

**How does pre-reduction MRI affect surgeon's behaviour  
when reducing Distraction-Flexion injuries of the cervical  
spine?**

By

**Mark Alexander Fleming**

Student Number: FLMMAR004

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN

In fulfilment of the requirements for the degree

**Master of Medicine (MMED)**

**Orthopaedic Surgery**

Faculty of Health Sciences

University of Cape Town

Date of submission: 15 August 2013

**Supervisor: Professor Robert Dunn**

**Consultant Spine and Orthopaedic Surgeon**

**Pieter Moll and Nuffield Chair of Orthopaedic Surgery:**

University of Cape Town

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

## DECLARATION

I, **Mark Fleming**....., hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature: **signature removed**.....

Date: **18/11/2013**.....

University of Cape Town

# Abstract

**Study design:** Retrospective review

**Objective:** To identify factors affecting surgeons' management decisions regarding acute cervical Distraction Flexion reduction and consequences thereof.

**Summary of background data:** There is clinical benefit when early (<24hours) decompression in Distraction Flexion (DF) injuries with cord injury is performed. The risk of secondary cord injury during awake closed reduction is low. The need for MRI scanning prior to reduction is controversial. MRI scanning may identify patients with uncontained herniated discs that may be drawn into the spinal canal during reduction, causing further cord injury. Surgeons' belief regarding the importance of pre-reduction MRI varies. Thus in many clinical scenarios, treatment algorithms are chosen individually by the surgeon on the merits of each case.

**Methods:** Analysis was performed on 110 consecutive patients with DF injuries of the cervical spine. Pre-reduction MRI scans were assessed by 2 independent, blinded teams to determine patients with a "disc at risk". This subgroup was then investigated as to the management decisions, neurological status and outcome.

**Results:** 19 (21%) patients were identified to have a perceived "disc at risk". 6 patients underwent anterior surgery. Initial closed reduction was attempted in the other 13, none deteriorated neurologically. Presenting neurological status was found to have a large impact on surgeons' choice of reduction. Of the 9 ASIA A patients, 7 had initial closed reduction. Whilst in the 3 ASIA E group only 1 had closed reduction.

**Conclusion:** Patients with agreed MRI features of a perceived "disc at risk" had no increased risk of secondary cord injury. The presence of these disc lesions

only influenced our surgeons to choose open reduction in 4 cases (21%).  
Neurological status had a much greater effect on surgical decision making.  
Early reduction need not wait for MRI imaging and should be performed as soon as possible in cord injured patients.

University of Cape Town

# PART A

## Protocol

University of Cape Town

## Research proposal

### **Title:**

The impact pre-intervention MRI has on management of cervical spine Distraction Flexion (DF) injuries (facet dislocation) - A retrospective review

### **Aims:**

1. To assess whether the pre-intervention MRI findings in DF injuries influenced the management plan.
2. To determine how surgeons are influenced by MRI findings of a 'dangerous disc'.
3. To identify the sub-group most likely to benefit from MRI prior to cervical spine reduction.

### **Background:**

Patients with DF cervical injuries and spinal cord injury require urgent reduction to prevent further injury to the already injured cervical cord by re-aligning the spine in a normal anatomical position and indirectly decompressing the canal. Reduction may be performed via closed traction or open surgical means. There is controversy as to the value of the pre-reduction MRI. Should a prolapsed cervical disc be drawn back into the canal during closed reduction, neurological deterioration may occur. A pre-reduction MRI May be utilized in an effort to avoid this potentially devastating complication. MRI is a costly investigation, it is not universally available leading to delays to intervention. MRI interpretation is subjective with differences of opinion as to the extent of the disc injury and protrusion. A recent publication highlights the incongruities between surgical disciplines whilst managing these patients acutely. To achieve early rapid reduction, some of these patients may be managed without performing MRI.

### **Significance:**

Early reduction of dislocated cervical spine is optimal; the earliest reduction possible would normally be done whilst the patient is awake by closed means in a casualty

setting under fluoroscopy. Disc prolapse identified prior to closed reduction may not predict neurological decline when reduced closed. Identifying which groups benefited from MRI enables us to propose an algorithm to better manage patients in the future.

**Categories:**

4 cohorts are identifiable based on neurological status:

- 1) Patients in Spinal shock (as yet undetermined potential for recovery)
- 2) Incomplete spinal cord injury (potential for recovery)
- 3) Complete spinal cord injury (no potential for cord recovery)
- 4) No spinal cord injury (potential for new spinal cord injury)

**Blinding:**

Two teams reviewed MRI images, these included two Radiologists in the one team and two Orthopaedic surgeons in the other. An interrater assessment study was performed assessing agreement between the two teams on the of features of disc prolapse. Both specialties will be blinded to patient information.

**Inclusion and Exclusion Criteria:**

We include a consecutive series of patients with acute cervical DF injuries in whom MRI was performed prior to reduction. Patients whose notes were not available and chronic injuries will be excluded from analysis since closed reduction is not appropriate for this group.

**Research methods:**

This will be a retrospective study that analyses both the pre intervention MRI findings and the influence that MRI had on our treating surgeon's decisions. MRI analysis will be performed by two teams, a Radiology consultant and Radiology registrar in the one, the second team includes an Orthopaedic spine consultant and an Orthopaedic registrar. The MRI will be assessed for features of intervertebral disc injuries/herniation and surrounding soft tissue injury.

Results from each team will be compared. Determining the Interrater agreement for a number of variables suggesting the presence of a 'dangerous disc'- that type of disc injury that may be drawn back into the spinal canal during closed reduction causing secondary cord injury. After determining which cases have these 'dangerous disc'

lesions in the supporting study, a clinical note review is performed identifying the treatment algorithm chosen by the treating surgeon and their reasons for choosing that specific algorithm. We note the individual patients' neurological status and look for any correlation with neurological status.

**Risks and benefits:**

No risk, we hope to provide benefit by determining a reproducible treatment algorithm to be employed in our unit.

**Privacy:**

Data reviewed remains private to the researchers

**Data Analysis and Monitoring:**

Standardized MRI analysis by MRI trained Radiology team and Orthopaedic team. Interrater reliability assessment will be performed using Cohen's Kappa value to identify the best variables to use when looking for 'dangerous disc' lesions. Statistical advice to be provided by Prof Dunn and Mr Cararra.

**Conflicts of interest:**

No Conflict of interest

# PART B

# Literature review

University of Cape Town

## Literature review

### Objectives:

Cord injury secondary to disc herniation in DF cervical spine injuries was first described in 1944 by Brooke[1]. In this post mortem study a single patient was found to have a large central disc herniation at the same level as a unifact dislocation.

Eismont and Green described secondary cord injury related to disc herniation during closed reduction attempts[2]. In their case reports they include six patients over 7 year duration a cohort of 68 patients treated with reduction for cervical spine injuries. With growing awareness of these devastating complications, other reports surfaced indicating that early closed reduction carries risk of secondary cord injury[3–6] . With this growing body of evidence great concern was expressed over reduction under anaesthesia[6]. Awake closed reduction has been shown to carry a lower risk of neurological sequelae[7].

Authors have suggested that the use of imaging such as MRI provides the treating surgeon with information that would stop treating surgeon from trying to close reduce a cervical spine with a prolapsed 'dangerous disc'[2].

Whilst the rationale for soft tissue imaging makes general sense, it's clinical applicability has been called into question, and may lead to over diagnosis of herniated discs. The efficacy of MRI to improve neurological status in the long-term by avoiding secondary cord injury is very difficult to prove; the presence of disc lesions prior to reduction does not necessarily lead to secondary cord injury.

Basic science experiments using Canine and Rodent subjects that investigated cord injury due to cord compression have shown definite benefit to decompression. Both the degree of compression and the duration of compression have been shown to affect the ability for the cord to recover[8, 9]. This makes medical sense, but until recently has not been proven in humans. Vaccaro has recently published results derived from multicentre prospective study which shows significant neurological recovery in patients who had adequate decompression of the space available for the cord within 24 hours of injury[10].

Controversy has surrounded the need for soft tissue imaging prior to reduction. Arguments against the use of MRI are that it is costly, time-consuming, unavailable in many areas and is performed in a room that may pose serious risks to the patient should they need resuscitation whilst being scanned. Protagonists for the use of MRI argue that prolonged cord compression is less of a concern than the risk of secondary cord injury

from a 'dangerous disc'. They argue that it is safer to perform an anterior open discectomy after having identified herniated intervertebral disc than to try closed reduction without imaging[11].

Whilst reviewing the literature related to this controversy it has become clear that a significant difference in opinion exists amongst individual doctors and between specialties. Doctors who are involved with managing these patients include Neurosurgeons, Orthopaedic surgeons, Trauma surgeons and Radiologists. MRI requires interpretation, thus the interrater agreement of the features of a 'dangerous disc' should be reliable to ensure its successful use. The validity of these features relating to clinical importance is also in question. Grauer et al published work[12] where a clinical vignette of a DF injury was provided to fellowship trained spinal surgeons. They were asked whether they would request MRI imaging or proceed to closed or open reduction. Having noted their responses a second vignette was supplied with MRI images supplied. The Surgeons were asked whether they would perform open or closed reduction. The Vignettes were provided with 3 different clinical scenarios according to neurological status. The findings included very poor interrater reliability of treatment decisions. Orthopaedic surgeons were more likely to perform closed reduction after seeing an MRI than Neurosurgeons. Neurologically complete patients carried the worst treatment interrater reliability.

We have noted a similar trend within our acute spinal care team.

