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Traumatic facet joint dislocations in Western Australia

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TRAUMATIC FACET JOINT DISLOCATIONS IN WESTERN AUSTRALIA

DR VIVEK ERANKI

MASTERS MEDICINE AND SURGERY

2015

SCHOOL OF MEDICINE SYDNEY

**PROJECT
SUPERVISORS:**

Dr David Dillon

Professor George L. Mendz

RESEARCH DISSERTATION DECLARATION:

I, Vivek Eranki, principal researcher confirm that the content of this research dissertation is my own work and contains no material which has been accepted for the award of any other degree or diploma in any university or other institution.

To the best of my knowledge, the thesis contains no material previously published or written by another person.

The supervisors, *Mr David Dillon* and *Professor George Mendz* kindly provided their time in editing and clinical reasoning throughout the course of the Master's research project.

The development of this research dissertation, its writing, submitted journal article have been the work of the principal researcher, Vivek Eranki.

Signed: _Vivek Eranki_

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Traumatic Facet Joint Dislocations in Western Australia

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The research has been published in the European Spine Journal on October 26th 2014. Publication is attached with this dissertation in a PDF format.

(Journal article is attached in Appendix 2)

List of Tables, Graphs and Figures

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List of Abbreviations

ASIA   American Spinal Injury Association

AIS   ASIA Impairment Scale

AMS   ASIA Motor Score

CT   Computed Tomography

MRI   Magnetic Resonance Imaging

MUA   Manipulation Under Anesthesia

RPH   Royal Perth Hospital

STASCIS Surgical Timing in Acute Spinal Cord Injury Study

WA   Western Australia

Abstract

Background: Early enlocation of dislocated cervical facets is important to minimize long term neurological deficit.

Aims: To assess impact of delay in enlocation on clinical outcome in patients with facet dislocations and propose a scheme for enlocation for rural patients who usually have longer enlocation times.

Methods: A retrospective analysis of consecutive cervical spine facet joint dislocations presenting to Royal Perth Hospital from January 2009 to November 2012 was carried out to assess factors affecting final neurological outcome (ASIA score) at discharge.

Results: A total of 51 patients were included in the study. More patients in the urban group had higher final ASIA score than in the rural group. Strong correlation in both the urban and rural populations were found between enlocation time final ASIA score

Conclusion: Enlocation through closed reduction should be done as early as possible at local centres for awake rural patients having dislocated cervical facets.

Chapter 1

Introduction

Cervical spine injury is not uncommon after blunt trauma and is associated with devastating neurological deficits depending on the severity of injury[1]. Facet dislocation is a form of flexion-distraction injury to cervical spine resulting in misalignment of vertebral bodies and cord compression. Neurological deficits are seen depending on degree of cord compression, narrowing of vertebral canal, and associated other injuries like facet fractures, hematomas, and spinal cord oedema. Restoring the alignment of vertebral bodies by enlocation of dislocated facets and decompression of spinal cord is of paramount importance in minimizing permanent neurological deficits. Both animal (canine) and retrospective clinical studies have demonstrated that enlocation must be performed as early as possible to achieve better clinical outcomes [2, 3]. Enlocation can be performed by closed reduction and open reduction. Open reduction is done mostly in urban specialized spinal trauma center's. While closed reduction is usually carried out by Emergency Department medical staff under Orthopaedic guidance. Appropriate reduction of the facet joint prevents any further worsening of the deficit caused by pressure effects. Once the facet joint is enlocated, the patient can undergo definitive fixation. Rehabilitation is commenced after fixation of the appropriate spinal levels.

Western Australia (WA) is Australia's largest state by land and Perth is its largest population centre. Royal Perth Hospital (RPH) is the major spinal trauma centre and patients with cervical facets dislocation from all over the state are transferred here for enlocation and further management. As such with no emergency spinal trauma services undertaken in any other hospitals in the state there is an inevitable delay in management of patients being transferred from the non metropolitan area This results in considerable delay in enlocation and decompression of spinal cord for rural patients who require much time in transporting them from local hospitals to RPH.As early enlocation is very important, these rural patients have worse clinical outcomes than their urban counterparts.

From a logistical viewpoint, a patient who suffers a spinal injury in a rural area has to wait for ambulance services to attend to the scene of trauma and transport the patient to the rural hospital. Transport from the rural centre to RPH itself takes several hours. During this time, the secondary injury to the spinal cord can be progressing and the window of opportunity available for recovery diminishing.

Due to the disruption of the soft tissue and bony stabilisers of the spinal cord, dislocated facet joints are very vulnerable. Patient transfers and turbulence experienced amid transfer could potentially worsen the primary injury to the spinal cord. A spine that is reduced and immobilised by an appropriate collar has much of its stability return and would be much safer to transfer. This early reduction would also minimise the impact of the secondary injury, thus avoiding unnecessary neurological decline.

As things stand currently, there is existing infrastructure and appropriate training in rural WA to diagnose and reduce facet joint dislocations within the rural centres. If there were a protocol in place to reduce these dislocations in rural hospitals, there would be a potential to deliver the same care to the rural members of the community as their urban counterparts.

To propose such a protocol, data on the outcomes of facet joint dislocations in WA is required to identify cohorts of population who have a confirmed disadvantage. Even though WA is unique in its economies of distance, there is currently an evidence gap in treatment protocols and outcomes of facet joint dislocations. There is currently no literature available quantifying or examining the outcomes of this injury from the developed world. There has not been a protocol for enlocation of these injuries in current literature (worldwide). The data from this study would help us identify cohorts who are suffering a poorer outcome and thus enable us to propose a protocol for enlocation of these spines such that their outcomes are on par with the best practice.

