patients treated with extirpative surgery to spinal metastases from a renal cell carcinoma primary had a significantly longer survival time from surgery to those treated with palliative decompressions alone. There were no significant differences in age or time from diagnosis to surgical treatment between groups. There were no cases of operative mortality, but significant intraoperative bleeding was encountered in extirpative treatment of the affected vertebra, despite preoperative embolisation.

Discussion: The role of surgical treatment in metastasis to the spine is of current interest. Our results have shown significant survival times are possible with extirpative treatment of renal metastases. Whilst this may not apply directly to metastases from other primary tumours, careful selection of cases and co-operation between spinal surgeons and oncologists is important to ensure maximal quality and length of survival for these patients. These cases are surgically challenging, and care is required to minimise and anticipate blood loss.

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SPINAL INJURIES IN MAJOR TRAUMA.

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Introduction: Little is known about the epidemiology of spinal injuries in large major trauma populations. The aim of this study, therefore, is to describe mechanisms of injury, patient and injury characteristics and outcomes following spinal injuries in major trauma patients.

Methods: Data was extracted from the State Trauma Registry for Victoria (population 4.6 million) on all patients registered between 1 July 2001 and 31 June 2003 with spinal injuries and an Injury Severity Score (ISS) >15. Injuries were defined using Abbreviated Injury Score (AIS) codes. Major trauma patients with spinal injuries were compared with those without spinal injuries with respect to age, gender, ISS scores, mechanism of injury, number and site of spinal and associated injuries, acute length of stay and discharge destination.

Results: 2194 major trauma patients were identified, of which 548 (25%) had spinal injuries. Spinal injuries occurred in 412 males (75%) and 136 females (25%), with a median age of 36 years (range 2-94 years). There was no difference in age or gender compared with patients with no spinal injury. 316 patients (58%) had multiple spinal injuries. 22% of patients with spinal injuries had associated spinal cord injuries. Most spinal fractures occurred and were more likely to occur as the result of motor vehicle (46%) or motorcycle (16%) crashes or falls from heights greater than 1 metre (15%).

The median ISS score was 24 (range 16-75) and not significantly different from patients with no spinal injury. The median number of associated injuries was 5 (range 0-23) and patients with spinal injuries were more likely to have associated thoracic, abdominal and extremity injuries and less likely to have associated head injuries than patients with no spinal injury. Patients with spinal injuries were more likely to be discharged to rehabilitation or convalescent hospitals and less likely to die than patients with no spinal injury.

Discussion: Spinal injuries are common and often multiple in major trauma patients and are associated with a greater need for rehabilitation. Further studies are required to determine the impact of spinal injuries on the functional outcomes of major trauma patients.

RETURN TO SPORT FOLLOWING CERVICAL SPINE INJURY

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Introduction: Sports injuries to the cervical spine account for about one in ten of all cervical spine injuries. They occur at all levels of participation. Fortunately, the number of patients suffering spinal cord injury is relatively small. Neurological injuries may range from transient quadriparesis through to complete quadriplegia. The decision to allow sportsmen to return to sport following a cervical spine injury is complex. It is based on such factors as history, clinical examination, the nature of the injury, as well as age and other psychosocial factors. The evidence that exists to aid this decision process is at times conflicting. The aim of this presentation is to review some of the contentious issues that exist in the decision making by reference to case presentations of high level sportsmen who were treated following a variety of cervical spine injuries.

Methods: Four high-level rugby players (22-31 years old) presented with different cervical spine injuries sustained during sporting activities. Two subjects sustained a "stinger" and two a transient quadriparesis which rapidly resolved. Radiological evaluation included assessment of spinal canal diameter.¹

Results: Two had a C5-6 disc bulge with developmental spinal stenosis. A third had a congenital fusion C2-3 with a disc bulge and developmental stenosis at C3-4. Case 4 had degenerative disc disease at C5-6. All were treated non-operatively and returned to sport. All suffered a recurrence of the neurological symptoms and subsequently underwent an anterior interbody fusion (Case 4 for subluxation of C6-7). Three successfully resumed rugby six months after surgery while one elected not to continue.

Discussion: The decision to allow a patient to return to contact sports following a cervical spine injury may be difficult. The four cases presented highlight some of these contentious issues such as transient neurological deficit and the effect that surgery may have on a patient's ability to return safely to sport. A review of the literature may assist in the decision making.^{1,2} This may be conflicting and difficult to interpret. Neurological signs, instability, displacement, fusion of more than one level and occipito-atlanto-axial pathologies are considered absolute contraindications.³

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MONOSEGMENTAL PEDICLE SCREW FIXATION FOR THORACO-LUMBAR BURST FRACTURE

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Introduction: The management of thoraco-lumbar burst fractures remains controversial. Different authors have advocated immobilisation, external bracing or internal fixation by either anterior or posterior approaches. Advocates of posterior fixation have in general performed stabilisation one level above and one level below the site of the fracture, resulting in fixation of two motion segments. It is known that multi-segmental spinal fusion produces undesirable biomechanics. To

stabilise the site of the fracture and avoid unnecessary fixation of an uninjured segment the senior author (T.S.) for selected patients has been using a novel technique of monosegmental fixation with placement of pedicle screws directly into the fractured vertebral body.

Methods: All patients with thoraco-lumbar burst fractures admitted to St Vincents and Concord Hospitals between January 2001 and October 2003 were considered for monosegmental fixation. Patients with severe osteoporosis or complete loss of vertebral body height (“vertebra plana”) were excluded. All patients underwent surgical decompression and fixation within 10 days of injury. Fixation was obtained with 4 titanium pedicle screws and a single transverse connector (Xia System Stryker Spine). Reduction of kyphotic deformity was carried out in selected patients. Average blood loss for the procedure was 250 ml with no patients requiring transfusion. All patients had a minimum of 6 months radiological and clinical follow-up.

Results: Since January 2001, 18 patients with thoracolumbar burst fractures (T10-L2) were treated with single-level pedicle screw fixation. All patients were mobilised within 10 days of surgery. One patient experienced a minor superficial wound infection. There were no other postoperative complications. All patients had a stable fusion construct at 6 weeks following surgery. No patient experienced neurological deficit or have developed a delayed kyphotic deformity. There were no instances of instrument failure. 17 out of 18 patients report no significant back pain with any limitation of function by three months following surgery. One patient reports mild mechanical lower back pain 12 months following the injury.

Discussion: Single level fixation for selected cases of thoracolumbar burst fracture is a safe and effective procedure to decompress the neural elements and obtain fixation and fusion of the fractured segment. It allows for rapid mobilisation and avoids a two-level fusion procedure with its subsequent detrimental effect on spinal biomechanics. It is considerably less invasive than anterior/lateral approaches which require extensive muscle dissection, rib removal and even diaphragmatic division.

BIOMODELLING AS AN AID TO SPINAL INSTRUMENTATION

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Introduction: Recently frameless stereotaxy has been introduced to assist with the spinal instrumentation. The mobility of individual vertebra however limits its accuracy and ease of use. The authors have developed a novel method of spinal stereotaxy using exact plastic copies of the spine manufactured using biomodelling technology.

Methods: Fifteen patients with complex spinal disorders requiring instrumentation were recruited. A 3D CT scan of their spine was performed and the data were transferred via DICOM network to a computer workstation. ANATOMICS BIOBUILD software was used to generate the code required to manufacture exact acrylate biomodels of each spine using rapid prototyping. The biomodels were used to obtain informed consent from patients and simulate surgery. Simulation was performed using a standard power drill to place trajectory pins in the appropriate pedicles. Acrylate drill guides were manufactured using the biomodels as templates. The biomodels and templates were sterilised and used intra-operatively to assist with the placement of the instrumentation.