The objective of this literature review is to clarify current recommendations with regard to the need for MRI before reduction. We hope to find more information regarding the safety of closed reduction without MRI and help us determine the risks of delay to reduction and guide our management in order to simplify the treatment pathway of DF injuries. In South Africa transfer distance from a district hospital to an academic centre with an MRI scanner may be very far. The inherent delays associated with these transfers may not be in the patient's best interest.

#### **Literature review strategy**

Pubmed and Google Scholar internet databases were used to search for relevant publications relating to DF injuries.

Keyword searches were performed including facet dislocation, distractive flexion, distraction flexion, secondary cord injury, early rapid reduction, intervertebral disc herniation and spinal cord compression.

Certain authors were identified having published extensively on the topic including Alexander Vaccaro, Michael Fehlings and Steven Rizzolo. Their peer-reviewed articles were analysed and their references sought out and read.

Due to the nature of spinal cord injury, prospective controlled work is not a possibility, thus lower level of evidence needs to be carefully read with a particular awareness of bias.

Until recently case reports and retrospective reviews formed the bulk of literature available on this topic[2–7]. With sporadic retrospective reporting the multifactorial aetiology of secondary cord injury has been difficult to analyse.

Treatment rationale has been guided by basic science experiments with regard to cord injury[9, 13],but this cannot be performed in the human model.

The fact that the incidence of secondary cord injury due to disc lesions is unknown poses a particular problem when planning treatment algorithms. Secondary cord injury is uncommon and thus proving clinical benefit in management protocols is difficult, the size of the study group to show clinical benefit has got to be very large, thus multicentre collaborations hold the most appeal. Bias may be reduced significantly in these large studies by the use of multivariate regression analysis. Large studies of this kind are starting to emerge[10, 14], providing us with higher level of evidence, that we may start to decipher the important factors affecting potential for neural recovery.

### **Quality Criteria**

The scientific quality of each of the academic papers used for the preparation of this dissertation was assessed.

The highest level of evidence in literature currently is that of prospectively collected cohort studies in a well-planned multicentre study using multivariate regression analysis to increase external validity of results (level III). Due to the nature of spinal cord injury it is unlikely that better levels of evidence will in the future be achieved.

The bulk of literature available is a retrospective in nature and comprises sporadic case reporting, this low level of evidence (level IV), although important to include within this dissertation, must be considered as such when interpreting data.

Some expert opinion (Level V) articles have been used, the value of these relate to the individuals involved and the peer-reviewed journals within which they are published. More importantly they provide contextual understanding of the controversies which exist within this field.

## Summary of the literature

### Definition and classification

From the earliest report of intervertebral disc herniation associated with facet dislocation by Brooke in 1944 in his classic post-mortem description, it has been recognised that associated with cervical facet subluxation there is a constellation of soft tissue injuries[1].

Our current classification system was described by Allen and Ferguson, describing DF injuries according to the extent of anterior translation and rotation. They provided a staging system from stage I to stage IV. These injuries are often described as either uni-facet subluxation (stage II) or bifacet subluxation stage III and IV. With greater translation there is a greater soft tissue envelope of injury proceeding from failure of the posterior interspinous ligaments, the posterior longitudinal ligament stretching and ultimately failing. With greater translation the disco-ligamentous complex fails and the anterior longitudinal ligament becomes disrupted[15]. This classification has proved clinically useful as it is mechanistic, and although initially for use with radiographic evaluation, the associated soft tissue constellation of injury follows the progression of severity. Neurological injury patterns seem to follow this classification with increasing neurology with increasing stage.

### Aetiology of spinal cord injury

The energy required to cause DF injuries is mostly attributable to violent situations associated with motor vehicle accidents, interpersonal violence and some sporting pursuits. The majority of these incidents occur in completely uncontrolled environments where the patient's physiology and spinal immobilisation following the injury are often suboptimal. This poses significant difficulty when trying to identify one factor amongst a myriad of others that could affect neurological outcome. This is part of the problem associated with research in this field.

Intervertebral disc pathology is very common in DF injuries, the incidence ranges from 12 to 80% depending on the stage of injury[2, 6, 16, 17].

Spinal cord injury associated with these injuries has been shown to be more severe with higher stage injuries. Initial neurological presentation does correlate with final neurological outcomes usually. This is thought to be related to the degree of initial displacement at the time of injury compressing the spinal cord causing cord contusion.

Subsequent changes occur within the cord which may exacerbate the initial injury. This 'second hit' to a damaged cord may be related to further biological and pathological changes occurring within the cord occurring after the original insult. The key mechanism outlined by Tator et al is ischaemia[18]. Local changes to microvascular perfusion within the cord as well as major systemic vascular changes have been identified by various perfusion studies. Clinical correlation has been identified with neurological fallout proven on motor and somatosensory evoked potentials corresponding with reduction in perfusion. Ongoing cord compression has been shown clearly that in animal models to cause irreversible cord changes [9] and must be added to the list of 'second hit' culprits.

### **Imaging**

Allen and Ferguson used features on radiographs to diagnose the stage of injury[15]. Stages II to IV are evident on standard AP lateral cervical spine views. Stage one injuries are less obvious on standard radiographs and require flexion extension views to determine increased space between the posterior spinous processes.

Improved soft tissue imaging with CT myelogram, diagnosing cord compression and subsequently with MRI have provided surgeons the ability to diagnose posteriorly herniated intervertebral discs in DF injuries aiding the surgeon to choose the appropriate surgical approach[11, 19]. MRI is able to identify the extent of soft tissue injury[20] and identify spinal cord pathology, aiding in prognosticating neurological recovery[21, 22]. The sensitivity of MRI in diagnosing soft tissue injuries is very high, the clinical relevance of this has been called into question[23].

Timing of MRI is however contentious. Vaccaro et al suggest that there is little role for pre-reduction MRI in DF injuries in the awake co-operative patient[24]. That early closed reduction should not be delayed by special investigations. Hart describes, with his gamblers theory that the decision should rest on the neurological status. Those patients presenting with serious neurological impairment have the least to lose and the most to gain from early closed reduction whilst the patient presenting without neurological impairment has the most to lose, and the least to gain, motivating that MRI prior reduction in these cases is imperative [11].

### **Treatment methods**

After basic radiographs and thorough neurological assessment our treatment goals include preventing secondary cord injury, provision of stability for the cervical spine and supportive measures related to neurological fallout. The second hit phenomenon is avoidable by the use of appropriate fluid resuscitation and maintaining mean blood

pressures and adequate oxygenation. Certain drugs including Dopamine, Steroids and Nimodipine have been shown to maintain cord perfusion[18]. Adequate spinal decompression within 24 hours of injury mitigates this second hit phenomenon[10].

Facet dislocation requires reduction acutely, this is done by Gardner Wells traction with progressive weights, light sedation whilst using fluoroscopy. The spine is pulled in a slightly flexed manner until the facet joints have been pulled out of length at which point the cervical spine is gently extended and the weights reduced, allowing the facet joints to reduce to their natural position. This is performed in an awake patient in order for them to report any progressive neurological fallout/pain.

Following reduction these injuries mostly need stabilisation with internal fixation. Bohlman in his large study showed bifacet dislocations to have 42% incidence of late instability if managed conservatively[25]. Choosing either anterior or posterior fixation may be based on the findings of MRI following reduction, available skills, resources and the degree of instability[26]. Large disc herniations mandate an anterior surgical approach, should there be no disc lesion, posterior surgery alone or combined approaches may be required[27].

### **Outcomes**

Until recently animal studies alone have suggested that early decompression in spinal cord injured subjects would yield better neurological recovery[9, 13].

Results published from the S.T.A.S.C.I.S. study (Surgical timing in acute spinal cord injury study) have shown statistically significant neurological recovery at six months following surgery in patients who received decompression of the spinal canal within 24 hours of injury[10]. This level III evidence is the strongest available guidance with regards to DF injuries. It is with this in mind that treatment algorithms must be designed to achieve the most rapid cord decompression as possible and that unnecessary delays should be removed from this treatment pathway

### **Identification of gaps or need further research**

Current levels of evidence available are limited to well-designed prospective cohort studies this level III evidence provide us with moderate strength recommendations should the data be well adjusted through multivariate regression analysis.

Due to the nature of spinal cord injuries it is unlikely in the future to be able to derive any higher level of evidence. The unpredictability of environment that these high energy injuries occur in makes it very difficult for researchers to be able to standardise research related to the insult pathway that the spinal cord is exposed to from the time of initial injury to the time that the surgeon decompresses the cord. Pre-hospital cord monitoring using motor and somatosensory evoked potentials might provide interesting data on the progression of neurological impairment from the time of injury until hospital care is instituted.

DF injuries account for 6 to 15% of cervical spine injuries. The resultant effect is that small numbers are attainable through single units. To derive adequate numbers to draw accurate conclusions multicentre studies are required, this adds multiple differing variables further confounding research quality.

MRI clinical relevance needs to be further studied.