Although early enlocation is recommended, however currently there is no evidence on the timeframe for decompression via enlocation of facet joint dislocations. Currently enlocation via closed reduction is not being performed at rural health centres of WA for unknown reasons and all patients are transferred to RPH for treatment after initial

management. This creates a system where rural patients with cervical spine dislocations have delayed decompression of the cervical spine.

Aims and objectives:

As early enlocation is important in minimizing neurological deficits after cervical facet dislocations and rural patients usually have longer enlocation times, I sought to do a retrospective analysis of both rural and urban patients with traumatic facet dislocations presenting to Royal Perth Hospital in a 3-year period (2009-2012). The aims and objectives of my research were following:

1. To assess the impact of different variables including enlocation time on neurological outcome at discharge in both rural and urban patients with traumatic cervical facet dislocations.
2. To review the safety and efficacy of enlocation via closed reduction.
3. To propose a protocol for enlocation of facet joints based on enlocation time and distance from RPH to appropriate large rural centres.

Research Questions:

1. Do rural patients with facet dislocations have higher enlocation times than their urban counterparts?
2. Do rural patients with facet dislocations have worse neurological outcome than their urban counterparts?
3. What is the impact of enlocation times and distance from rural centre to RPH on neurological outcome at discharge?
4. What is the safety and efficacy of enlocation via closed reduction?

Study Design:

It was a retrospective observational study involving consecutive patients of cervical facet dislocations who presented to RPH from January 2009 to December 2012.

Chapter 2

Literature Review

Cervical spine injuries are usually seen in patients with trauma to face or head or in those patients who become unconscious following blunt trauma. Although their prevalence may be low, but if present they are associated with devastating clinical outcomes. Hackl W et al reported an incidence of 6.7% for cervical spine injuries following facial trauma (28). Milby AH et pooled data from 65 publications (281,864 patients) to determine the prevalence of cervical spine injury following blunt trauma (26). The prevalence of cervical spine injury in all trauma patients, alert patients only, and clinically unavailable patients was 3.7%, 2.8%, and 7.7% respectively. Overall 41.9% patients were clinically unstable. Goldberg W et al (29) prospectively evaluated for cervical spine injury in blunt trauma patients at 21 centres. Of 34,069 patients with blunt trauma, 2.4% patients had cervical spine injuries. The second cervical vertebra was the most common level of injury (24.0% fractures) while 39.3% fractures occurred in the 2 lowest cervical vertebrae (C6 and C7). In another study involving blunt trauma patients, prevalence of cervical spine injury was 2.2% but majority of these injuries (67.9%) were clinically significant(6). A recent large Chinese epidemiological study has shown that of all the traumatic injuries to spinal cord, cervical spinal injuries carry worst prognosis and highest medical cost (7).

Facet dislocations are flexion-distraction injuries to cervical spine due to high energy trauma. They are often associated with ligaments' disruption, facet fractures and fracture of vertebral bodies(8). Facet dislocations encompass a spectrum of injuries which include facet subluxation, unilateral facet dislocation, bilateral facet dislocation, and complete dislocation. Neurological deficit after a facet joint dislocation is caused by primary and secondary injury. The primary injury is caused by the dislocation itself and cannot be avoided or reversed. The secondary injury is caused by the pressure effect. There are several aetiologies of this, most notable being the bony and soft tissue structures, haematomas and spinal cord oedema. The neurological deficit caused by the secondary injury has been shown to be time dependent. For obvious ethical reasons, there is no human study assessing the effect of pressure on the spine cord. Animal

studies however have shown that the neurological deficit from the pressure effect is reversible if it is addressed within 1 hour. Between 3-6 hours, some clinical neurological recovery is possible and after 24 hours, the benefits plateau. These studies also demonstrated that the size of the lesion was another key factor in determining the neurological decline (2, 9).

A recent Canadian prospective cohort study compared neurological outcomes after early (<24 hours) and late (>24 hours) decompression surgery following spinal cord trauma. A significantly greater proportion had at least a two-grade American Spinal Injury Association (ASIA) Impairment Scale (AIS) improvement at discharge in the early-surgery group(3). Surgical Timing in Acute Spinal Cord Injury Study (STASCIS) was a multicentre prospective cohort study comparing outcomes after early (<24 hours) versus delayed (>24 hours) decompression after traumatic cervical spinal cord injury(10). They enrolled 313 patients between 2002 and 2009 at six North American centres. At six-month follow up, 19.8% of patients undergoing early surgery showed a ≥ 2 grade improvement in AIS compared to 8.8% in the late decompression group. After adjusting for preoperative neurological status and steroid administration, the odds of ≥ 2 grade AIS improvement were 2.8 times higher amongst those who underwent early surgery as compared to those who underwent late surgery.After reviewing 19 pre-clinical and 22 clinical studies Furlan JC et al concluded that spinal decompression should be performed no later than 8 to 24 hours after spinal cord injury (11).Early decompression therefore is the key to preventing worsening of the neurological deficit and optimising the outcome after traumatic cervical spinal cord injuries.

A recent cohort study by Wilson JR et al in 2013 has compared long term clinical outcomes between patients with facet dislocations and without facet dislocations after cervical spine injury (6). The primary outcome was change in American Spinal Injury Association (ASIA) motor score (AMS) at 1-year follow-up. Patients with facet dislocations had more baseline neurologic deficits than those without facet dislocations. Bilateral facet dislocations resulted in worse baseline clinical parameters than unilateral facet dislocations.At one year follow up, patients with facet dislocation had worse AMS score than those without facet dislocation.