Results: The biomodels were found to be highly accurate and of great assistance in the planning and execution of the surgery. The ability to drill optimum screw trajectories in the biomodel and then accurately replicate the trajectory was judged especially helpful. Accurate screw placement was confirmed with post-operative CT scanning. The design of the first two templates was sub-optimal as the contact surface area was too great and complex. Approximately 20 minutes was spent pre-operatively preparing each biomodel and template. Operating time was reduced, as less reliance on intra-operative X-ray was necessary. Minimal invasive surgery was greatly facilitated in planning and execution. Patients stated that the biomodels improved informed consent.

Conclusion: Biomodel spinal stereotaxy is a simple and accurate technique which may have advantages over frameless stereotaxy.

ANATOMICAL CHARACTERISATION OF IDEAL SUBLAMINAR LATERAL MASS SCREW PLACEMENT AT C1

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Introduction: C1 lateral mass screw fixation offers a powerful alternative biomechanical fixation for upper cervical disorders. The anatomical constraints to this fixation have not been described yet and are essential to ensure avoidance of neurovascular damage.

Methods: 50 patients (including 5 patients with rheumatoid arthritis) underwent upper cervical CT scans. Analysis of these CT scans involved use of calibrated scan measurements to identify the midpoint of the posterior lateral mass, the dimensions of the lateral mass, the direction of optimum screw passage, the position of the vertebral foramen at C1 and the ideal entry point for lateral mass screw fixation.

Results: The average length of screw within the lateral mass was 20 mm with 13.5mm of screw not in bone, behind the lateral mass, but necessary to allow rod placement posteriorly adjacent to other fixation points. The safest entry point was directly beneath the medial edge of the lamina origin. The ideal direction of screw angulation is parallel with the posterior arch, in the saggital plane. This entrypoint was on average 8.8 mm from the vertebral artery foramen laterally and 5.8 mm from the medial aspect of the lateral mass. Vertical space available for sublaminar screw placement was 3mm or less in 9% of lateral masses.

Discussion: C1 lateral mass screws are best placed beneath the lamina origin, parallel with the arch in the saggital plane using an entrypoint in line with the medial edge of the lamina origin. An entry point under the midpoint of the lamina origin, or passing through the lamina at its attachment to the lateral mass, is likely to damage the vertebral artery in a significant proportion of cases.

SPINAL NAVIGATION

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Stereotactic navigation in cranial surgery is a well-established technique, in routine clinical use since the turn of the century. The advent of computer guided stereotaxis since the early 1990's has led to an explosion in applications for the technology in cranial surgery, with the development of new surgical techniques, minimal access and consequent claimed reduction in morbidity and mortality.

Computer guidance also allows application of stereotactic techniques in spinal surgery. Early interventions have concentrated on the insertion of pedicle screws with improvement in accuracy and certainty of optimal screw placement. The use of fluoroscopic guidance allows the insertion of percutaneous pedicle screws and truly minimal access fusion techniques for the lumbar spine. More recently the development of improved registration has allowed the application of this technology to thoracic spinal surgery and to the cervical spine. Percutaneous techniques for C1/C2 arthrodesis, image guided vertebrectomy and transoral surgery, have been reported. The technology allows the development of surgical techniques designed not only for individual pathology but adapted to the anatomy of the individual patient. Disadvantages include a significant learning curve, especially for cervical spine surgery, the cost and need for registration which may be time consuming.

Advantages include claimed accuracy in decompression, hardware placement, minimal access

techniques and a three-dimensional solution to what is essentially a three dimensional problem. More recently non-computer based navigation systems have become available with improved hardware placement without the problems associated with computer based systems. The purpose of this paper is to review computer guided spinal surgery, present new techniques based on its application to the adult spine, discuss advantages and disadvantages of those techniques and present the results of studies on the new non-computer based navigation systems.

THE ROLE OF THE INTERVERTEBRAL DISC, THE FACETS, THE STERNUM, AND THE COSTOSTERNAL ARTICULATIONS IN THORACIC SAGITTAL PLANE MOTION: A BIOMECHANICS COMPARISON OF THREE DIFFERENT SEQUENCES OF SURGICAL RELEASES.

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Introduction: The anatomy and biomechanics of the thoracic spine is different from the cervical and lumbar spine particularly due to the ribs and sternum which contribute to stability and controlling motion. The role of the sternum and costosternal articulation in the biomechanics of thoracic fracture or deformity correction has not been well studied. The effects of releasing each of these structures, whether alone or in combination, is potentially relevant in the surgical correction of thoracic deformities such as severe kyphosis. The purpose of this study was to investigate the relative effects of releasing the intervertebral disc, the costosternal joint, the sternum, and the facet joints on sagittal thoracic motion and the consequences of altering the sequence of the releases.

Methods: Eighteen human torsos were tested in three experiments (A, B, and C) to determine the effect on sagittal motion due to three different sequences of three surgical releases. In Experiment A the release sequence was back to front: Total facetectomy, then radical discectomy, then sternal osteotomy plus costosternal release. In experiment B the release sequence was front to back: Sternal osteotomy plus costosternal release, then radical discectomy, then total facetectomy. In Experiment C, it was disc first: Radical discectomy, then sternal osteotomy plus costosternal release, then total facetectomy. The different sequences allowed separate analysis of each component and the synergistic patterns. In each of the three experiments, the torso was flexed then extended each time by an applied force (25 N) before and after each release. The extent of both angular flexion and angular extension were compared to the intact condition, and after each release.

Results: Radical discectomy provided the greatest increase ($P<0.05$) in range of motion (ROM) as compared to the other two single releases, no matter what the sequence. For paired release combination, the radical discectomy and sternal osteotomy plus costosternal release (as in Experiments B and C) provided a significant ($P<0.05$) increase in sagittal ROM compared to the combination of radical discectomy and total facetectomy (Experiment A). In Experiment A, if sternal osteotomy and costosternal release (the final release) had not been carried out, then 42% of the sagittal motion would have been lost compared to the 27% related to the total facetectomy (Experiment B). All of the releases allowed more extension than flexion; the only exception was facetectomy when carried out first as in Experiment A.

Conclusions: To increase sagittal thoracic range of motion radical discectomy provided the greatest increase in both extension and total ROM as compared to total facetectomy or sternal osteotomy plus costosternal release, no matter what the sequence. For two releases, the combination of radical discectomy and sternal osteotomy plus costosternal release provided the greatest increase in both extension and total ROM. Total facetectomy was the least useful release. These data have relevance for surgical strategies to correct severe thoracic sagittal plane deformity. The sequence of combined release has important clinical implications.

POST-TRAUMATIC SAGITTAL IMBALANCE: THE ORIGIN OF PAIN.

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Introduction: Flat Back is a syndrome of sagittal imbalance often associated with back pain commencing in the lumbar region and progressively ascending. It is noted after posterior instrumentation to the lumbosacral junction, with various arthropathies and following compression fractures of the dorsolumbar and lumbar spines. In an attempt to maintain vertical posture, muscle fatigue causes back pain which persists until the condition is rectified. A compensatory pelvic tilt produces hip/hamstring pain and is relieved once lumbar correction is established. The cause of pain is unknown. The aim of this radiological study is to identify abnormal parameters which may contribute to sagittal imbalance and back pain.