## References

1. Brooke WS (1944) Complete transverse cervical myelitis caused by traumatic herniation of an ossified nucleus pulposus. *J Am Med Assoc* 125:117–120.
2. Eismont FJ, Arena MJ, Green BA, et al. (1991) Extrusion of an intervertebral disc associated with traumatic subluxation or dislocation of cervical facets . Case report Traumatic of an Intervertebral Subluxation Disc Associated of Cervical with Facets or Dislocation of five. *jbjs,am* 73:1555–1560.
3. Berrington N, Staden J., Willers J, van der westerhuizen J (1993) Cervical intervertebral disc prolapse associated with traumatic facet dislocations. *Surg Neurol* 40:395–399.
4. Olerud C, Jónsson H (1991) Compression of the cervical spine cord after reduction of fracture dislocations. Report of 2 cases. *Acta Orthop Scand* 62:599–601.
5. Mahale Y, Silver J, Henderson N (1993) Neurological complications of the reduction of cervical spine dislocations. *jbjs,br* 75:403–9.
6. Lee A s., Maclean JCB, Newton DA (1994) Rapid Traction for reduction of cervical spine dislocations. *jbjs,br* 76-B:352–6.
7. Grant G a, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg* 90:13–8.
8. Fehlings MG, Perrin RG (2006) The timing of surgical intervention in the treatment of spinal cord injury: a systematic review of recent clinical evidence. *Spine (Phila Pa 1976)* 31:S28–35; discussion S36. doi: 10.1097/01.brs.0000217973.11402.7f
9. Tarlov IM (1954) Spinal cord compression studies III. Time limits for recovery after gradual compression in dogs. *Neurol Psychiatry* 71:588–597.
10. Fehlings MG, Vaccaro A, Wilson JR, et al. (2012) Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One* 7:e32037. doi: 10.1371/journal.pone.0032037
11. Hart RA, Vaccaro AR, Nachwalter RS (2002) Controversies in Spine Cervical Facet Dislocation : When Is Magnetic Resonance Imaging Indicated ? *Spine (Phila Pa 1976)* 27:116–118.
12. Grauer JN, Vaccaro AR, Lee JY, et al. (2009) The timing and influence of MRI on the management of patients with cervical facet dislocations remains highly variable: a survey of members of the Spine Trauma Study Group. *J Spinal Disord Tech* 22:96–9.
13. Carlson GD, Gorden CD, Oliff HS, et al. (2003) Sustained Spinal Cord Compression Part I: Time-Dependent Effect on Long-Term Pathophysiology. *J Bone Jt Surg* 85:86–94.
14. Wilson JR, Vaccaro A, Harrop JS, et al. (2013) The impact of facet dislocation on clinical outcomes after cervical spinal cord injury: results of a multicenter North American prospective cohort study. *Spine (Phila Pa 1976)* 38:97–103. doi: 10.1097/BRS.0b013e31826e2b91
15. Allan BL, Ferguson RONL, Lehmann T, O'brien RP (1982) A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine (Phila Pa 1976)* 1:1–27.
16. Vaccaro a R, Falatyn SP, Flanders a E, et al. (1999) Magnetic resonance evaluation of the intervertebral disc, spinal ligaments, and spinal cord before and after closed traction reduction of cervical spine dislocations. *Spine (Phila Pa 1976)* 24:1210–7.

17. Rizzolo SJ, Piazza MR, Cotler JM, balderston RA, Shaefer D FA (1991) Rizzolo SJ, Piazza MR, Cotler JM, et al. Intervertebral disc injury complicat- ing cervical spine trauma. *Spine* 1991;16S:187–9. *Spine (Phila Pa 1976)* 16:187–189.
18. Tator C, Fehlings M (1991) Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. *J Neurosurg* 75:15–26.
19. Dvorak MF, Fisher CG, Fehlings MG, et al. (2007) The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. *Spine (Phila Pa 1976)* 32:2620–9. doi: 10.1097/BRS.0b013e318158ce16
20. Vaccaro AR, Madigan L, Schweitzer ME, et al. (2001) Magnetic Resonance Imaging Analysis of Soft Tissue Disruption After Flexion-Distraction Injuries of the Subaxial Cervical Spine. *Spine (Phila Pa 1976)* 26:1866–1872.
21. Silberstein M, Tress BM, Hennessy O (1992) Prediction of neurologic outcome in acute spinal cord injury: the role of CT and MR. *Am J Neuroradiol* 13:1597–1608.
22. Flanders AE, Schaefer DM, Doan HT, et al. (1990) Acute cervical spine trauma: correlation of MR imaging findings with degree of neurologic deficit. *Radiology* 177:25–33.
23. Benzel EC, Hart BL, Ball P a, et al. (1996) Magnetic resonance imaging for the evaluation of patients with occult cervical spine injury. *J Neurosurg* 85:824–9. doi: 10.3171/jns.1996.85.5.0824
24. Kwon BK, Vaccaro AR, Grauer JN, et al. (2006) Subaxial cervical spine trauma. *J Am Acad Orthop Surg* 14:78–89.
25. Bohlman HH (1979) Acute fractures and dislocations of the cervical spine. An analysis of three hundred hospitalized patients and review of the literature. *jbjs,am* 1119–1142.
26. Storm M, Surgery O, Dunn R, et al. (2007) Management of unilateral cervical facet dislocations – a review of 49 cases. *SAOJ* 14–21.
27. Toit AB, Dunn R, Town C (2008) Bifacet dislocations of cervical spine : acute management and outcome. *SAOJ III*:30–36.
28. Ouff HS, Pillai JAYJ, Lamanna JC (2003) Sustained spinal cord compression. 85:
29. Fleming M, Westgarth-Taylor T, Candy S, Dunn R (2013) Inter-observer reliability in determining the presence of hazardous disc disruption in flexion distraction injuries of the C-spine- an MRI study. *Bone Jt J Orthop Proceedings Suppl* 95-B:26.
30. Kwon BK, Beiner J, Grauer JN, Albert TJ (2003) Anterior/posterior operative reduction of cervical spine dislocation: techniques and literature review. *Curr Opin Orthop* 14:193–199. doi: 10.1097/00001433-200306000-00012
31. Wiseman DB, Bellabarba C, Mirza SK, Chapman J (2003) Anterior versus posterior surgical treatment for traumatic cervical spine dislocation. *Curr Opin Orthop* 14:174–181. doi: 10.1097/00001433-200306000-00009
32. Gliklich dreyer (2010) Data Collection and Quality Assurance. Agency for Healthcare Research and Quality (US)
33. Grant GA, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg Spine* 90:13–18. doi: 10.3171/spi.1999.90.1.0013

34. Rizzolo SJ, Piazza MR, Cotler JM, et al. (1991) Intervertebral Disc Injury Complicating Cervical Spine Trauma. *Spine (Phila. Pa. 1976)*. 16:
35. Cotler JM, Herbison GJ, Nasuti JF, et al. (1993) Closed reduction of traumatic cervical spine dislocation using traction weights up to 140 pounds. *Spine (Phila Pa 1976)* 18:386–90.
36. Hadley MN, Walters BC (2013) Introduction to the Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries. *Neurosurgery* 72 Suppl 2:5–16. doi: 10.1227/NEU.0b013e3182773549
37. Reynolds-Haertle RA, McBride R (1992) Single vs. Double data entry in CAST. *Control Clin Trials* 13:487–494. doi: [http://dx.doi.org/10.1016/0197-2456\(92\)90205-E](http://dx.doi.org/10.1016/0197-2456(92)90205-E)
38. Kilem Gwet, Gwet K (2002) Inter-Rater Reliability: Dependency on Trait Prevalence and Marginal Homogeneity. *Stat Methods Inter-Rater Reliab Assess* 2:1 – 10.
39. Doran SE, Papadopoulos SM, Ducker TB, Lillehei KO (1993) Magnetic resonance imaging documentation of coexistent traumatic locked facets of the cervical spine and disc herniation. *J Neurosurg* 79:341–5. doi: 10.3171/jns.1993.79.3.0341

## PART C

# MANUSCRIPT

**This manuscript will be submitted to the European Spine Journal. The format and referencing style is as according to the Instructions for Authors of the Journal.**

University of Cape Town

**How does pre-reduction MRI affect surgeon's behaviour when reducing  
Distraction-Flexion injuries of the cervical spine?**

Dr M A Fleming, Dr T Westgarth-Taylor, Dr S Candy, Professor R Dunn

Groote Schuur Hospital, University of Cape Town

Study design: Retrospective review

Objective: To identify factors affecting surgeons' management decisions regarding acute cervical Distraction Flexion reduction and consequences thereof.

Summary of background data: There is clinical benefit when early (<24hours) decompression in Distraction Flexion (DF) injuries with cord injury is performed. The risk of secondary cord injury during awake closed reduction is low. The need for MRI scanning prior to reduction is controversial. MRI scanning may identify patients with uncontained herniated discs that may be drawn into the spinal canal during reduction, causing further cord injury. Surgeons' belief regards the importance of pre-reduction MRI varies. Thus in many clinical scenarios, treatment algorithms are chosen individually by the surgeon on the merits of each case.

Methods: Analysis was performed on 110 consecutive patients with DF injuries of the cervical spine. Pre-reduction MRI scans were assessed by 2 independent, blinded teams to determine patients with a "disc at risk". This subgroup was then investigated as to the management decisions, neurological status and outcome.

Results: 19 (21%) patients were identified to have a perceived "disc at risk". 6 patients underwent anterior surgery. Initial closed reduction was attempted in the other 13, none deteriorated neurologically. Presenting neurological status was found to have a large impact on surgeons' choice of reduction. Of the 9 ASIA A patients, 7 had initial closed reduction. Whilst in the 3 ASIA E group only 1 had closed reduction.

**Conclusion:** Patients with agreed MRI features of a perceived “disc at risk” had no increased risk of secondary cord injury. The presence of these disc lesions only influenced our surgeons to choose open reduction in 4 cases (21%). Neurological status had a much greater effect on surgical decision making. Early reduction need not wait for MRI imaging and should be performed as soon as possible in cord injured patients.