Although time to decompression is very important in predicting neurological recovery, however baseline AIS grade (injury severity) has its own importance. Coleman WP et al (34) have presented a retrospective analysis of 760 patients with traumatic spinal cord injury. Recovery was defined as improvement of at least two grades from AIS at baseline to Modified Benzel Scale at Week 26.AIS Groups C and D had significantly higher recovery rate (84.0%) than Group B (46.6%), which recovered more than Group A (12.8%). In another study age and initial ASIA motor score were significantly associated with neurologic improvement after traumatic cervical facet dislocation(14). In another retrospective study involving 341 patients with traumatic spinal cord injury, 28.3% subjects admitted with AIS grade C walked at discharge as compared to 0.9% subjects with AIS grade A or B injuries. Similarly significantly more subjects admitted with AIS grade D (67.2%) than AIS grade C (28.3%) injuries walked at discharge (15).

Diagnosis of facet dislocation is usually made on plain radiographs or computed tomography (CT) of cervical spine in suspected patients following blunt trauma. CT is better than plain x-ray in diagnosing dislocations and fractures and should be performed if available (6). Magnetic resonance imaging can better visualize the compressive nature of injury, disc herniation, or hematoma, but it is not widely available, especially in rural areas. The aims of treatment in cervical facet dislocation-fracture are to reinstate bony alignment and decompress the area as early as possible. Enlocation of dislocated facets can be done in two ways: closed reduction through in-line axial traction and open reduction followed by internal fixation. In closed reduction, we usually start with a small traction weight and gradually increase it until required alignment has been achieved. After each increment in traction weight, neurological and radiological assessment through serial x-rays is done. Closed reduction for facet dislocation was first described by Walton G in 1893 (37). Tongs for in-line axial traction were introduced by Crutchfield in 1933 (17). Closed reduction can also be performed under anesthesia; this procedure is called manipulation under anesthesia (MUA). Lee AS et in 1994 showed that closed reduction through rapid traction is safer and effective than MUA for dislocated cervical facets (4). Open reduction can be performed by two approaches: Anterior and posterior (19).

Recent guidelines published by the Society of Neurological Surgeons in 2013advocate early closed reduction with craniocervical traction following cervical facet dislocation-fracture injuries in awake patients(20). Once the patient has been stabilized, open reduction-internal fixation can be performed when facilities are available. Authors of these guidelines did not recommend closed reduction in unconscious patients and in patients with additional rostral injury.

Some investigators have suggested for a pre-reduction MRI to look for spinal cord compromise due to disc disruption and herniation as some studies have shown that closed reduction in patients with disc herniation or disruption can lead to worsening of neurological outcomes. In a study by Doran et al in 1993, three out of nine patients developed worsening of neurological outcomes after closed reduction for traumatic locked facets (15). These patients were subsequently found to have disc herniation on MRI. Investigators then changed their treatment protocol and did pre-reduction MRI in subsequent four cases. All patients had post-reduction MRI and frank disc herniation was present in majority of cases. Robertson et al in 1992 presented three cases of facet dislocation that were treated with closed reduction. All of them had disc herniation and developed worsening of neurological outcomes after closed reduction (40). Herniated discs were subsequently removed. Wimberley et al described a case of acute quadriplegia after closed reduction following cervical facet dislocation (41). Post-reduction MRI showed severe spinal stenosis at C5, C6 level as a result of ossification of posterior longitudinal ligament or a large herniated disc. Anterior decompression was performed immediately and patient regained full motor and sensory function. Berrington NR et al in 1993 described four cases of cervical facet dislocation in which patients deteriorated following closed reduction and subsequent imaging studies found an extruded disc as the cause of deterioration (13). Authors concluded that before undergoing either closed reduction or open reduction, MRI should be done to rule out herniated disc or any any space occupying lesion within spinal canal as reduction in the setting of herniated disc can result in further compression injury to spinal cord. In another study published by Hadley et al in 1992, closed reduction was performed in 66 patients of cervical fracture-dislocation. Success rate of closed reduction was 58% and seven patients had neurological deteriorationthat subsequently underwent open

reduction and internal fixation.Of patients who had successful closed reduction, 78% of them had improvement in neurological functions. Internal-fixation and open reduction had a success rate of 83%. However, only 10 patients had significant neurological recovery overall and in these patients time to decompression was more important than the method of decompression (14). Of the 10 patients who made meaningful recoveries after severe initial neurological compromise, all were reduced within 8 hours of injury, 6 patients within 5 hours of injury. Despite seven patients deteriorating during closed reduction (that were subsequently treated with open reduction), authors concluded that the time from injury to decompression after trauma to the cervical cord is important with respect to the potential for neurological recovery. Reduction of facet dislocation injuries should be performed by closed or open means as early as possible after injury, unless contraindicated by the medical condition of the patient.

To date there has not been a single case of permanent neurological deficit reported as a result of closed reduction in awake, alert, and cooperative patients. The reason may be that during closed reduction in awake and cooperative patients, frequent clinical and radiological monitoring is performed and closed reduction is immediately stopped if patient shows signs of further spinal compression. Open reduction is then performed.