Methods: Seven fully mobile subjects without fractures served as normal cohorts. Thirty-four consecutive patients aged 18 to 83 years with vertebral compression fractures were studied. There were 28 males. CT scout views of the full length spine in prone and supine positions provided functional scanograms for the Cobb measurement of thoraco-lumbar kyphosis and lumbar lordosis. Degrees of sagittal imbalance were graded as I, II and III, in accordance with the presence of dorsolumbar kyphosis, loss of lumbar lordosis and rigidity in functional views. Previous CT, MRI, Bone Scans were used to exclude other sources of pain such as protruding discs, annular tears, listhesis or un-united fractures. No patients with neurological signs were included. Three sets of measurements were taken:

a. Dorsolumbar angulation: On prone films, Cobb angle was measured at upper T12 and lower L1 end plates (normal 0° ; with standard deviation $+3/-3$).

b. Lumbosacral angular motion: On functional films, lines were drawn on the upper end plates of L5 and S1. The resulting differences [(+)-(-)] between functional angles were compared with the normal values obtained from the literature (i.e. in excess of 26° of combined motion). The difference between standing lateral functional radiography and the prone/supine scanography was accepted.

c. Sacral inclination: On supine films, the angle between a vertical line (a perpendicular to horizontal baseline) and the upper S1 endplate.

Results: There was significant reduction in the radiation dose for CT scanograms when compared to conventional radiography: with sparing of bone marrow by 74-80%.

The frequency of the abnormal radiological parameters was as follows:

A. Dorsolumbar angulation: 26 showed (positive) kyphotic angles up to 30° - 40° .

B. Lumbosacral angular motion: In view of the spinal rigidity found in most cases, a compensatory excess mobility was expected at L5/S1 level, but the opposite was confirmed. Indeed, 27 patients showed exaggerated (negative) extension shift (of -5° - -10°); amongst these 10 were with complete loss of flexion; 12 were with partial flexion (a forward shift of up to 15°), but 5 with full flexion, permitted by a lumbar kyphosis.

C. Sacral inclination: twenty-eight patients showed a shift to a diminished angle of 25° - 35° as compared to 35° - 55° in 15 control spines.

The patients were grouped according to the number of selected abnormal radiological parameters present. The cases were graded: Grade I (1 abnormality) - 2 cases, Grade II - 13 cases and Grade III - 19 cases. The threshold for imbalance was (1) at least one severe thoraco-lumbar compression (or an equivalent combination of multiple minor thoraco-lumbar compression fractures) for D/L kyphosis and (2) a single lumbar fracture with at least 50% compression.

Discussion: The cause of pain in post-traumatic sagittal imbalance remains unclear. This study suggests three possible sources of pain, individually or in combination, namely altered angulation at the dorsolumbar junction, reduced motion at L/S level and sacral verticalisation. A more extensive study will be required for verification and interpretation of these preliminary data. It is important to expand the study to variants other than loss of lumbar lordosis.

THE SHEEP AS A MODEL FOR VERTEBRAL OSTEOPOROSIS: A PILOT STUDY

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Introduction: Vertebral compression fractures are common in osteoporosis, resulting in spinal deformities, severe back pain and decreased mobility. Vertebroplasty and kyphoplasty procedures aim to restore the integrity of the deformed vertebral body by injection of biocompatible cement. To date, there have been no long-term studies of the bone-cement interaction in this setting. A reliable large animal model of vertebral osteoporosis would be useful to fully characterise the disease process, to assess potential treatment regimens and to investigate the biocompatibility of bone cements used in kyphoplasty and vertebroplasty. The aim of this pilot study was to develop such a model with ovariectomy, low calcium diet and continuous steroid treatment.

Methods: To induce osteoporosis, ten lactating ewes (mean age 8 years) were ovariectomised, injected weekly with 9 mg dexamethasone (Dexafort, Intervet, Australia) and fed low calcium diet. Weekly serum samples were taken to quantify generalised bone resorption (Type 1 collagen C-telopeptide [CTX], β -Cross Laps assay, Roche Diagnostics, Australia). Dual-energy X-ray absorptiometry (DEXA, Hologic QDR 1000+, USA) was used to monitor bone mineral density (BMD) in the lumbar spine (L3-L6) after 0, 2, 4, 6 and 9 months of treatment. At each time interval two sheep were killed by barbiturate injection. The entire lumbar spine (L1-L6) was processed for histology, quantitative histomorphometry, mechanical testing and micro-CT (computed tomography).

Results: CTX levels increased rapidly after two months ($p < 0.05$). Baseline BMD in the lumbar spine ($0.87 \pm 0.06 \text{ g/cm}^2$) decreased by $16.9 \pm 3.8\%$ or 2.72 standard deviations ($p < 0.001$) after nine months of treatment. Structural parameters of cancellous bone also showed osteoporotic change. Trabecular bone volume of L2, L3 and L6 vertebrae (pooled) progressively decreased from $24.9 \pm 1.2\%$ at two months to $16.5 \pm 0.47\%$ at nine months ($p < 0.05$). Trabecular thickness decreased from $0.14 \pm 0.01 \text{ mm}$ to $0.09 \pm 0.01 \text{ mm}$, ($p < 0.05$) and trabecular spacing increased from $0.42 \pm 0.03 \text{ mm}$ to $0.47 \pm 0.02 \text{ mm}$ in the same period. The compressive load at which the L1 vertebrae failed decreased by 39.4% after 9 months.

Discussion: This pilot study has demonstrated by DEXA, cancellous bone histomorphometry and mechanical testing, significant bone loss in the sheep lumbar spine up to nine months after ovariectomy and continuous steroid treatment. Assuming that the baseline BMD is representative of mature sheep, the changes in the lumbar spine could be interpreted as osteoporotic. Vertebral bone loss did not reach levels that would result in fracture. However, further work is underway using higher steroid doses to accelerate bone loss. This experimental model will be used to assess aspects of osteoporosis in general and vertebral augmentation procedures in particular.

AN INVESTIGATION OF CHANGES IN PARAVERTEBRAL TEMPERATURE AND SPINAL CORD FUNCTION DURING VERTEBROPLASTY IN A LIVE SHEEP MODEL

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Introduction: Vertebroplasty using polymethylmethacrylate (PMMA) is an established technique in the treatment of osteoporotic fractures of the vertebra. Complications of vertebroplasty associated with PMMA leakage can include damage to the spinal cord. Previous studies have sought to investigate thermal changes in the paravertebral region, but used smaller volumes of cement than are used clinically¹, or used in vitro experimental techniques.² We have designed an in vivo sheep

model to investigate the thermal changes after injection of clinically relevant volumes of PMMA, and to measure change in cord function associated with PMMA extrusion.

Methods: Five sheep were anaesthetised and 1.0ml of PMMA was injected into the spinal canal at the L1 level, with measurement of the temperature by thermocouple. The L2 to L5 vertebral bodies were then exposed and 9 thermocouples placed at points in and around the vertebra (superior and inferior endplate, disc above and below, central body, posterior wall, and spinal canal) to measure paravertebral temperature for a 10- minute period after injecting 6.0mls of PMMA. All animals were then humanely euthanased, and the T12 to L2 vertebrae harvested to examine the effect of temperature on the vertebral body and spinal cord using light microscopy.

Results: The experiments showed significant increases in the paravertebral temperature, especially at the endplates (mean temperature 51.7°C, mean increase in temperature +16°C). This is contrary to studies using small cement volumes or in vitro conditions. Intradiscal and posterior wall temperature did not significantly rise. Spinal canal temperature reached a mean 75.4°C in the presence of “extruded” cement. Microscopic examination showed thermal damage to the spinal cord.