**Keywords:** distraction flexion, cervical spine, uniface, bifacet, pre-reduction MRI, secondary cord injury

University of Cape Town

Cervical spine dislocation carries inherent risk of cord injury. Although we have little influence over the primary injury, we can improve outcome by limiting the secondary effects of manipulation, ongoing compression and physiological circumstances which lead to ischaemia and cellular changes of the cord[13, 18, 28]. Animal models confirm that persistent cord compression has time related adverse effects on ability to recover[9, 13]. Clinical benefit has been demonstrated with cervical reduction performed earlier than 24 hours following injury[10].

The safety of closed reduction has been questioned with sporadic case reports of secondary cord injury occurring with unrecognised cervical disc prolapse [2–6]. Eismont and Green concluded that pre-reduction MRI will identify cervical disc prolapse thus allowing the surgeon to avoid secondary cord injury during reduction. Evidence of a prolapsed disc might change clinical management by dictating an immediate anterior decompression.

Although the incidence of disco-ligamentous lesions in distractive flexion injuries has been reported as high as 18 – 80%[16, 17, 29], the incidence of secondary cord injury following closed reduction is considered low[7].

Thus a discrepancy exists between identifiable disc lesions on MRI and clinical significance. Reporting of disc lesions does not carry high interrater reliability[29]. MRI is often not readily available due to distances involved between district hospitals and academic centres with MRI facilities and competition for resources. These factors may result in delay to cervical reduction with possible reduced neurological outcome.

Treatment pathways chosen by surgeons have been demonstrated to be inconsistent[12]. Some surgeons perform pre-reduction MRI scans on all DF injuries, whereas others perform closed reduction on selective patients based on neurological status and stage of DF injury.

For this reason we performed this study to identify our surgeons' reduction decision making process and consequences thereof.

### **Aim**

This retrospective review evaluates the management behaviour of our surgeons when faced with decision-making in acute DF injuries of the cervical spine, particularly with reference to the impact MRI features, and the presenting neurological status of the patients.

## **Methods**

Following local Institutional ethics approval (HRC Ref:091/2011), 110 consecutive DF injuries were identified from the senior authors database. All were managed at a single tertiary hospital over a 10 year period.

An initial study was performed to assess the interrater agreement of MRI variables between a Radiology team and an Orthopaedic team[29]. The MRI features of disc injury that had the highest agreement was found to be the presence of posterior disc herniation (based on defined posterior, inferior and corner to corner lines) and containment variables. These variables were then used to define the perceived “disc at risk”. Both teams were blinded to patient’s clinical data and worked completely independently.

19 of the 110 MRI DF injuries satisfied both teams that there was the presence of a ‘disc at risk’. Clinical data of this sub-group was then assessed. Case notes were reviewed, noting the management algorithm chosen and reasons for doing so. When employed, closed reduction involved skeletal traction applied with skull tongs to the awake patient. Sequential weights are added whilst visualising the cervical spine with an image intensifier in a flexed position. The patient is monitored clinically for onset of neuralgia or weakness. Once the facets had been distracted sufficiently the head is gently repositioned in extension, the weights are reduced when the facets are visualised to be reduced. Following reduction, the patient was kept in the extended position in skeletal traction until definitive fixation was performed. Should open reduction be performed, an anterior Smith-Robinson cervical approach was utilised and a discectomy performed prior to reduction [26, 27]. Frequently skull traction was combined with a levering manoeuvre using a MacDonald or Cobb in the interbody space on the side of the dislocation (Cloward/reverse-Cloward manoeuvre). A cage or structural allograft was placed in the disc space and anterior locked plating is performed[30, 31].

Chronic injuries are not applicable to closed reduction. Patients presenting with a delay more than three weeks from time of injury (n=15) and patients with clinical notes missing (n=6) were excluded from data analysis.

Data was collected and entered utilising a double entry method thereby reducing entry error[32]. Epidata and STATA statistical software was used.

## **Results**

### **(Image 1)**

#### **“Disc at risk” cases**

Nineteen patients (21%) had a perceived “disc at risk” based on uncontained, posteriorly herniated intervertebral disc based on independent, blinded assessment by both radiologists and Orthopaedic surgeons.

Of these, 6 had anterior discectomy and reduction performed primarily. Four of these were operated upon due to the surgeon recognising MRI features of a disc lesion. One was done due to the surgeon finding the patient to be neurologically intact thus being concerned over the possibility of neurological deterioration and one patient for an undocumented reason.

The remaining 13 patients had an attempted closed reduction despite the presence of the “disc at risk” on MRI. Six (46%) of these failed to reduce, at which point, attempts were aborted in favour of open reduction. There was no secondary cord injury in any of these patients.

### **(Image 2)**

When assessing neurological status against the management chosen, there was a strong correlation between initial neurological impairment, and the likelihood of the surgeon initially choosing closed reduction. Of the 9 patients that were neurologically complete (ASIA A), 7 had attempted closed reduction. The 7 that were neurologically incomplete (ASIA B/C/D), 5 had attempted closed reduction. The 3 patients who were neurologically intact, two had initial open discectomy and reduction.

#### **Neurological deterioration**

Of the 89 patients included in total data analysis (early presenting cases/with notes available), fifty four had initial attempted closed reduction. One patient deteriorated following aborted closed reduction (1.8%), this patient was assessed as motor-sensory complete (ASIA A) prior to reduction. During the attempted reduction the patient lost 2 MRC grades in the C8 myotome (5/5 to 3/5). This patient had a unifacet dislocation and did not have agreed features of a ‘disc at risk’.

## **Discussion**

With evolving evidence that the risk of secondary cord injury during awake reduction for distraction flexion injuries is low, there has been a resurgence of intent to reduce these injuries closed acutely[6, 16, 17, 33–35].

Fehlings et al reported significant neurological improvement six months following spinal cord injury, if adequately decompressed within 24hrs of injury [10]. This author considers closed reduction, demonstrated with MRI scanning as adequate decompression.

MRI scanning consumes time that could be spent decompressing the cervical spine. The interpretation of the MRI may at times be a source of disagreement and may steer us toward operative reduction, if relying on Radiologists' reporting exclusively[29]. MRI may demonstrate disc lesions well, however the relevance of these disc lesions with regard to risk of secondary cord injury is thrown into question by our findings and others[23]. Despite agreed features of a "disc at risk"; thirteen patients underwent attempted closed reduction and none deteriorated neurologically.

What we may conclude from our findings is that these disc lesions predict a high likelihood of failed closed reduction, 46%, as opposed to 2.6% failed reduction rate in other studies[7].

We also note the high incidence of neurological impairment in this subgroup. Patients with DF injuries and uncontained, herniated discs had 89% incidence of neurological compromise on presentation. This is in keeping with the understanding that the original injury was more severe with greater initial displacement when disc lesions are present. This finding is in keeping with recent level 3 evidence linking poorer neurological outcomes with increasing stage of DF injuries[14].

Our surgeons' choice to attempt closed reduction initially is influenced greatly by presence of initial neurology and far less so by the presence of a "disc at risk" lesion. The principle of continued compression in an injured swelling cord steers our surgeons to choose early closed reduction. Closed reduction is performed preferentially initially in the emergency room as described above. The need to perform MRI prior to reduction is now in question and may be best performed following reduction to prove decompression[10].

In light of recent evidence promoting early decompression and the findings of this work we have amended our MRI policy. Performing MRI initially in the acute injury may only be done should it not delay the reduction. Neurological

status is an important factor to be considered, severely neurologically impaired (Asia A) patients have the least to lose and the most to gain whilst patients who have no neurological impairment have got the most to lose and the least again from early closed reduction without MRI imaging[11]. The goal being early reduction as suggested by level III evidence guidelines [36], within 24 hours of cord injury.