Despite these reports of neurological deterioration after closed reduction, there is ample data available from pre-MRI era that strongly supports closed reduction in awake patients with facet fracture-dislocation. A review paper in 2002 studied success and complication rates of closed reduction following facet fracture-dislocations. More than 1200 patients underwent closed reduction and success rate was 80%. The rate of permanent neurological complications was less than 1% (11 out of 1200) and of transient neurological deterioration was 1.6% (26). The transient deficits improved spontaneously, or after reduction of weight, or after open reduction. Of 11 patients who developed permanent neurological deterioration after closed reduction, two had nerve root injuries (27, 28), and two had ascending spinal cord deficits(29, 30). Nature or cause of deterioration was not described for seven patients (31).

It is interesting to note that disc herniation is present in a significant proportion of patients with facet fracture-dislocation. Rizzolo et al studied 55 patients of acute

cervical spine trauma by using MRI. Disc herniation was found in 42% of patients within 72 hours of trauma. Moreover, 80% of patients with bilateral facet dislocations had disc herniation (16). In another study by Schafaer et al, 38% patients with acute cervical spine trauma had disc herniation (33). Many studies have concluded that despite high percentage of patients having concurrent disc herniation and disruption, closed reduction is highly successful in facet fracture-dislocation injuries of cervical spine. Grant et al in 1999 reported an incidence of 22% for cervical disc herniation on post-reduction MRI in patients with cervical injuries (44). In their study, no pre-reduction MRI's were done and success rate of closed reduction was 97.6%. They used plain radiographs for serial assessment after each increment in traction weight. Vaccaroet al in 1999 looked for disc herniation using MRI in 11 awake patients with facet dislocation before and after closed reduction. Before closed reduction, two patients had disc herniation. Nine patients out of eleven had successful closed reduction while 5 patients (56%) had disc herniation after reduction. The difference between pre-reduction and post-reduction disc herniations on MRI was not statistically significant. No patient developed neurological worsening despite increased number of patients with disc herniation after closed reduction (18). Of the two patients had failed closed reduction, one had C5–C6 unilateral facet dislocation treated 4 days after the initial injury, and the other had a C7–T1 bilateral facet dislocation. These two patients underwent open reduction. Neither of these two patients had disc herniation. In another study by Hussain M et al (45) MRI did not change the treatment decision in 50 patients with facet dislocations who presented within four hours of injury. In the study by Rizzolo et al, although disc herniation was very common but no patient deteriorated after attempted closed reduction. Investigators attempted closed reduction only in awake patients (16).

The above discussion entails that although disc herniation is present in about one third to one half of patients with cervical injury, it does not affect outcome after closed reduction. Closed reduction is safe and effective in awake patients for spinal decompression after cervical facet fracture-dislocation. It is interesting to note that Society of Neurological surgeons' 2013 guidelines recommend MRI if closed reduction fails or if patient is unconscious (20). Doing a pre-reduction MRI to assess disc injury in

awake patients will only delay decompression and promote secondary cord injury. Early decompression of spinal cord following cervical fracture-dislocation is the key to better neurological outcomes. Moreover MRI facilities are not available in most rural centres and patients will need to be transported to some MRI facility which will consume precious time.

Closed reduction in most centres is performed under plain radiographical monitoring. Darsaut TE et al performed magnetic resonance imaging guided closed reduction through in-line axial traction in 17 patients of cervical fracture-dislocation. They showed that closed reduction was safe and effective and did not worsen neurological outcomes. Although pre-traction disc disruption was present in majority of patients and 4 patients had posterior disc herniation, but disc elements moved to their normal position after reduction. Traction weight was increased gradually with each increment followed by an MRI (46). Investigators used a specially designed MRI-compatible traction board. However MRI-guided closed reduction is still in research phase and has not been recommended yet.

Chapter 3

Methods

This study involves retrospective review of all consecutive cervical spine facet joint dislocations presenting to RPH between 1st January 2009 to 1st November 2012. All patients were treated with open reduction followed by internal fixation (ORIF). Methylprednisone was not administered because it is not part of treatment protocol at RPH. All patients were evaluated with magnetic resonance imaging of cervical spine before ORIF. After ORIF, only those patients underwent repeat MRI who developed complications.

The patients were identified on the Spinal Surgery Team inpatient list between the aforementioned time period. The data collected was on the patient demographics, age, sex and mechanism of injury. Neurological assessment based on ASIA classification was collected at four distinct times-: at the presentation of the injury, initial presentation to RPH, immediately post surgical reduction and post rehabilitation (final ASIA). Mechanism of injury was determined by the initial RFDS or Ambulance data sheet. Enlocation time was divided into long (>12hrs) and short (<12hrs), with outcomes being divided into good and poor based on final ASIA score. 'Poor' ASIA scores being defined as ASIA A, B or C. 'Favourable' ASIA scores were defined as ASIA D and E.

Using the data, we aimed to identify variables that correlate strongly with the final ASIA score. Since the study uses distinct variables, Spearman correlation coefficient was calculated to determine correlation of final ASIA score with other ordinal or continuous variables. Spearman correlation is a nonparametric measure of statistical dependence between two variables. It assesses how well the relationship between two variables can be described using a monotonic function. Chi-square test for independence and fisher's exact tests were used where appropriate for comparing percentages. The chi-square test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories. Is this difference between the expected and observed due to sampling variation, or is it a real difference. Independent samples Mann-Whitney U test was done

to compare urban and rural patients regarding enlocation time, receiving time, and distance to RPH. All data analysis was conducted using SPSS software version 21.0. P value <0.05 was considered significant.

Results (Submitted Paper)

Introduction

Western Australia (WA) is Australia's largest state by land mass and with an area of 2,645,615km^2. Perth is the largest population centre, but significant number of Perth residents work in the mining industry on a fly-in, fly-out basis. Geographically many of these mining operations are located in remote areas of the state. Australia wide, WA has the highest incidence of spinal injuries occurring outside the metropolitan area and overall the highest incidence at a state level.