Discussion: The experiments indicate that neurological complications associated with vertebroplasty are likely to be thermally mediated, and that the analgesic effects of vertebroplasty are likely to be, at least in part, due to thermal damage to endplate neurological structures.

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A PROSPECTIVE STUDY OF A TITANIUM/POLYOLEFIN ARTIFICIAL LUMBAR DISC

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Introduction: The purpose of this study was to evaluate the design of a titanium/polyolefin artificial disc, assess its safety and measure outcome to determine if a RCT is justified.

Methods: All subjects entered this pilot study with one or two-level disc disruption at L4/L5 and/or L5/S1 and had disabling low back pain for at least 12 months. The diagnosis was confirmed by discography. Independent assessment included physical examination, VAS for pain, Low-Back Outcome Score (LBOS), Oswestry Disability Index (ODI), SF-36, lateral flexion/extension radiographs and MRI. This was carried out preoperatively, at 6 and 12 weeks, 6 months and at 1 and 2 years. Surgery was performed by an anterior retroperitoneal approach.

Results: Twenty-eight cases (14 males; average 41 years) were operated on during 1998-2000. Surgery was performed at L5/S1 in 19, L4/L5 in 5 and both levels in 4. Operating time averaged 130 minutes with 180mls average blood loss. There were no operative complications and average length of stay was 6 days. At 2 years there was 39% average improvement in vas, 15-point average improvement in ODI, 14 point average improvement in LBOS and improvement in 5 of the 8 SF-36 sub-scales. Complications included detection by plain radiographs of early partial displacement of implant in one case and late heterotopic calcification in another. Thin section helical CT, first carried out in early 2001, revealed polyolefin tears in 10 patients, four undergoing revision surgery since 2-year follow-up. CT revealed instances of osteolysis associated with polyolefin failure and heterotopic bone formation not seen on plain radiographs.

Discussion: Although improvements in clinical outcome comparable to that reported with fusion were obtained at two years, detection of elastomer tears by thin section CT in 36% of patients indicated the prosthesis was not suitable for clinical use. This finding was unexpected given the results of prior extensive mechanical testing¹.

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COMPARISON OF ANTERIOR AND POSTERIOR FUSION WITH DISC ARTHROPLASTY FOR DISCOGENIC BACK PAIN

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Introduction: Surgical management of discogenic low back pain has in the past been limited to spinal fusion. Recently disc arthroplasty has become available. The rationale for disc arthroplasty is that it may avoid the long term consequences of adjacent segment degeneration. Avoidance of long term consequences is of no value unless the short term outcome is at least equivalent between fusion and arthroplasty.

Methods: A series of patients with chronic low back pain with concordant lumbar discography and a negative control discogram were surgically treated. Prospective data was collected preoperatively and at regular intervals during the post-operative period for a historical series of combined anterior and posterior lumbar fusion (n =24), a series of SB Charité (DePuy Spine) disc replacements (n =23), and recently, a series of Maverick (Medtronic Sofamor Danek) artificial disc replacements (n =9). Self assessed outcome measures of visual analog pain score (VAS), Low Back Outcome Score (LBOS) and SF12 general health data was obtained at intervals after the surgery. This paper presents the results of the consecutive series that have a minimum of 3 months follow-up.

Results: The data for the two groups of arthroplasty was combined and compared to the fusion group. The mean age for the fusion group was 37.6 years and the mean age for the arthroplasty group was 38.6 years. There were 5 compensation cases (20.8 %) in the fusion group and 5 cases (15.6 %) in the arthroplasty group. Both groups had 69% male patients. The mean VAS dropped from 7.5 to 3.7 (p<0.001) in the arthroplasty group and from 7.3 to 3.5 (p<0.001) in the fusion group. The mean LBOS improved from 22.0 to 36.5 (p<0.001) in the arthroplasty group and from 19.6 to 37.1 (p<0.001) in the fusion group.

There was no apparent difference between the clinical improvement in VAS and LBOS (p=0.91 and p=0.45 respectively) for each group. Analysis of the power of the comparison showed an 86% power for comparison of VAS improvement using a clinically important difference (delta) of 1 VAS point and there was 98% power for the LBOS improvement comparison using a clinically important difference (delta) of 10 LBOS points. Complications appeared higher in the arthroplasty group with foraminal encroachment requiring revision in 3 cases and one case of polyethylene failure in the Charité group at 3 years. This case occurred with an 8mm polyethylene insert (since removed from inventory by the manufacturer)

Discussion: Disc arthroplasty in the lumbar spine appears to offer similar short term results to that of fusion for chronic low back pain. The surgical complication rate may be higher in the early learning curve of the procedure.

A PROSPECTIVE RANDOMIZED U.S. FDA STUDY OF THE CHARITÉ DISC REPLACEMENT – A RADIOGRAPHIC OUTCOME ANALYSIS OF 276 CONSECUTIVE PATIENTS

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Introduction: A prospective randomized study of artificial disc replacement vs. lumbar fusion for one-level disc pathology with 2 year minimum follow-up was completed in compliance with a U.S. FDA protocol.

Methods: A total of 15 investigational sites enrolled 375 subjects with a randomization in a 2:1 ratio. Of the 375, 205 were randomized to receive the Charité artificial disc, and 99 were randomized to receive anterior lumbar interbody fusion with BAK cages. An additional group of 71 patients received the Charité disc as “training cases” prior to beginning randomization. Clinical outcome measures included VAS, Oswestry Disability Index, and SF-36 Healthy Surveys. A total of 6,900 radiographs were digitized throughout the 24 month treatment interval. The 276 disc replacement patients were allocated into one of three groups based on radiographic technical parameters-- Group I – Ideal, defined as Charité disc placement within 3 mm of ideal in both planes. Coronal plane = AP radiograph = midline or within 3 mm of midline. Mid-Sagittal plane = Lateral radiograph = 2mm posterior to middle of vertebral body or within 3mm of this axis. Group II —Suboptimal (not ideal) and Group III – Poor.

Results: The Charité prosthesis was significantly more effective than BAK in restoring the height of the collapsed disk space ($p < 0.001$). In Charité cases, the mean initial disc space height at the L5-S1 operative level was 5.2 mm +/- 1.44 (Std Dev) and increased to a mean of 13.5 mm +/- 1.18 (Std Dev). For BAK, the initial disc space height was 5.9 mm +/- 1.74 and increased to an immediate post-operative disk space height of 11.9 mm +/- 2.07. There was less subsidence with the Charité disk replacement than the BAK control at 2 years ($p < 0.001$). Of the 276 subject radiographs analysed with Charité disc replacement, 83% were classified as Group I, 11% as Group II, and 6% as Group III.

The mean Oswestry Disability Index scores at 2 years correlated with technical accuracy in placement of the prosthesis: Group I - 24.1; Group II - 30.3; and Group III - 36.3 ($p < .05$). The Mean VAS scores at 2 years correlated with technical accuracy in placement of the prosthesis: Group I - 28.3; Group II - 35.4; and Group III - 48.4 ($p = 0.016$). The mean flexion/extension range of motion and prosthesis function also correlated with device placement: Group I - 7.12 +/- 4.06 degrees; Group II - 7.47 +/- 4.41 degrees; and Group III - 3.15 +/- 3.51 degrees ($p = 0.003$).

Discussion: The surgical technical accuracy of Charité artificial disc placement correlated with clinical outcome, range of motion, and device functionality at 2 years. The Charité Lumbar Disk replacement proved to be a successful alternative to traditional lumbar fusion in every parameter. The results from this U.S. Investigational study confirm that proper placement of the Charité artificial disc improves clinical and radiological outcomes.