University of Cape Town

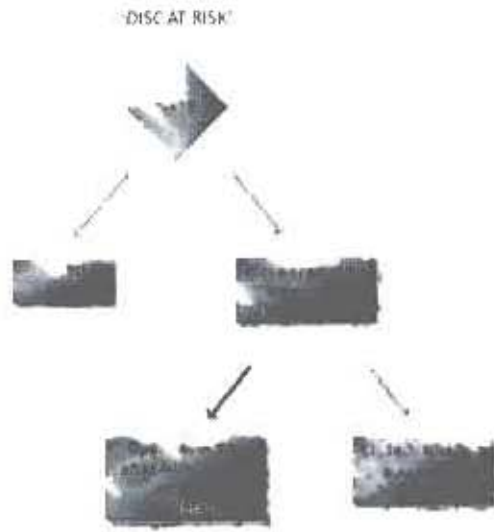
## References

1. Brooke WS (1944) Complete transverse cervical myelitis caused by traumatic herniation of an ossified nucleus pulposus. *J Am Med Assoc* 125:117–120.
2. Eismont FJ, Arena MJ, Green BA, et al. (1991) Extrusion of an intervertebral disc associated with traumatic subluxation or dislocation of cervical facets . Case report Traumatic of an Intervertebral Subluxation Disc Associated of Cervical with Facets or Dislocation of five. *jbjs,am* 73:1555–1560.
3. Berrington N, Staden J., Willers J, van der westerhuizen J (1993) Cervical intervertebral disc prolapse associated with traumatic facet dislocations. *Surg Neurol* 40:395–399.
4. Olerud C, Jónsson H (1991) Compression of the cervical spine cord after reduction of fracture dislocations. Report of 2 cases. *Acta Orthop Scand* 62:599–601.
5. Mahale Y, Silver J, Henderson N (1993) Neurological complications of the reduction of cervical spine dislocations. *jbjs,br* 75:403–9.
6. Lee A s., Maclean JCB, Newton DA (1994) Rapid Traction for reduction of cervical spine dislocations. *jbjs,br* 76-B:352–6.
7. Grant G a, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg* 90:13–8.
8. Fehlings MG, Perrin RG (2006) The timing of surgical intervention in the treatment of spinal cord injury: a systematic review of recent clinical evidence. *Spine (Phila Pa 1976)* 31:S28–35; discussion S36. doi: 10.1097/01.brs.0000217973.11402.7f
9. Tarlov IM (1954) Spinal cord compression studies III. Time limits for recovery after gradual compression in dogs. *Neurol Psychiatry* 71:588–597.
10. Fehlings MG, Vaccaro A, Wilson JR, et al. (2012) Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One* 7:e32037. doi: 10.1371/journal.pone.0032037
11. Hart RA, Vaccaro AR, Nachwalter RS (2002) Controversies in Spine Cervical Facet Dislocation : When Is Magnetic Resonance Imaging Indicated ? *Spine (Phila Pa 1976)* 27:116–118.
12. Grauer JN, Vaccaro AR, Lee JY, et al. (2009) The timing and influence of MRI on the management of patients with cervical facet dislocations remains highly variable: a survey of members of the Spine Trauma Study Group. *J Spinal Disord Tech* 22:96–9.
13. Carlson GD, Gorden CD, Oliff HS, et al. (2003) Sustained Spinal Cord Compression Part I: Time-Dependent Effect on Long-Term Pathophysiology. *J Bone Jt Surg* 85:86–94.
14. Wilson JR, Vaccaro A, Harrop JS, et al. (2013) The impact of facet dislocation on clinical outcomes after cervical spinal cord injury: results of a multicenter North American prospective cohort study. *Spine (Phila Pa 1976)* 38:97–103. doi: 10.1097/BRS.0b013e31826e2b91

15. Allan BL, Ferguson RONL, Lehmann T, O'Brien RP (1982) A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine (Phila Pa 1976)* 1:1–27.
16. Vaccaro a R, Falatyn SP, Flanders a E, et al. (1999) Magnetic resonance evaluation of the intervertebral disc, spinal ligaments, and spinal cord before and after closed traction reduction of cervical spine dislocations. *Spine (Phila Pa 1976)* 24:1210–7.
17. Rizzolo SJ, Piazza MR, Cotler JM, balderston RA, Shaefer D FA (1991) Rizzolo SJ, Piazza MR, Cotler JM, et al. Intervertebral disc injury complicat- ing cervical spine trauma. *Spine* 1991;16S:187–9. *Spine (Phila Pa 1976)* 16:187–189.
18. Tator C, Fehlings M (1991) Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. *J Neurosurg* 75:15–26.
19. Dvorak MF, Fisher CG, Fehlings MG, et al. (2007) The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. *Spine (Phila Pa 1976)* 32:2620–9. doi: 10.1097/BRS.0b013e318158ce16
20. Vaccaro AR, Madigan L, Schweitzer ME, et al. (2001) Magnetic Resonance Imaging Analysis of Soft Tissue Disruption After Flexion-Distraction Injuries of the Subaxial Cervical Spine. *Spine (Phila Pa 1976)* 26:1866–1872.
21. Silberstein M, Tress BM, Hennessy O (1992) Prediction of neurologic outcome in acute spinal cord injury: the role of CT and MR. *Am J Neuroradiol* 13:1597–1608.
22. Flanders AE, Schaefer DM, Doan HT, et al. (1990) Acute cervical spine trauma: correlation of MR imaging findings with degree of neurologic deficit. *Radiology* 177:25–33.
23. Benzel EC, Hart BL, Ball P a, et al. (1996) Magnetic resonance imaging for the evaluation of patients with occult cervical spine injury. *J Neurosurg* 85:824–9. doi: 10.3171/jns.1996.85.5.0824
24. Kwon BK, Vaccaro AR, Grauer JN, et al. (2006) Subaxial cervical spine trauma. *J Am Acad Orthop Surg* 14:78–89.
25. Bohlman HH (1979) Acute fractures and dislocations of the cervical spine. An analysis of three hundred hospitalized patients and review of the literature. *jbjs,am* 1119–1142.
26. Storm M, Surgery O, Dunn R, et al. (2007) Management of unilateral cervical facet dislocations – a review of 49 cases. *SAOJ* 14–21.
27. Toit AB, Dunn R, Town C (2008) Bifacet dislocations of cervical spine : acute management and outcome. *SAOJ III*:30–36.
28. Ouff HS, Pillai JAYJ, Lamanna JC (2003) Sustained spinal cord compression. 85:
29. Fleming M, Westgarth-Taylor T, Candy S, Dunn R (2013) Inter-observer reliability in determining the presence of hazardous disc disruption in flexion distraction injuries of the C-spine- an MRI study. *Bone Jt J Orthop Proceedings Suppl* 95-B:26.

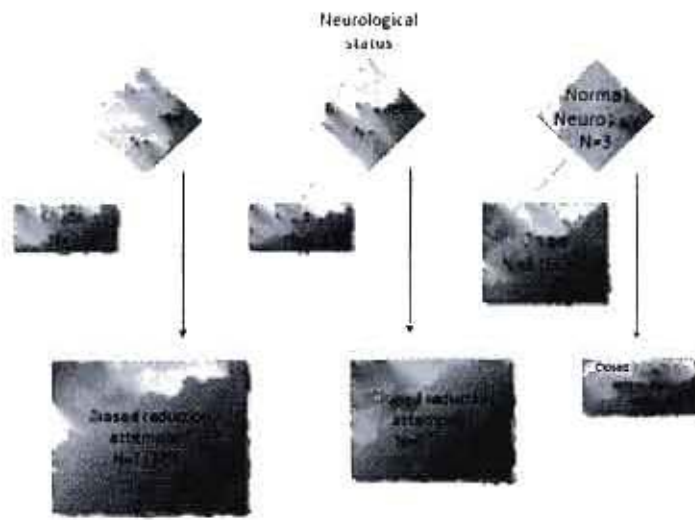
30. Kwon BK, Beiner J, Grauer JN, Albert TJ (2003) Anterior/posterior operative reduction of cervical spine dislocation: techniques and literature review. *Curr Opin Orthop* 14:193–199. doi: 10.1097/00001433-200306000-00012
31. Wiseman DB, Bellabarba C, Mirza SK, Chapman J (2003) Anterior versus posterior surgical treatment for traumatic cervical spine dislocation. *Curr Opin Orthop* 14:174–181. doi: 10.1097/00001433-200306000-00009
32. Gliklich dreyer (2010) Data Collection and Quality Assurance. Agency for Healthcare Research and Quality (US)
33. Grant GA, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg Spine* 90:13–18. doi: 10.3171/spi.1999.90.1.0013
34. Rizzolo SJ, Piazza MR, Cotler JM, et al. (1991) Intervertebral Disc Injury Complicating Cervical Spine Trauma. *Spine (Phila. Pa. 1976)*. 16:
35. Cotler JM, Herbison GJ, Nasuti JF, et al. (1993) Closed reduction of traumatic cervical spine dislocation using traction weights up to 140 pounds. *Spine (Phila Pa 1976)* 18:386–90.
36. Hadley MN, Walters BC (2013) Introduction to the Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries. *Neurosurgery* 72 Suppl 2:5–16. doi: 10.1227/NEU.0b013e3182773549
37. Reynolds-Haertle RA, McBride R (1992) Single vs. Double data entry in CAST. *Control Clin Trials* 13:487–494. doi: [http://dx.doi.org/10.1016/0197-2456\(92\)90205-E](http://dx.doi.org/10.1016/0197-2456(92)90205-E)
38. Kilem Gwet, Gwet K (2002) Inter-Rater Reliability: Dependency on Trait Prevalence and Marginal Homogeneity. *Stat Methods Inter-Rater Reliab Assess* 2:1 – 10.
39. Doran SE, Papadopoulos SM, Ducker TB, Lillehei KO (1993) Magnetic resonance imaging documentation of coexistent traumatic locked facets of the cervical spine and disc herniation. *J Neurosurg* 79:341–5. doi: 10.3171/jns.1993.79.3.0341

Image 1



University of Cape Town

Image 2



**Co-Authors**

Professor Robert Dunn

Dr Tracy Westgarth-Taylor

Dr Sally Candie

**Contributors**

Gen Chang –clerical work

Henri Carrara for initial advice on Statistical methods

University of Cape Town

## Instructions for authors European Spine Journal

### Original Articles

should have no more than 2,500 words with an abstract of 150 words and 25 references

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, telephone and fax numbers of the corresponding author

### Abstract

Please provide a structured abstract of 150 to 250 words which should be divided into the following sections:

- Purpose (stating the main purposes and research question)
- Methods
- Results
- Conclusions

### Keywords

Please provide 4 to 6 keywords which can be used for indexing purposes.

### Please note:

The maximum number of authors is limited to six.

### Text Formatting

Manuscripts should be submitted in Word.

- Use a normal, plain font (e.g., 10-point Times Roman) for text.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Manuscripts with mathematical content can also be submitted in LaTeX.

- LaTeX macro package (zip, 182 kB)

### Headings

Please use no more than three levels of displayed headings.

### Abbreviations

Abbreviations should be defined at first mention and used consistently thereafter.

### Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols.

Always use footnotes instead of endnotes.

## Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section before the reference list. The names of funding organizations should be written in full.

## Citation

Reference citations in the text should be identified by numbers in square brackets.

Some examples:

1. Negotiation research spans many disciplines [3].
2. This result was later contradicted by Becker and Seligman [5].
3. This effect has been widely studied [1-3, 7].

## Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

### Artwork and Illustrations Guidelines

For the best quality final product, it is highly recommended that you submit all of your artwork – photographs, line drawings, etc. – in an electronic format. Your art will then be produced to the highest standards with the greatest accuracy to detail. The published work will directly reflect the quality of the artwork provided.