Royal Perth Hospital (RPH) provides a statewide spinal trauma service. As such with no emergency spinal trauma services undertaken in any other hospitals in the state there is an inevitable delay in management of patients being transferred from the non metropolitan area. This creates a system where a cohort of patients with cervical spine dislocations have delayed decompression of the cervical spine. Currently there is no evidence on the timeframe for decompression via enlocation of facet joint dislocations.

As there is a significant morbidity associated with facet joint dislocation, this study is designed as a retrospective analysis. Our primary aim is to identify any prejudicial clinical outcomes as a consequence of delay in enlocation. Using this data, we wish to propose a protocol for enlocation of facet joints based on distance from RPH to appropriate large rural centres.

Methods

This study involves retrospective review of all consecutive cervical spine facet joint dislocations presenting to RPH between 1st January 2009 to 1st November 2012. All patients were treated with open reduction followed by internal fixation (ORIF). Methylprednisone was not administered because it is not part of treatment protocol at RPH. All patients were evaluated with magnetic resonance imaging of cervical spine

before ORIF. After ORIF, only those patients underwent repeat MRI who developed complications.

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Using the data, we aimed to identify variables that correlate strongly with the final ASIA score. Spearman correlation coefficient was calculated to determine correlation of final ASIA score with other ordinal or continuous variables. Chi-square test for independence and Fisher's exact tests were used where appropriate for comparing percentages. Independent samples Mann-Whitney U test was done to compare urban and rural patients regarding enlocation time, receiving time, and distance to RPH. All data analysis was conducted using SPSS software version 21.0. P value <0.05 was considered significant.

Results

Between the period of 1st January 2009 to 1st November 2012, a total of 51 patients with traumatic facet joint dislocations were admitted to the RPH. Table 1 summarises the comparison of urban and rural patients regarding demographic features, enlocation time, receiving time, and distance to RPH. As indicated by the significance values, rural patients had statistically larger enlocation time, receiving time, and distance to RPH.

Table1- Demographics of Patients

Table 1	Urban n=23	Rural n=28	P value
Median Age (range)	36 (16-79)	30.5 (18-75)	0.33
M:F (%)	74:26	93:7	0.12
Median distance to RPH in kms (range)	22 (0-85)	981 (129- 2875)	**<0.01**
Median RPH receiving time in hours (range)	3 (1-144)	13 (2-31)	**<0.01**
Median Enlocation time in hours (range)	10.5 (3-288)	27 (4-311)	**0.01**

Overall, for both groups, the most common mechanism of injury was motor vehicle accident. 65% of these MVAs occurred outside the Perth metropolitan area and 75% of injuries took place during daytime. The mechanisms of injury are summarised graph 1.
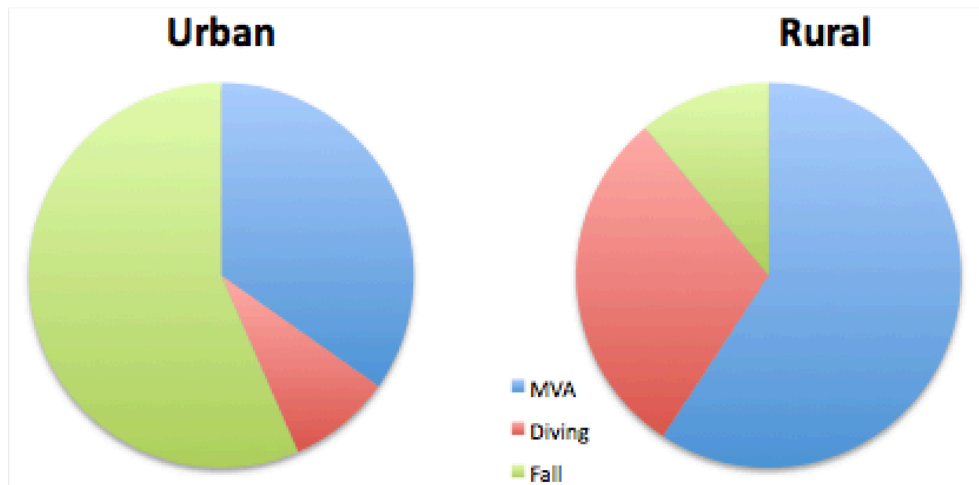
GRAPH 1- Mechanism of Injury

The breakdown of the ASIA scores in the urban and rural groups are tabulated in Table 2. The majority of urban patients had ASIA score E at scene of injury and ended with an ASIA score E. At the site of injury, 56.5% (13/23) of urban patients and 60.7% (17/23) of rural patients had a poor ASIA scores but this difference was not statistically significant (P 0.76). Comparison of final ASIA scores between rural and urban patients

showed that a significantly higher proportion of urban patients achieved good final ASIA scores as compared to rural patients {78.3% (18/23) for urban patients, and 39.3% (11/28) for rural patients, P <0.01). The difference between rural and urban patients regarding final ASIA scores was significant too even after adjusting for ASIA score at injury site (P< 0.01).