REVISION DISC REPLACEMENT SURGERY

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Introduction: Prosthetic devices have been developed to partially or totally replace symptomatic discs. Potential postoperative complications include infection, mechanical failure, loss of fixation, and neurological irritation or deficit. In the event of a complication, a sound surgical salvage strategy can result in a satisfactory outcome for the patient.

Methods: The study is a retrospective review of five revision cases in patients implanted with the third-generation Charité artificial disc prosthesis. The study involves a series of 182 patients since 1997, performed by a single surgeon. Of the 182 cases, 5 (2.7%) required surgical revision. The outcome measures used included back and leg VAS, Oswestry Disability Index (ODI), Roland-Morris Disability Questionnaire (R-MD), and patient self-assessment of outcome.

Results: Patient #1 had total disc replacement (TDR) at L3-4 and L4-5 and developed an early anterior subluxation at L3-4. The original device was removed and a new prosthesis inserted.

Patient #2 had TDR at L4-5 and L5-S1 and experienced a core dislocation at L5-S1 resulting in a left iliac vein obstruction. This patient had an inferior vena cava umbrella with removal of the prosthesis and conversion to ALIF. Patient #3 had TDR at L4-5 and L5-S1 and experienced increased L5 radicular pain due to over distraction at L5-S1. This patient underwent removal of the prosthesis and conversion to instrumented circumferential fusion. Patient #4 had TDR at L5-S1 and experienced a core dislocation. The prosthesis was removed and an ALIF was performed. Patient #5 had TDR at L5-S1 and developed a spondylolisthesis secondary to progression of facet arthropathy. The prosthesis remained in situ and was supplemented with an instrumented posterolateral fusion. Mean back VAS was 4.2 (0-7). Mean leg VAS was 2.1 (0-7). Mean ODI was 32.4 (0-58). Mean R-MD was 11.4 (1-18). Patients were asked to rate their satisfaction with their revision outcome with choices of excellent, good, satisfactory, or poor. Four rated their outcome as excellent and one as good. Two patients suffer from the significant co-morbidity of rheumatoid arthritis and one is in early postoperative phase.

Discussion: Considerable scepticism exists about the advantages of total disc replacement and significant attention has been given to revision procedures and complications. A surgical revision rate of 2.7% from a single surgeon's experience was reported. This rate is well below the rate suggested in the literature in relation to lumbar fusion. Careful patient selection and preoperative planning remain paramount in avoiding the need for revision. As with other types of spinal surgery, a reliable and predictable surgical revision strategy is necessary to manage complications.

OSTEOLYSIS AND COMPLICATIONS ASSOCIATED WITH ARTIFICIAL DISC REPLACEMENT

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Introduction: Prosthetic disc surgery is a rapidly growing field in patients with symptomatic degenerative disc disease. Few reports of long-term follow up are yet published, but several authors have published case series including a report of significant complications and difficulties with revision surgery¹. Advocates of disc replacement surgery have claimed that osteolysis, whilst being a potential problem associated with artificial disc replacement, has not yet been reported.

Methods: The literature relating to the laboratory research into performance of artificial disc replacement, focusing on wear debris and particle generation is reviewed. Reports of complications are reviewed. A case of significant osteolysis associated with artificial disc replacement is reported.

Results: Our report involves a 42-year-old lady with degenerative disc disease who underwent L5/S1 anterior lumbar interbody fusion in July 1999, with a simultaneous L4/L5 Charité disc prosthesis. In May of 2002 she developed significant back pain, and further investigation revealed polymer disintegration and associated osteolysis. Attempted revision surgery in May 2003, using a combined anterior approach by a vascular and spinal surgeon, led to damage to the adherent common iliac vessels and inferior vena cava, and the attempt to remove the prosthesis was abandoned. Histological samples taken at surgery confirmed the presence of polyethylene wear debris. Posterior instrumented fusion was performed in June 2003 and the patient made a successful recovery.

Discussion: It is important in modern spinal practice to be fully aware of both reported and potential risks of the use of new prostheses. Wear of an artificial disc causing osteolysis is anticipated. This is believed to be the first case in the world literature of this important complication associated with the use of artificial disc replacement. Revision of disc prostheses with osteolysis is challenging, and a combined surgical approach is advised.

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1. van Ooij A, Oner FC, Verbout AJ. Complications of artificial disc replacement: a report of 27 patients with the SB Charité disc. *J Spinal Disord Tech.* 2003;16:369-83.

ARTIFICIAL LUMBAR DISC REPLACEMENT – A SYSTEMATIC REVIEW OF THE LITERATURE, 2002-2003.

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Introduction: Following a systematic review of the literature, de Kleuver¹ concluded that there was insufficient data to assess the performance of total disc replacement. In the absence of controlled trials, the relative merits and efficacy of artificial disc replacement as a treatment option for degenerative disc disease was unproven. Observational studies reported a moderate success rate (50-81%), but a relatively high complication rate (3%-50%). In particular, 4% of the operated levels fused spontaneously or after revision surgery.

Methods: Using the research methodology of the above study, all subsequent published studies of artificial lumbar disc replacement were identified and reviewed by meta-analysis. In the two years (2002-2003) since the above study, a further nine case series and three controlled studies have been reported. The three randomised controlled trials compared disc replacement with spinal fusion. Seven prospective studies (include the randomised controlled studies) had defined indications, exclusions and outcome measures.

Results: A total of 623 disc replacements were performed in 510 patients. The outcomes were classified as “good” or “excellent”, ranged from 70-93% (mean=83%). Complications were observed in up to 35% (mean=3%) of patients. Eight patients subsequently underwent spinal arthrodesis at the level of the disc replacement. Two patients were reported to have heterotopic ossification.

The outcomes for the 2002-2003 publications were better (MWp=0.02) than for the de Kleuver study. Fewer patients had disc replacement at more than one level (FEp<0.01). The number of patients undergoing secondary surgery (FEp<0.01) and arthrodesis (FEp=0.04) was less and the incidence of prosthetic subsidence or migration was lower (FEp=0.28). This overall improvement in recent studies highlights the importance of patient selection and the use of a disc replacement of appropriate size.

Following disc replacement, there was a significant improvement in outcome measures at six-week follow-up. This improvement was maintained at two years. While disc replacement reported significantly less pain and disability in the early period following surgery compared with the fusion, the difference was not significant by six months.

Discussion: In the short to medium term, disc replacement is as effective as spinal fusion in the treatment of degenerative disc disease in critically selected patients. Although the number of complications has been reduced, some serious complications were reported.² A satisfactory salvage procedure for failed disc replacement is yet to be found. The long-term biological effects of disc replacement are unknown. Late failure of disc replacement is predictable in a substantial number of patients. Long-term studies of ten or more years are necessary to adequately define the place of disc replacement in the treatment of lumbar disc disorders. Because the numbers of disc replacement patients is likely to be small, protocols and outcome measures should be standardised and data centrally recorded.

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A MULTICENTER, PROSPECTIVE, RANDOMIZED, STUDY OF THE PRESTIGE ARTIFICIAL CERVICAL DISC VERSUS FUSION FOR PRIMARY CERVICAL DISC SURGERY.

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Introduction: A prospective, randomized, controlled study has been conducted to compare the clinical outcomes of patients treated with an artificial cervical disc to patients who receive fusion after cervical discectomy for the treatment of primary cervical disc disease. It is hypothesized that maintenance of motion after anterior cervical discectomy will prevent the high rate of adjacent level premature degeneration. The primary purpose of the study is to prove equivalence (non inferiority) of outcome of the disc prosthesis in the short term compared with fusion. Enrolment has closed and this is a report of the data with 50 cases with 6 month follow-up and 9 cases having reached 24 month final follow-up.