## Electronic Figure Submission

- Supply all figures electronically.
- Indicate what graphics program was used to create the artwork.
- For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MS Office files are also acceptable.
- Vector graphics containing fonts must have the fonts embedded in the files.
- Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.
  - Authors must indicate whether or not they have a financial relationship with the organization that sponsored the research. They should also state that they have full control of all primary data and that they agree to allow the journal to review their data if requested.
  - Therefore the manuscript must be accompanied by the "Conflict of Interest Disclosure Form". To download this form, please follow the hyperlink on the right.

# Appendix

University of Cape Town

# Supporting paper

University of Cape Town

**Interrater reliability assessment of MRI features identifying hazardous disc disruption on pre-reduction MRI in distractive-flexion cervical spine injuries.**

Dr M A Fleming, Dr T Westgarth-Taylor, H Carrera, Dr S Candy, Professor R Dunn

Groote Schuur Hospital

University of Cape Town

University of Cape Town

**Study design:**

Retrospective blinded comparative review

**Summary of background data:**

Closed reduction of Distraction Flexion (DF) injuries has been associated with secondary cord injury in a small number of published reports. Although the risk of this occurring during awake reduction is recognised to be low, the consequence of this complication is devastating. MRI has been used to identify disc lesions that may pose risk during closed reduction. Use of MRI prior to reduction is controversial as it may over report injury and delay cord decompression. In addition, MRI interpretation in this regard is variable.

**Aim:**

This study assessed the interrater reliability of MRI assessment of intervertebral disc lesions by radiologists and Orthopaedic surgeons. The most reliable MRI features of intervertebral disc lesions are identified for future use.

**Methods:**

Pre-reduction MRI scans of 110 consecutive DF injuries were reviewed independently by a Radiology and an Orthopaedic Surgical team. All cases were managed at a single tertiary referral unit over a 10 year period. Variables included for assessment were: disc herniation (posterior, superior), disc disruption, posterior longitudinal ligament disruption and disc containment. A double data entry method was used. Cohen's Kappa value was used to determine Interrater reliability.

**Results:**

Perfect agreement was never achieved between the two teams. The variables that had the highest Interrater agreement were posterior disc prolapse and impression of containment. When disagreement occurred, the Radiologist team would tend to define the lesions as more severe than the Orthopaedic team.

**Conclusion:**

MRI assessment of disc lesions carries moderate to fair interrater reliability at best. We conclude that the treating surgeon should review scan images personally prior to choosing a treatment algorithm, not relying solely on a written report. We identify that posterior herniation and disc containment carry the highest interrater reliability when identifying these lesions.

**Keywords:**

Intervertebral disc prolapse, MRI interrater reliability, secondary cord injury, distraction flexion , unifacet dislocation, bifacet dislocation

Eismont et al identified the risk of secondary cord injury in Distractive Flexion (DF) injuries management in 1991[2]. Pre-reduction MRI has been proposed to identify disc injuries that may compress the cord following spinal reduction causing a secondary cord injury. The necessity for pre-reduction MRI has been disputed by some due to accessibility issues and resultant delays. Hart and Vaccaro[11] debate the issue where protagonists argue that MRI will identify patients requiring open discectomy prior to reduction as opposed to those that argue that the clinical risk of awake closed reduction is too small to justify MRI related delays to closed reduction and thus indirect decompression. In many countries, MRI access is limited due to distance and cost.

Although the use of sensitive MRI scanning may detect disc pathology, its clinical correlation has been called into question [23]. The interrater reliability of MRI interpretation and reporting been assessed.

Vaccaro et al assessed the timing and influence of MRI on management of DF injuries[12]. They found poor interrater reliability between the surgeons with regard to their use of MRI, as well as treatment modalities between the groups. Orthopaedic surgeons were found to be much more likely to perform closed reduction having seen an MRI.

In addition to inconsistent MRI use, there is frequent difference of opinion between clinical and radiological staff as to the disc status making clinical decision making difficult.

### **Aim**

The aim of this study was to compare the interpretation of pre-reduction MRIs of DF injuries between radiologists and Orthopaedic surgeons and determine consensus regarding the "dangerous disc". A 'dangerous' disc was defined as an uncontained disc, herniating posteriorly, that may be drawn into the spinal canal during closed reduction.

### **Methods**

Following approval by the Institutional Ethic committee (enter number), 110 consecutive cases of DF injuries were identified over a 10 year period from the senior authors database.

MRI Scans (DICOM data) were collated from the hospital archive. The scans included sagittal and axial images in T1, T2 weighted sequences and sagittal STIR sequences.

These scans were independently reviewed by a Radiology and an Orthopaedic team. The radiology team comprised an MRI-trained Senior Radiology Registrar and Head Consultant of Radiology and the other, a Senior Orthopaedic Registrar and senior Spinal Orthopaedic Surgeon.

A meeting was held prior to the start of the scan review, where consensus was achieved on the variables to assess and the definition thereof as below. These two teams were blinded to the clinical scenarios and worked independently.

The data obtained from each team was independently accrued and entered into Epidata statistical software. A double entry system was employed to reduce entry error[37]. All data was categorical except disc heights.

Interrater reliability/agreement was determined using the Cohen Kappa value. This statistical measure is used when comparing two researchers' observations. It is a measure used to determine the agreement whilst excluding the predicted agreement due to chance[38]. Values of 0.6 to 1 show

almost perfect agreement. Values of 0.4-0.6 are considered moderate agreement. 0.2 to 0.4 describe fair agreement. Less than 0.2 indicate poor agreement.

#### **MRI variables assessed**

1. The Posterior longitudinal ligament (PLL) was assessed as disrupted, intact or unsure.
2. Disc heights were measured in millimetres at the midpoint on mid-sagittal view.
3. Disc disruption was measured by the presence of an intervertebral disc signal on T2-weighted images.

We defined lines to indicate disc herniation. These included the Posterior Vertebral Body Line, a vertical line extended cephalad from the posterior body of the vertebral body caudal to the injury.

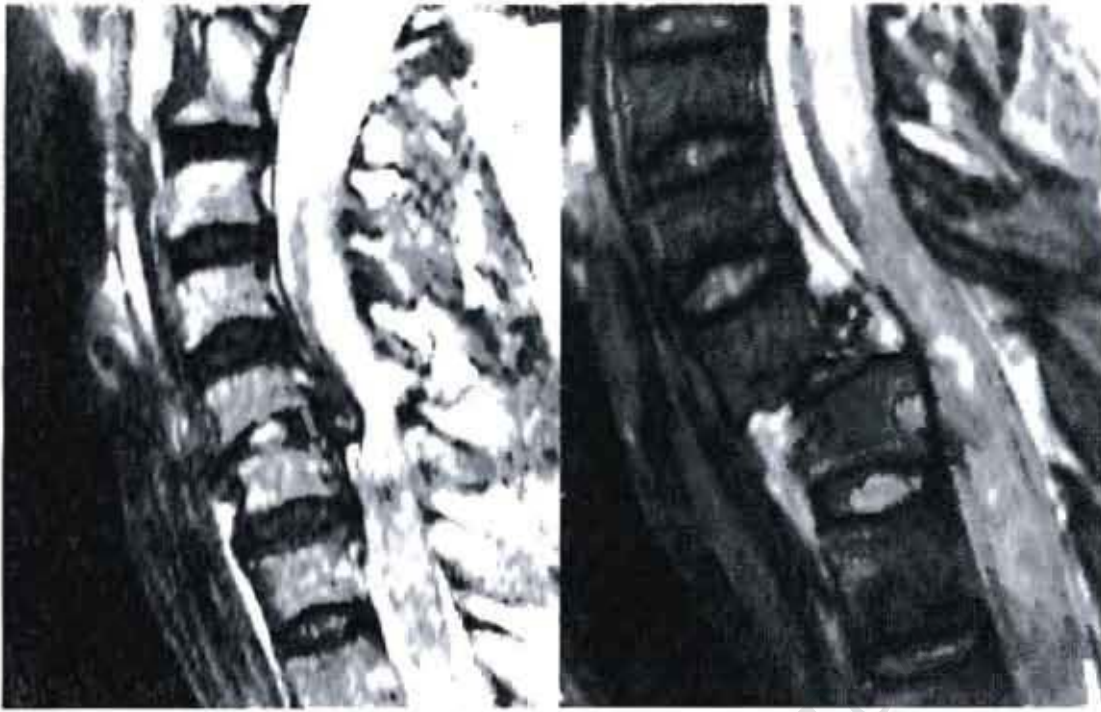


#### **Posterior body line**

The inferior vertebral body line, a horizontal line extended posteriorly from the inferior border of the vertebral body superior to the injured disc.