**Table 2- Breakdown of ASIA scores: rural patients (Red- poor outcomes, Green-good outcomes)**

URBAN PATIENTS	A	B	C	D	E
Origin	5	2	6	1	9
RPH	6	2	5	3	7
Final	4	1	0	8	10
RURAL PATIENTS	A	B	C	D	E
Origin	12	3	2	6	5
RPH	13	4	1	7	3
Final	10	1	6	6	5

Graph 2 shows the progression in ASIA scores in the rural and urban group. More patients in the urban group had substantial improvements in their ASIA score and a higher final ASIA score. Excluding the patients who went from ASIA A to ASIA A, all other patients had a final ASIA score of D OR E (ie favourable). In the group that ended up with an ASIA score of A, only 1 patient started with a higher score of B. In the rural group, of the patients that ended with an ASIA sore of D, 2 started with an ASIA score of E while the other 2 started with as ASIA D. In the patients that ended up with an

ASIA A, B or C, 3 started at ASIA B and 3 as ASIA A. Final ASIA scores are demonstrated in Graph 3.
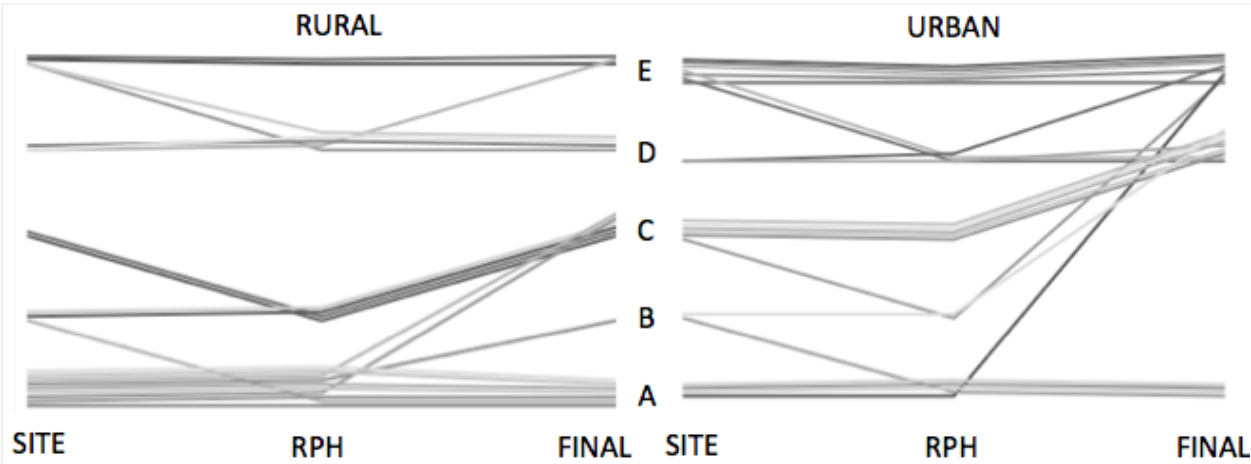
GRAPH 2- Progression of ASIA scores in Rural and Urban groups.
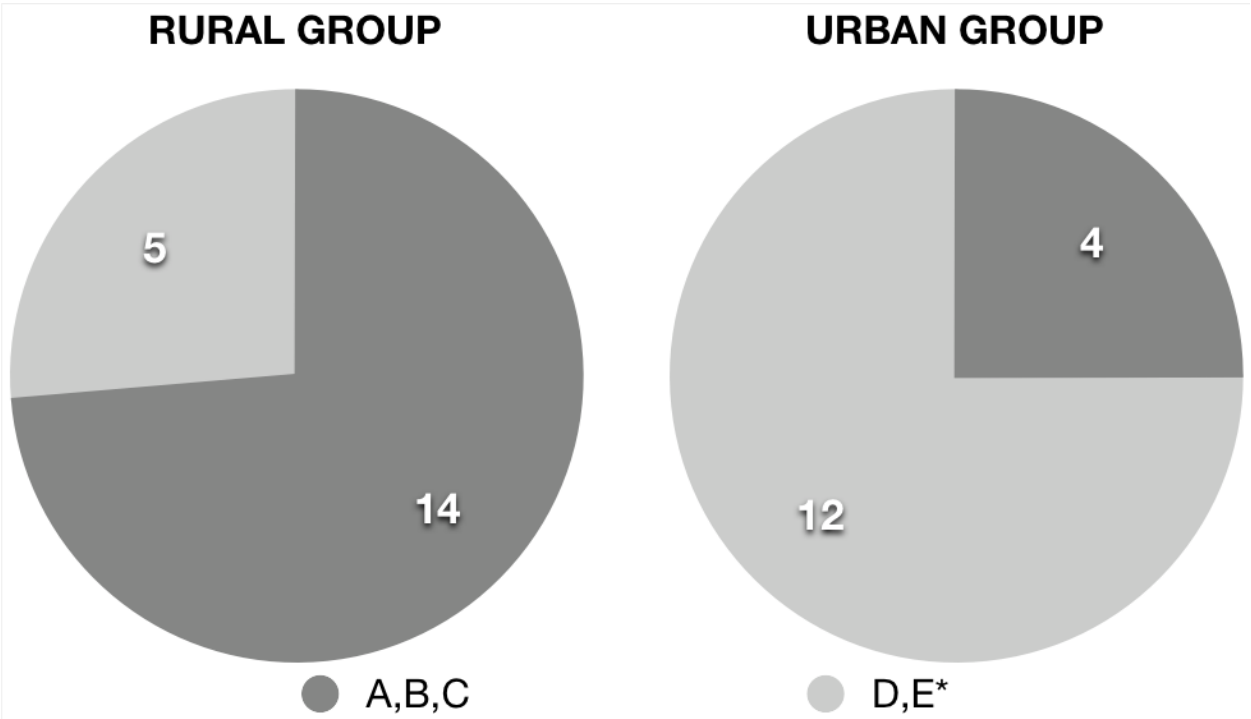
GRAPH 3- Final ASIA score (*excluding patients who were ASIA E throughout)