Methods: In four centres, 52 patients with primary, single level cervical disc disease producing radiculopathy and/or myelopathy were randomised prospectively to receive anterior cervical discectomy with either fusion or artificial cervical disc replacement. The patients were evaluated with pre- and post-operative serial flexion-extension cervical x-rays at 6 weeks, 3, 6, 12, and 24 months. At the same intervals, the patients had pre and postoperative neck disability indexes, visual pain analogue scales, European myelopathy scores, SF-36 general health scores, and neurological status examinations assessing the patient's reflex, motor and sensory function.

Results: At 6 weeks the neck disability index reduced by 34.1 for the investigational group compared to 35.2 for the fusion group. The pain score had reduced by 7.7 for the investigational group and by 9.7 for the control group. This improvement appeared to be maintained until the 12 month follow-up. The mean pain scores at 24 months were similar (4.3 and 5.6 respectively) In general there appeared to be a slightly better outcome for the investigational group, though the investigational group showed slightly less preoperative pain ($p=0.091$) and disability ($p=0.055$) than the fusion group. Both pain score and disability scores improved statistically significantly compared to the pre op scores ($p<0.001$ all comparisons). Analysis of non-inferiority of outcome for the investigational group using ANCOVA with the preoperative score as the covariate and a non-inferiority margin of 5 points (5%) showed statistical significance at 12 weeks for Neck Disability Index.

Discussion: Anterior cervical discectomy and fusion has a good short-term outcome though there is a high incidence of failure at adjacent levels over time. It is hypothesized that the maintenance of motion of a segment will prevent adjacent premature degeneration. It will take long term follow-up studies however to prove this. In the mean time, the justification to insert artificial cervical prostheses rests on being able to prove equivalence of outcome between fusion and prosthesis in the short term. This paper shows that the outcomes appear to be equivalent. Though there is insufficient power to prove equivalence with a clinical margin of 5%.

BRYAN CERVICAL DISC ARTHROPLASTY: 12-MONTH MINIMUM FOLLOW-UP IN 14 PATIENTS.

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Introduction: While anterior cervical decompression and fusion has been shown to be clinically effective in cases of myelopathy or radiculopathy, several studies have suggested an increased risk

of development of adjacent segment degeneration. The Bryan Cervical Disc Prosthesis was developed to address this complication and was first used clinically in Europe in January 2000. The author began to use the device in June of 2001 and since that time has implanted 30 prostheses in 22 patients. The present prospective study was commenced at the time (concurrently with an ASERNIPS study) with a view to examine the clinical efficacy and safety of this device. The results in the author's first 14 patients are reported, all with a minimum follow-up of 12 months (mean 20 months).

Methods: An observational audit of 14 consecutive patients with cervical radiculopathy (6 patients), myelopathy (6 patients) or discogenic neck pain (2 patients) operated upon between July 2001 and November 2002. Average age was 48 years (range 27 – 61 years). 5 patients underwent two level procedures. Operative / post-op complications and clinical / radiological outcomes were recorded at 6 weeks, 3, 6, 12 months and January 2004.

Results: Follow-up data is available at >12 months on 13 of the 14 patients at an average 23 months post op (Range: 14-30 months). The patient for whom data is not available is known to have had a poor clinical outcome. She developed an unusual symptom complex with complex regional pain syndrome and is very unhappy with the surgery. Of the other 13 patients, 12 consider their outcome to have been excellent and 1 fair. In the two patients who underwent surgery purely for discogenic neck pain, substantial relief was reported. In the 8 patients with pre-operative arm pain, 6 reported complete relief, 1 substantial relief and one partial relief. There were no intra-operative complications. Two patients developed dysphagia which resolved after several months, one has described a clicking sensation in his neck for which no cause has been identified and one experiences persistent 'neural surges'. One patient required surgery for a disc herniation at an adjacent level, 9 months post-op while in another patient, on routine 12 month follow-up MRI scan, an asymptomatic disc herniation adjacent to the operated segment had resolved spontaneously. One patient underwent foraminotomy for recurrent arm pain, 19 months post-op. All prostheses appear mobile on dynamic x-rays but it is apparent that the Bryan device does not correct any pre-operative degenerative deformity using the current technique.

Discussion: The current study appears to indicate satisfactory clinical outcomes at an average of 23 months post surgery in this group of patients. Longer follow-up and larger patient numbers are required as well as comparative studies.

AUTOLOGOUS COSTAL CHONDROCYTES PREVENT LUMBAR DISC DEGENERATION

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Introduction: Disc degeneration is consistent with advancing age and in many cases is associated with back pain and restricted mobility. The traditional surgical treatment for chronic back pain has been spinal fusion to immobilize the painful level. Long-term studies, however, suggest that fusion actually promotes degeneration at adjacent levels. One of the hallmarks of disc degeneration is aggregation of chondrocytes in the nucleus of chondrones, and more recently apoptosis has been implicated as a factor controlling the longevity of the cells. Recent research suggests that it may be possible to restore normal function to degenerate discs by introducing a fresh population of cells. This study investigated the potential for autologous costal chondrocyte implantation to prevent lumbar disc degeneration after annular injury in the sheep.

Methods: the lumbar spines of eight adult sheep were exposed. In four animals, full thickness annular incisions were made in three alternate discs. No annular incisions were made in the other four sheep. A minimum of 500 mg of cartilaginous tissue was harvested from the twelfth rib of all animals. Tissue was cultured in vitro and the chondrocytes were labelled with a fluorescent marker

for retrospective identification. After six weeks the chondrocytes were injected into the lower two alternate discs of all animals, leaving the uppermost discs and those untouched as internal controls. The animals were killed at intervals from three to twenty-four weeks and MRI, plain x-ray, histology and immunocytochemistry were evaluated.

Results: MRI at twelve and twenty-four weeks showed apparent preservation of all incised discs that had been transplanted with autologous chondrocytes. Histology revealed clusters of viable chondrocytes of normal appearance within the nucleus. These cells stained positive for the fluorescent label. The same cells and the surrounding matrix were also positive for collagen type II. Serial X-ray measurements suggested that progressive disc degeneration was arrested in the discs that received autologous costal chondrocytes.

Discussion: This pilot study showed evidence that cultured autologous costal chondrocytes remained viable and produced extracellular matrix following transplantation into normal and degenerate discs. In contrast to other studies that have used mesenchymal stem cells or chondrocytes harvested directly from discs, this study demonstrated success with cells from a source other than the disc. Costal cartilage is a convenient source of cells for transplantation and this technique warrants further investigation as a potential treatment for degenerative disc disease.

PROPHYLACTIC CEPHAZOLIN AND THE WINDOW OF PREVENTION.

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Introduction: Although prophylactic antibiotic administration is common in spinal surgery, the choice of drug, dose, and timing of administration often varies. Little is known about the activity of antibiotics in the spine and indeed if they are distributed throughout the disc and if the time intervals are optimal. Because infections that produce iatrogenic discitis generally arise within the disc, the antibiotic concentration of the disc is more relevant than serum concentrations.

The aims of the study were to determine if a 2g dose of cephazolin was effective at preventing discitis over a four-hour period in immature ovine discs that were both non-degenerate and degenerate; and also to determine the concentration of cephazolin in serum and disc tissue.