#### **Inferior body line**



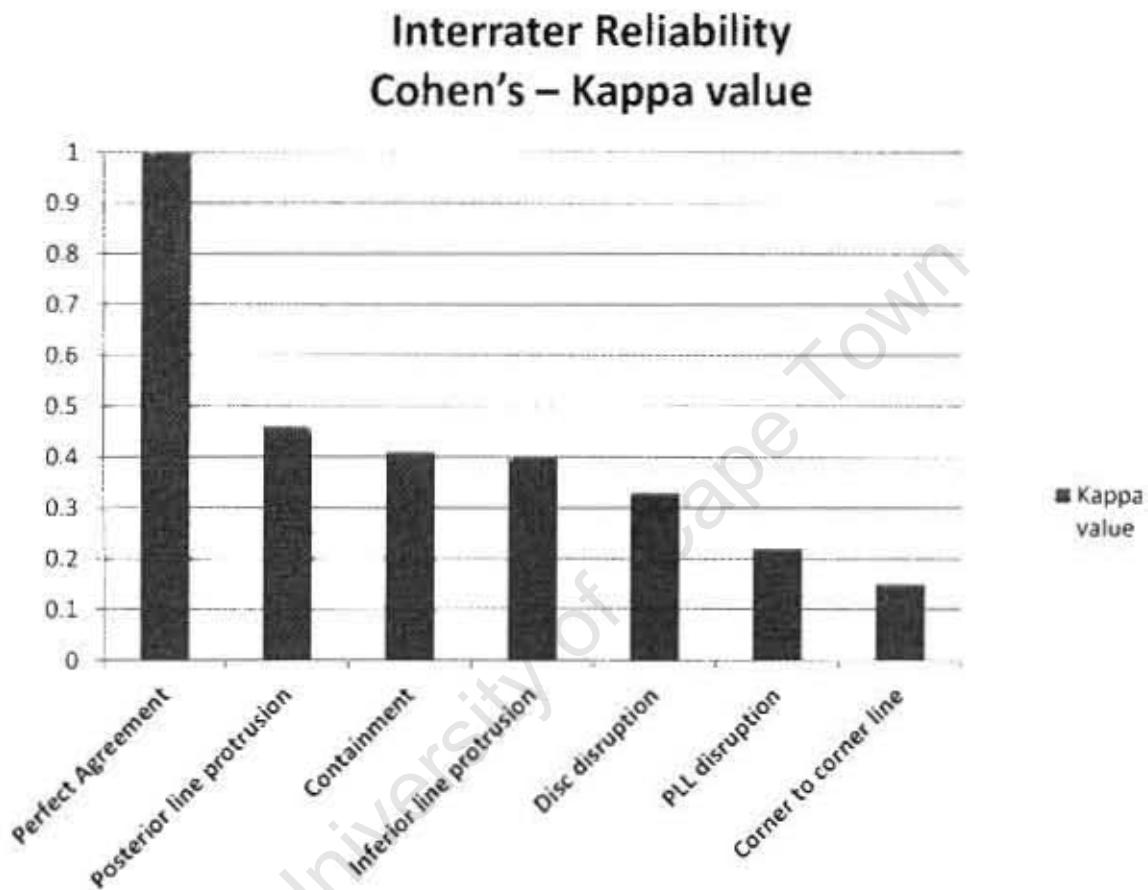
#### Corner to corner line

Corner-to-Corner line, a line from the super-adjacent posterior vertebral body corner to the infero-adjacent posterior body corner spanning the injured posterior disc on the sagittal views. (Figure ?)

We defined Intervertebral Disc Containment as the researchers overall impression score, having seen all the MRI views and sequences and having judged all the parameters already stated relating to disruption, PLL injury and presence of prolapse.

## Results

Graph 1



The interrater agreement was never excellent as determined by the Cohen-Kappa values. There was moderate agreement on the Posterior line, Inferior line and containment assessment, with fair agreement on the rest.

The manner of disagreement was however consistent. Radiologists reported a more injurious appearance, whereas the Orthopaedic team reported a less injurious assessment. The Radiologists were unsure of the appearance more often than the Orthopaedic team.

Posterior Longitudinal Ligament	Orthopaedic Team			
		Intact	Disrupted	Unsure
Radiology Team	Intact	4	20	9
	Disrupted	2	72	3
	Unsure	0	0	0

An example of this pattern is shown above. The large numbers in blue blocks represent the agreed assessment between the Radiologists and Orthopaedic Surgeons, whereas the white blocks represent the disagreements. The horizontal lines represent the Orthopaedic assessment and the vertical the Radiologists. Thus in line one, the Orthopaedic assessment was 34 "intact" cases. The radiologist only agreed in 4 cases, calling 20 of these disrupted and 9 unsure.

The numbers indicating *disagreement* are larger to the right superior area of the matrix. This trend persisted with all variables tested (see attached tables). The weight of *disagreement* may be interpreted as Radiologists assessing an injury to be more injurious than the Orthopaedic team when disagreement was present.

### Discussion

The requirement of pre-reduction MRI in DF injuries has become popularised since early case reports of secondary spine injury inflicted during closed reduction by uncontained cervical discs. Literature highlights these isolated case reports as preventable by identifying uncontained/prolapsed discs with MRI prior to reduction.

The incidence of concerning disc lesions in DF injuries is high, ranging from 15-77% [16][3][39][5] with a markedly increased incidence in locked bifacet injuries [39]. Our agreed incidence of uncontained disc lesions was 63%.

The senior author questions to what extent this expensive and time consuming investigation alters our management acutely. MRI certainly introduces a delay in time to reduction within the confines of our state service. Delay in the cord injured patient may preclude the only chance a patient may have to gain some recovery from severe spinal cord injuries [10]. Until recently this rationale made good clinical sense and was supported in animal studies [9, 13] however evidence is only coming to the fore recently indicating the benefits from reduction within 24 hours [10]. It is with this in mind that early reduction should be prioritised rather than the possible risk of secondary cord injury during reduction, this is subject to the patient being alert and able to communicate during closed reduction.

Although the use of MRI scanning has been employed for many years now there has been no clear guidelines on which disc injuries will cause secondary cord injury during closed reduction. Additionally the low interrater agreement whilst reviewing these scans in this study indicates difficulties in relying on MRI reporting.

The high incidence of these lesions in DF injuries coupled with the very low incidence of secondary cord injury during closed reduction indicates that if we were to act on every MRI scan showing disc prolapse then there would be an incredible cumulative time delay prior to adequate reduction in this patient cohort. This is likely to account for greater cumulative neurologic deficit due to failed rehabilitation/recovery than the incredibly uncommon secondary cord injury.

This forms the first part of a larger study that combines clinical data and decision making to identify whether the presence of these disc lesions altered our clinical approach.

In this study our most reliable interrater variable to ascertain the presence of a hazardous disc lesion was posterior protrusion of the disc and the clinical impression as to whether the disc was contained or not.

There is a possible selection bias in that our cohort had pre-reduction MRI's. There is an unproven chance that if every patient had an MRI there would be a higher incidence of serious pathology since there is a trend amongst surgeons to reduce neurologically complete patients without MRI. This phenomenon adheres to the gambling theory explaining that these patients have the most to gain and the least to lose so require immediate decompression.[11]

The use of Cohen Kappa value has been charged with being a conservative statistical tool [38]but it has become the standard tool amongst orthopaedic literature when comparing two parties agreement.

## **Conclusion**

Interrater agreement of pre-reduction DF injury MRI's in this study was never excellent. The best agreement was found in the assessment of posterior disc prolapse and the researchers' impression of containment. Radiologists tended to interpret a more severe disc injury than Orthopaedic surgeons.

For these reasons we advocate that the treating surgeon personally assess the MRI scan prior to clinical decision making rather than relying on a report.

Now that some consensus has been reached on the MRI features of a perceived "dangerous disc", a second study has been done correlating it with clinical management and outcome.

## References:

1. Brooke WS (1944) Complete transverse cervical myelitis caused by traumatic herniation of an ossified nucleus pulposus. *J Am Med Assoc* 125:117–120.
2. Eismont FJ, Arena MJ, Green BA, et al. (1991) Extrusion of an intervertebral disc associated with traumatic subluxation or dislocation of cervical facets . Case report Traumatic of an Intervertebral Subluxation Disc Associated of Cervical with Facets or Dislocation of five. *jbjs,am* 73:1555–1560.
3. Berrington N, Staden J., Willers J, van der westerhuizen J (1993) Cervical intervertebral disc prolapse associated with traumatic facet dislocations. *Surg Neurol* 40:395–399.
4. Olerud C, Jónsson H (1991) Compression of the cervical spine cord after reduction of fracture dislocations. Report of 2 cases. *Acta Orthop Scand* 62:599–601.
5. Mahale Y, Silver J, Henderson N (1993) Neurological complications of the reduction of cervical spine dislocations. *jbjs,br* 75:403–9.
6. Lee A s., Maclean JCB, Newton DA (1994) Rapid Traction for reduction of cervical spine dislocations. *jbjs,br* 76-B:352–6.
7. Grant G a, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg* 90:13–8.
8. Fehlings MG, Perrin RG (2006) The timing of surgical intervention in the treatment of spinal cord injury: a systematic review of recent clinical evidence. *Spine (Phila Pa 1976)* 31:S28–35; discussion S36. doi: 10.1097/01.brs.0000217973.11402.7f
9. Tarlov IM (1954) Spinal cord compression studies III. Time limits for recovery after gradual compression in dogs. *Neurol Psychiatry* 71:588–597.
10. Fehlings MG, Vaccaro A, Wilson JR, et al. (2012) Early versus delayed decompression for traumatic cervical spinal cord injury: results of the Surgical Timing in Acute Spinal Cord Injury Study (STASCIS). *PLoS One* 7:e32037. doi: 10.1371/journal.pone.0032037
11. Hart RA, Vaccaro AR, Nachwalter RS (2002) Controversies in Spine Cervical Facet Dislocation : When Is Magnetic Resonance Imaging Indicated ? *Spine (Phila Pa 1976)* 27:116–118.
12. Grauer JN, Vaccaro AR, Lee JY, et al. (2009) The timing and influence of MRI on the management of patients with cervical facet dislocations remains highly variable: a survey of members of the Spine Trauma Study Group. *J Spinal Disord Tech* 22:96–9.
13. Carlson GD, Gorden CD, Oliff HS, et al. (2003) Sustained Spinal Cord Compression Part I: Time-Dependent Effect on Long-Term Pathophysiology. *J Bone Jt Surg* 85:86–94.
14. Wilson JR, Vaccaro A, Harrop JS, et al. (2013) The impact of facet dislocation on clinical outcomes after cervical spinal cord injury: results of a multicenter North American prospective cohort study. *Spine (Phila Pa 1976)* 38:97–103. doi: 10.1097/BRS.0b013e31826e2b91