Table 3 shows correlations of ASIA origin, and ASIA final to different patients' variables and their significance among the urban, rural and whole population. Negative correlation was found between distance to RPH and the final ASIA score in urban, rural and whole population but it was significant only for whole population (P = 0.01). We feel that it is because of small sample size in our study which limits the power to discriminate significant correlations. Among the urban population, strong negative correlations were found between degree of listhesis and ASIA score at origin and final ASIA score. Negative correlation was found between enlocation time and final ASIA score among rural patients and whole population but it was not statistically significant. Similarly a higher proportion of patients with favourable final ASIA score had enlocation time <12 hours as compared to patients with poor final ASIA score (44.8% vs 27.3%) but gain it did not reach statistical significance (P = 0.19) owing to less sample size and power of study. However this difference is clinically significant nevertheless.

Table 3- Correlation

Table 4- Variables	Urban	P value	Rural	P value	Total	P value
Distance to RPH- ASIA Origin	-0.1	0.59	-0.2	0.41	**-0.3**	**0.06**
Distance to RPH- ASIA Final	-0.1	0.71	-0.2	0.41	**-0.4**	**0.01**
ASIA Origin- ASIA Final	**0.7**	**<0.01**	**0.9**	**<0.01**	**0.8**	**<0.01**
% Listhesis- ASIA Origin	**-0.4**	**0.06**	-0.1	0.76	-0.2	0.27
% Listhesis- ASIA Final	**-0.5**	**0.01**	-0.2	0.27	-0.2	0.09
Enlocation time- ASIA Final	0.2	0.24	-0.2	0.25	-0.1	0.44

Relation between initial and final ASIA scores with unilateral vs bilateral dislocations

Overall 27 out of 51 patients had unilateral facet dislocation while 24 out of 51 patients had bilateral facet dislocation. Among the rural patients, 53.3% (8/15) of patients with unilateral dislocation had poor initial ASIA score as compared to 69.2% (9/13) of patients with bilateral dislocation but this difference was not statistically significant (P = 0.39). However among the urban patients, a significantly (P <0.01) higher proportion of patients with bilateral dislocation had poor initial ASIA score (90.9%) as compared to that in patients with unilateral dislocation (25%). Similarly, overall a higher percentage of patients with bilateral dislocation had poor initial ASIA scores as compared to that in patients with unilateral dislocation (79.2% vs 40.7% respectively, P <0.01).

Final ASIA score was not associated with unilateral versus bilateral dislocation in either rural or urban patients.

Neurological Complications after ORIF:

Two patients developed tetraplegia and one patient developed central cord syndrome.

Discussion

Facet joint dislocation is generally a high-energy injury usually involving the younger and more active individuals in the population and can have devastating clinical outcomes. A large proportion of patients who suffer a facet joint dislocation have permanent residual neurological deficit secondary to spinal cord trauma. Based upon the level of injury, the deficit in neurology can involve both upper and lower limbs (quadriplegia). The personal cost of quadriplegia is immeasurable and hard to imagine. From an economic viewpoint, the latest Figures from World Health Organisation (WHO) puts the lifetime cost per quadriplegic individual in Australia at AUD$9.5 million, without taking into account the cost of the carer (1).

Neurological deficit after a facet joint dislocation is caused by both primary and secondary injury. The primary injury is caused by the dislocation itself and cannot be avoided or reversed. The secondary injury is caused by the pressure effect on the spinal cord. There are several causes for this, most notable being the bony and soft tissue structures, haematomas and spinal cord oedema. The neurological deficit caused by the secondary injury has been shown to be time dependent. Animal studies have shown that the neurological deficit from the pressure effect is reversible if it is addressed within 1 hour. Between 3-6 hours, some clinical neurological recovery is possible and after 24 hours, the benefits plateau. These studies also demonstrated that the size of the lesion was another key factor in determining the neurological decline (2, 3). Lee AS et al reported that among the patients who underwent closed reduction, 25% of patients presenting less than 12 hours improved by two or more Frankel grades as compared with 8% of those presenting after 12 hours. But this difference did not reach statistical significance (4). Based on their experience of 32 patients who were completely paralysed due to cervical facet dislocation, Newton D et al suggested that reduction should be performed within four hours of injury (5). A recent Canadian prospective cohort study compared neurological outcomes after early (<24 hours) and late (>24 hours) decompression surgery following spinal cord trauma. A significantly greater proportion had at least a two-grade American Spinal Injury Association (ASIA) Impairment Scale (AIS) improvement at discharge in the early-surgery group (6). After reviewing 19 pre-clinical and 22 clinical studies Furlan JC et al concluded that spinal decompression should be performed no later than 8 to 24 hours after spinal cord injury (7). Early reduction therefore is key to preventing worsening of the neurological deficit and optimising the outcome. Currently, there is no consensus in the literature regarding the appropriate enlocation times for humans. Based on these previous studies, we felt that 12 hour cut-off would be a reasonable criteria to distinguish between early and delayed enlocation.

This study has an almost equal split between the rural and urban patient size. As highlighted in Graph 2, 43% of the rural population at the scene of the accident had an ASIA score of A. This is very different to the urban population where 22% of the patients had an initial ASIA score A. Approximately twice as many urban patients

(39%) had an initial ASIA score of E. One factor that was difficult to quantify was the time interval between the accident and the arrival of medical care. This information is difficult to ascertain due to the lack of evidence, knowledge and presence of witnesses to the incident. Upon arrival of the paramedical staff, the rural patients were taken to their local regional centre followed by RPH. Enlocation was only attempted post arrival at RPH.