Methods: In 10 Merino wethers aged 12 weeks, three lumbar discs were “degenerated” by incising the posterolateral annulus with a scalpel blade and using ronguers, removing the bulk of the nucleus pulposus. After 12 weeks nine animals were anaesthetised and given a 2g dose of cephazolin (David Bull Laboratories, Australia) at predetermined time intervals over a four-hour period. The antibiotic was chosen for effectiveness against *Staphylococcus aureus* a common discitis-causing organism. One sheep (control) did not receive any antibiotics to follow the natural progression of infection. All animals had discography with radiographic contrast that contained *S. aureus* at two incised levels and at two non-incised levels. Lateral radiographs of the lumbar spine were taken at two, six and 12 weeks to monitor the bony changes. At 12 weeks all sheep were given a 2g intravenous dose of cephazolin at time intervals before being killed. The spines were removed and prepared for light microscopy to assess pathology of the discs and for biochemical analysis of antibiotic concentration. Success of treatment was judged using histologic and radiographic features.

Results: The control sheep that did not receive any antibiotics developed discitis at four levels. Histology at 12 weeks confirmed discitis in 10/36 “prophylactic discs”. Of these “prophylactic discs” 7/10 had previously been “degenerated”. Discitis only developed in immature discs that were administered cephazolin two hours prior to inoculation. When antibiotic was administered after inoculation discitis was prevented.

Biochemistry results confirmed that antibiotic diffused throughout the disc but was concentrated in the annulus more than the nucleus. Antibiotic levels in the disc peaked at 15 minutes (annulus mean concentration 15.5 mg/L, nucleus mean concentration 3.2 mg/L). Serum levels at 15 minutes were up to 50 times greater at this time (serum mean concentration 178 mg/L).

Discussion: The discs that were “degenerate” had a higher incidence of discitis compared to “non-degenerate” discs. However the concentration of antibiotic in degenerate discs was not significantly different than in non-degenerate discs. A 2 gram dose of cephazolin is reasonably effective (approx 70% success rate) at preventing discitis over a four-hour period.

IN VIVO AND COMPUTATIONAL MODELLING OF CSF PULSATIONS IN POST-TRAUMATIC SYRINGOMYELIA.

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Introduction: Enlarging cystic cavitations (syrinxes) form within the spinal cord in up to 28% of spinal cord injured patients. These post-traumatic syrinxes can cause neurological deterioration, and treatment results remain poor. Syrinxes are often found adjacent to regions of arachnoiditis.

The understanding of biological systems is increasingly dependent on modelling and simulations. Numerical simulation is not intended to replace *in vivo* experimental studies, but to enhance the understanding of biological systems. This study tests the hypothesis that pressure pulses in the SAS are high adjacent to areas of arachnoiditis and investigates the validity of a numerical model by comparison with *in vivo* experimental findings.

Methods: *Experimental Model:* Post-traumatic syringomyelia was induced in eight sheep by injection of kaolin into the subarachnoid space (SAS), and excitotoxic amino acid into the spinal cord of the upper thoracic spine. Cerebrospinal fluid (CSF) pressure studies were undertaken at either 3 or 6 weeks. Fibre-optic monitors were used to measure the pressure in the SAS 1 cm rostral and 1 cm caudal to the induced arachnoiditis.

Numerical Model: An axisymmetric fluid-structure interaction model was developed to represent the spinal cord and SAS under normal physiological conditions and in the presence of arachnoiditis. Arachnoiditis was modeled as a porous obstruction in the SAS.

Results: In both models the SAS pressure rostral to the arachnoiditis was found to be higher than the caudal SAS pressure. There was no statistically significant difference between the sheep at 3 and 6 weeks. Under normal conditions, both experimentally and in the numerical model, the pressure drop along the SAS was negligible. In the presence of arachnoiditis, the pressure drop across the arachnoiditis in the experimental model was 1.6 mmHg, whereas the numerical model predicted a pressure difference of 1.3 mmHg.

Discussion: The numerical model accurately predicts CSF pressures in the animal model under both normal and abnormal conditions, allowing predictions to be made to within 20% accuracy. The local increases in SAS CSF pressure demonstrated may act to increase fluid flow through perivascular spaces and be implicated in syrinx formation and enlargement.

CASPASE-3-MEDIATED PROTEOLYSIS OF AMYLOID PRECURSOR PROTEIN AND THE PRODUCTION OF AMYLOID-BETA IN HUMAN ACUTE AND CHRONIC COMPRESSIVE MYELOPATHY

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Introduction: This study aimed to analyse immunohistochemically the proteolysis of Amyloid Precursor Protein (APP) using Caspase-3-mediated APP proteolytic peptide (CMAP), beta-Amyloid (A β) and Active Caspase-3 in post-mortem human specimens in acute and chronic compressive myelopathy.

Compressive myelopathy, occurring through traumatic fracture/dislocation of vertebrae, iatrogenic injury, cervical spondylotic myelopathy (CSM), or metastatic tumour, causes much socio-economic and emotional disability for patients as well as physical consequences. In such conditions, APP is recognised as an early and specific marker of axonal injury. The proteolysis of APP in both acute and chronic compressive myelopathy has not yet been described. Studies analysing axonal injury after brain trauma suggest a role for Caspase-3 in the cleavage of APP¹. In addition, Caspase-3-mediated cleavage of APP has been found to be associated with the formation of A β , a neurotoxic protein thought to contribute to cell death in Alzheimer's disease². Furthermore, A β may subsequently encourage activation of Caspases -2, -3, and -6, the major effector molecules in apoptosis². The current study addressed two hypotheses; that APP provides a substrate for the Caspase-3 enzyme, and, that this event is associated with A β production in the compressed spinal cord.

Methods: Spinal cord material from 17 patients with documented SCI was analysed. The spatial distribution of cellular immunoreactivity was qualitatively assessed in injury due to trauma (n=5), iatrogenic event (n=1), CSM (n=6) and metastatic tumour (n=5). Morphological, immunohistochemical and immunofluorescent techniques were used to investigate APP proteolysis.

Results: Caspase-3, APP, CMAP and A β were present in anterior horn cells of the grey matter and axons of the white matter. An association was found between neuronal immunoreactivity and that of axons in motor tracts. Dual-immunolabelling revealed axonal co-localisation of CMAP with A β and Caspase-3 with A β . Although CMAP was present in axons which were immunopositive for APP, an inverse relationship was found as each marker was limited to its own, distinct region, consistent with the theory that CMAP actively cleaves APP. In neurons, co-localisation occurred between Caspase-3 and A β , and CMAP with A β . No neuronal co-localisation was shown between CMAP and APP in the acute and chronic state.

Discussion: Caspase-3 appears likely to contribute to the proteolytic cleavage of APP in compressive myelopathy. CMAP was associated with the production of A β as demonstrated using single and dual immunolabelling. Furthermore, evidence is given for the association of Caspase-3 itself with the neurotoxic peptide, A β . It is possible that activation of Caspase-3 via these secondary mechanisms may trigger the advancement of the apoptotic cascade with the subsequent demise of the cell.

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RADIOLOGICAL RESULTS AND FUNCTIONAL IMPROVEMENT IN PATIENTS UNDERGOING ANTERIOR LUMBAR INTERBODY FUSION

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Introduction: Anterior lumbar interbody fusion (ALIF) with posterior stabilisation is an established treatment for degenerative disc disease.¹ Some previous reports have advocated a goal of 360 degree fusion, and condemned posterior stabilisation as it does not achieve fusion of the posterior facet joints.² Others have claimed that the concept of a 'locked pseudarthrosis' gives satisfactory clinical results.³ There is also a contention that private or self-funding patients achieve better results after spinal fusion compared to those treated under compensation or Dept. Veterans Affairs (DVA) schemes.