15. Allan BL, Ferguson RONL, Lehmann T, O'brien RP (1982) A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. *Spine (Phila Pa 1976)* 1:1–27.
16. Vaccaro a R, Falatyn SP, Flanders a E, et al. (1999) Magnetic resonance evaluation of the intervertebral disc, spinal ligaments, and spinal cord before and after closed traction reduction of cervical spine dislocations. *Spine (Phila Pa 1976)* 24:1210–7.
17. Rizzolo SJ, Piazza MR, Cotler JM, balderston RA, Shaefer D FA (1991) Rizzolo SJ, Piazza MR, Cotler JM, et al. Intervertebral disc injury complicat- ing cervical spine trauma. *Spine* 1991;16S:187–9. *Spine (Phila Pa 1976)* 16:187–189.
18. Tator C, Fehlings M (1991) Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. *J Neurosurg* 75:15–26.
19. Dvorak MF, Fisher CG, Fehlings MG, et al. (2007) The surgical approach to subaxial cervical spine injuries: an evidence-based algorithm based on the SLIC classification system. *Spine (Phila Pa 1976)* 32:2620–9. doi: 10.1097/BRS.0b013e318158ce16
20. Vaccaro AR, Madigan L, Schweitzer ME, et al. (2001) Magnetic Resonance Imaging Analysis of Soft Tissue Disruption After Flexion-Distraction Injuries of the Subaxial Cervical Spine. *Spine (Phila Pa 1976)* 26:1866–1872.
21. Silberstein M, Tress BM, Hennessy O (1992) Prediction of neurologic outcome in acute spinal cord injury: the role of CT and MR. *Am J Neuroradiol* 13:1597–1608.
22. Flanders AE, Schaefer DM, Doan HT, et al. (1990) Acute cervical spine trauma: correlation of MR imaging findings with degree of neurologic deficit. *Radiology* 177:25–33.
23. Benzel EC, Hart BL, Ball P a, et al. (1996) Magnetic resonance imaging for the evaluation of patients with occult cervical spine injury. *J Neurosurg* 85:824–9. doi: 10.3171/jns.1996.85.5.0824
24. Kwon BK, Vaccaro AR, Grauer JN, et al. (2006) Subaxial cervical spine trauma. *J Am Acad Orthop Surg* 14:78–89.
25. Bohlman HH (1979) Acute fractures and dislocations of the cervical spine. An analysis of three hundred hospitalized patients and review of the literature. *jbjs,am* 1119–1142.
26. Storm M, Surgery O, Dunn R, et al. (2007) Management of unilateral cervical facet dislocations – a review of 49 cases. *SAOJ* 14–21.
27. Toit AB, Dunn R, Town C (2008) Bifacet dislocations of cervical spine : acute management and outcome. *SAOJ* III:30–36.
28. Ouff HS, Pillai JAYJ, Lamanna JC (2003) Sustained spinal cord compression. 85:
29. Fleming M, Westgarth-Taylor T, Candy S, Dunn R (2013) Inter-observer reliability in determining the presence of hazardous disc disruption in flexion distraction injuries of the C-spine- an MRI study. *Bone Jt J Orthop Proceedings* Suppl 95-B:26.

30. Kwon BK, Beiner J, Grauer JN, Albert TJ (2003) Anterior/posterior operative reduction of cervical spine dislocation: techniques and literature review. *Curr Opin Orthop* 14:193–199. doi: 10.1097/00001433-200306000-00012
31. Wiseman DB, Bellabarba C, Mirza SK, Chapman J (2003) Anterior versus posterior surgical treatment for traumatic cervical spine dislocation. *Curr Opin Orthop* 14:174–181. doi: 10.1097/00001433-200306000-00009
32. Gliklich dreyer (2010) Data Collection and Quality Assurance. Agency for Healthcare Research and Quality (US)
33. Grant GA, Mirza SK, Chapman JR, et al. (1999) Risk of early closed reduction in cervical spine subluxation injuries. *J Neurosurg Spine* 90:13–18. doi: 10.3171/spi.1999.90.1.0013
34. Rizzolo SJ, Piazza MR, Cotler JM, et al. (1991) Intervertebral Disc Injury Complicating Cervical Spine Trauma. *Spine (Phila. Pa. 1976)*. 16:
35. Cotler JM, Herbison GJ, Nasuti JF, et al. (1993) Closed reduction of traumatic cervical spine dislocation using traction weights up to 140 pounds. *Spine (Phila Pa 1976)* 18:386–90.
36. Hadley MN, Walters BC (2013) Introduction to the Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries. *Neurosurgery* 72 Suppl 2:5–16. doi: 10.1227/NEU.0b013e3182773549
37. Reynolds-Haertle RA, McBride R (1992) Single vs. Double data entry in CAST. *Control Clin Trials* 13:487–494. doi: [http://dx.doi.org/10.1016/0197-2456\(92\)90205-E](http://dx.doi.org/10.1016/0197-2456(92)90205-E)
38. Kilem Gwet, Gwet K (2002) Inter-Rater Reliability: Dependency on Trait Prevalence and Marginal Homogeneity. *Stat Methods Inter-Rater Reliab Assess* 2:1 – 10.
39. Doran SE, Papadopoulos SM, Ducker TB, Lillehei KO (1993) Magnetic resonance imaging documentation of coexistent traumatic locked facets of the cervical spine and disc herniation. *J Neurosurg* 79:341–5. doi: 10.3171/jns.1993.79.3.0341

#### Attached tables

Posterior line protrusion	Orthopaedic Team			
	Radiology Team	Nil	Protrusion	Unsure
Nil		44	20	0
Protrusion		10	36	0
Unsure		0	0	0

Disc Disruption	Orthopaedic Team			
		Intact	Disrupted	Upsure
	Intact	4	13	1
	Disrupted	0	91	1
	Upsure	0	0	0

University of Cape Town

Disc containment	Orthopaedic Team			
Radiology Team		Contained	Uncontained	Unsure
	Contained	14	15	4
	Uncontained	3	69	5
	Unsure	0	0	0

Corner to Corner Line	Orthopaedic Team			
Radiology Team		Nil	Protrusion	Unsure
	Nil	2	15	0
	Protrusion	4	93	0
	Unsure	0	0	0

University of Cape Town

Inferior line protrusion	Orthopaedic Team			
	Nil	Protrusion	Unsure	
Nil	10	20	0	
Protrusion	1	79	0	
Unsure	0	0	0	

University of Cape Town

# **Ethics approval letter**

University of Cape Town

FHS016: Annual Progress Report / Renewal

HREC office use only (FWA0001837; IRB0001938)  
This serves as notification of annual approval, including any documentation described below.

<input checked="" type="checkbox"/> Approved	Annual progress report	Approved or latest renewal date	5/02/2011
<input type="checkbox"/> Not approved	See attached comments		
Signature: Chairperson of the HREC		signature removed	Date signed: 17/7/2013
Comments to PI from the HREC		HUMAN RESEARCH ETHICS COMMITTEE 18 JUL 2013 FACULTY OF HEALTH SCIENCES UNIVERSITY OF CAPE TOWN	
Principal Investigator to complete the following:			
1. Protocol Information			
Date form:	16-7-13		
HREC REF Number	091/2011	Current Ethics Approval was granted until	18/6/2012
Protocol title	The impact of... under... management... is... of... brain... areas		
Protocol number (if applicable)			
Are there any sub-studies linked to this study?	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No		
If yes could you please provide the HREC Ref # for all sub-studies? Note: A separate FHS016 must be submitted for each sub-study.			
Principal Investigator	Dr. M. Fleming		
Department / Office Internal Mail Address	... ..		
1.1 Does this protocol receive US Federal funding?	<input type="checkbox"/> Yes	<input checked="" type="checkbox"/> No	
1.2 Does the study require All committee approval?	<input checked="" type="checkbox"/> Yes	<input type="checkbox"/> No	





24 February 2011

HREC REF: 091/2011

**Prof R Dunn**  
Orthopaedic Surgery  
H49, OHB

Dear Prof Dunn

**PROJECT TITLE: THE IMPACT PRE-INTERVENTION MRI HAS ON MANAGEMENT OF CERVICAL SPINE DISTRACTION-FLEXION INJURIES (FACET DISLOCATION) - A RETROSPECTIVE REVIEW OF 170 CASES**

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has formally approved the above-mentioned study.

**Approval is granted for one year till the 30<sup>th</sup> February 2012**

Please submit a progress form, using the standardised Annual Report Form if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.  
(Forms can be found on our website: [www.uct.ac.za/research/humanethics/forms](http://www.uct.ac.za/research/humanethics/forms))

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

**Please quote the HREC REF in all your correspondence.**

Yours sincerely,

signature removed

**PROFESSOR M BLOCKMAN**  
**CHAIRPERSON, THE HUMAN ETHICS**

Federal Wide Assurance Number: FW00001617

Institutional Review Board (IRB) number: (M000019)H

This serves to confirm that the University of Cape Town Human Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH-GCP) and Declaration of Helsinki guidelines.

The Human Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6, Note for Guidance on Good Clinical Practice (GMP)(ICH/135/95) and FDA Code Federal Regulation Part 312.56 and 312.

—