Methods: Twenty patients who had undergone an ALIF with posterior stabilisation were retrospectively reviewed. All had a follow-up greater than 12 months. 13 patients were private and 7 non-private. The groups were aged and sex matched. Radiological assessment of fusion was made with reconstruction CT scans. Oswestry Disability Index (ODI) scores were recorded preoperatively, 6 months and 12 months post operation.

Results: Patients with locked pseudarthrosis showed no significant difference in outcome compared to those with radiological fusion. Both groups showed significant improvement in ODI scores after ALIF (mean preop. = 52 – range 16-74; mean postop. = 18 – range 0-52; $p < 0.01$). There was a significantly greater improvement ($p < 0.02$) in ODI scores in private patients (mean reduction = 41 points) compared to worker's compensation or DVA patients (mean reduction = 22 points).

Discussion: The results indicate that ALIF with posterior stabilisation can achieve good clinical results even with a 'locked pseudarthrosis'. While there is no significant difference between outcomes in different health funding groups shown in the study, carefully patient select for this treatment is the key to success.

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RELIABILITY OF CT BASED CLASSIFICATION OF INCORPORATION OF FEMORAL ALLOGRAFT IN ANTERIOR COLUMN RECONSTRUCTION OF THE THORACOLUMBAR SPINE

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Introduction: Diaphyseal femoral allograft is well suited to anterior column reconstruction of the thoracolumbar spine due to its inherent structural properties and biocompatibility. The Bridwell system of interbody fusion assessment¹ is based on plain x-rays and therefore lacks sensitivity. A new classification system of bony union is proposed using high-speed spiral CT imaging.

Methods: Twenty-six patients who underwent anterior thoraco-lumbar reconstruction for burst fracture using femoral allograft were followed for a minimum of 2 years. Each subject underwent high speed spiral CT scanning through the reconstructed region of the thoracolumbar spine and a classification system of graft to endplate union and central cancellous autograft incorporation was established.

The classification system reflects gradually increasing biological stability of the construct. *Grade I* (complete fusion) implies cortical union of the allograft and central trabecular continuity. *Grade II* (partial fusion) implies cortical union of the structural allograft with partial trabecular incorporation. *Grade III* (unipolar pseudarthrosis) denotes superior *or* inferior cortical non-union of the central allograft with partial trabecular discontinuity centrally and *Grade IV* (bipolar pseudarthrosis) suggests both superior *and* inferior cortical non-union with a complete lack of central trabecular continuity. Intra- and inter-observer error studies were carried out involving spinal surgeons, radiologists and trainees to examine reliability of the classification

Results: In this series 84% of cases demonstrated Grade I or Grade II characteristics. 1 case (4%) was identified as Grade IV. The classification showed good reliability with a kappa score of over 0.7

Discussion: Plain radiographs have always proved unsatisfactory for the accurate assessment of incorporation of grafts in the thoraco-lumbar spine. The use of CT imaging in the assessment of graft union has allowed a more accurate assessment of union. The classification system presented allows a reproducible and relevant categorisation of allograft incorporation.

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MANAGEMENT OF PAEDIATRIC CHANCE FRACTURES

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Introduction: Chance fractures in children are rare the mechanism of injury is a flexion-distraction inertial force created during a motor vehicle accident when wearing a two-point seat belt or lap belt. High velocity paediatric Chance fractures are frequently associated with intra-abdominal injuries, although this may not be appreciated at the time of initial presentation.

Methods: The cases of two brothers who sustained Chance fractures with complete neurological deficits and intra-abdominal injuries from a motor vehicle accident are presented.

Results: The two brothers were rear seat passengers in car involved in a head-on collision with a tree. They were both wearing three point seat belts but had removed the chest straps, thus effectively converting them to a two-point harness.

Case 1. Boy age 3 years 10 months sustained a bony Chance fracture through the L3 vertebrae with a complete neurological deficit at the L1 level. There was an associated closed head injury and severe abdominal bruising. He underwent a CT scan of his abdomen on day of admission and posterior stabilisation of the spinal fracture on day 4. Seven days post-admission he was diagnosed with pancreatitis. He continued to have abdominal pain and vomiting. Further repeat abdominal CT scans, ultrasound examinations and abdominal contrast studies were performed. Ten weeks following admission he underwent laparotomy and a section of ischaemic small bowel was removed.

Case 2. Boy age 2 years 8 months presented with a ligamentous Chance fracture of L2 / L3 with a complete neurological deficit at T12. He had a closed head injury and severe abdominal bruising. He underwent CT scan on the day of admission and a diagnostic peritoneal tap on day two with aspiration of straw coloured fluid. The spinal fracture was stabilised 10 days post-admission with posterior instrumentation. On day 14 he underwent a laparoscopy and subsequent laparotomy with drainage of an abscess secondary to a perforated caecum.

Discussion: Chance fractures or flexion-distraction fractures of the spine are rare occurrences in children with few cases reported. They represent severe trauma and are often related to the wearing of two-point seat belt fixation. There is a high associated incidence of abdominal injuries which may be difficult to diagnose. The authors support the view of Beaunoyer¹ that a diagnostic laparoscopy or laparotomy should be considered strongly in patients with lumbar Chance fractures. Abdominal bruising and neurological deficit are cardinal signs, reflecting severe trauma.

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A REVIEW OF SPINO-PELVIC FIXATION

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Introduction: Pelvic fixation is undertaken in order to restore stability to an unstable pelvis or correct severe scoliotic degeneration of the spine. Instability of the pelvic ring can result from resection of tumours, fractures of the pelvis or infection of the pelvic joints and bones. A number of methods for stabilising the pelvis have been described in the literature including the Galveston Reconstruction (GR)¹ and the triangular frame reconstruction (TFR)². These are associated with an improvement in functional ability, however failure of instrumentation or loosening often occurs.³ A recent mechanical analysis of these techniques has found the technique used in this hospital (GR) performed most poorly.²

Methods: A scoring system was developed from a retrospective analysis of 8 patients. The patients were categorised into two groups (high score and low score) based on age, presence of infection and serious non-associated comorbidities. A patient aged 60 years or over scored 5 points. Patients with bony infection scored 10 points. The presence of serious comorbidity including osteoporosis scored 5 points with minor comorbidities scoring 1 point.

Results: Eight patients who underwent pelvic fixation for varied indications (2 after resection of tumours, 1 fracture, 2 scoliotic degeneration, 3 for infection) were analysed. Three patients had a good functional improvement without loosening of screws beyond 1 year after surgery. These patients were otherwise healthy, relatively young and had no disease processes that affected local bone quality at the site of fixation or serious comorbidities. The other 5 patients all showed evidence of early screw loosening within one year. Of these patients, 2 had a number of serious comorbidities well recognised to compromise bone quality (osteoporosis, long term steroid use) and 3 had pre-existing extensive bony infection.

Discussion: Bone quality of the pelvic bones appears to be the primary predictor of long term functional outcome after pelvic fixation. The 5 patients who had a number of comorbidities well recognised to compromise bone quality all saw early screw loosening within 1 year. Since fixation of the pelvis requires extensive surgery necessitating both posterior and anterior approach and has a number of severe complications such as alteration of urinary, sexual and recto-sigmoid functions the benefit of pelvic fixation should be considered in light of these factors which appear to predict long term outcomes. Further prospective studies of patients undergoing pelvic fixation are required to validate our scoring system.

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