Our results showed bilateral dislocations were associated with poor initial ASIA score in urban patients and also overall. Although higher percentage of bilateral dislocations also had poor initial ASIA score but it did not reach significance owning to small sample size and power.

A large number of urban patients had a final ASIA score of D or E (Graph 2). 18 patients had a final ASIA score of D or E while 5 patients had a final ASIA score of A,B or C. Looking at the rural group, 17 of patients had an initial ASIA score A, B or C and 11 of the patients had an initial ASIA score of D or E. Post treatment, 17 of patients had a poor outcome and 11 of patients had a good outcome.

Unlike the urban group, none of the patients in the rural group who had a poor ASIA score initially had a good final ASIA score. Further, only 2 patients in the rural group had improvement in their ASIA scores beyond 2 levels (both from A-C). In the urban group, 3 patients noted an improvement in their final ASIA core of more than 2 levels (A-E and B-E). Excluding patients with an ASIA score of A throughout the presentation, all patients had a good final ASIA score. This is in stark contrast to the rural group. In both of these groups, the mechanism of injury was similar however the rural patients had significantly longer enlocation time compared to their urban counterparts. This would have minimized the impact of the secondary injury.

Rural patients had statistically larger enlocation time, receiving time, and distance to RPH. The apparently large range of enlocation time and receiving time in urban group is because of just two patients out of 23 who have unusual values. Medians for enlocation time and receiving time for urban patients are much less than that of rural ones (Table 1).

The impact of the secondary insult can be minimised by early enlocation. Closed reduction of dissociated facet joints was first described in 1893 by Walton (8), by manipulation of cervical spine deformity. Crutchfield (9) introduced tongs for in-line traction reduction in 1933. Evans (10) and Kleyn (11) popularised reduction under anesthesia. At RPH, the current standard practice is to reduce cervical spine dislocations using Gardner Wells tongs. Under the right circumstances, traction can be applied in the emergency department with the patient sedated and under neurological observations. Recent reports of neurological deterioration after closed or open posterior reduction of cervical fracture-dislocation injuries has led some authors to recommend the use of pre reduction MRI to assess for ventral cord compromise caused by traumatic disc disruption. Eismont et al first described the extrusion of disc material with traumatic dislocation of facets using MRI (12). Berrington NR et al in 1993 described four cases of cervical facet dislocation in which patients deteriorated following closed reduction and subsequent imaging studies found an extruded disc as the cause of deterioration (13). Authors concluded that before undergoing either closed reduction or open reduction, MRI should be done to rule out herniated disc or any any space occupying lesion within spinal canal as reduction in the setting of herniated disc can result in further compression injury to spinal cord. In another study published by Hadley et al in 1992, closed reduction was performed in 66 patients of cervical fracture-dislocation. Success rate of closed reduction was 58% and seven patients had neurological deterioration that subsequently underwent open reduction and internal fixation. Of patients who had successful closed reduction, 78% of them had improvement in neurological functions. Internal-fixation and open reduction had a success rate of 83%. However, only 10 patients had significant neurological recovery overall and in these patients time to decompression was more important than the method of decompression (14). It was believed that disc disruption in association with facet fracture-dislocation increases the risk of spinal cord injury by disc material after reduction (9, 15) but this has been disproven. Vaccaroet al in 1999 looked for disc herniation using MRIin 11 awake patients Disc herniation after facet injuries is very common (16, 17) but its association with post-reduction neurological outcomes is still unknown with facet dislocation before and after closed reduction. Before closed reduction, two patients had

disc herniation. Nine patients out of eleven had successful closed reduction while 5 patients (56%) had disc herniation after reduction. The difference between pre-reduction and post-reduction disc herniation on MRI was not statistically significant. No patient developed neurological worsening despite increased number of patients with disc herniation after closed reduction (18). In the study by Rizzolo et al, although disc herniation was very common (42%) but no patient deteriorated after attempted closed reduction. Investigators attempted closed reduction only in awake patients (16). It is interesting to note that Society of Neurological surgeons' 2013 guidelines recommend MRI if closed reduction fails or if patient is unconscious (19). Doing a pre-reduction MRI to assess disc injury in awake patients will only delay decompression and promote secondary cord injury. Pre-reduction MRI assessment requires the transport of a patient with a highly unstable cervical spine fracture to the MRI suite (20). Due to the disruption of the soft tissue and bony stabilisers of the spinal cord, dislocated facet joints are very vulnerable. Patient transfers and turbulence experienced amid RFDS flights could potentially worsen the primary injury to the spinal cord. For example, if the perched facet in Figure 1 were to completely dislocate, the patient would have suffered significant injury to his cord that could render him a tetraplegic. A reduced and immobilised facet joint has better stability and would be safer for transfer. It would also minimise the impact of the secondary insult on the spinal cord. Due to lack of trained spinal surgeons in rural WA, closed reduction using traction is the only option. There has been extensive literature from the pre MRI period on closed reduction of cervical spines. Encompassing all patients show a total of 1200 patients treated with closed reduction in the acute or subacute period after injury. The success rate for restoring anatomic alignment by closed reduction in these studies was approximately 80%. The reported permanent neurological complication rate was less than 1.0% (14, 21-23). Of the 11 patients reported to develop new permanent neurological deficits with attempted closed reduction, two had root injuries (24), and two had ascending spinal cord deficits noted at the time of reduction (25). Seven patients were noted to have decreased ASIA scores post reduction, but neither the nature nor the cause of the new deficits in these patients was described (20).

Arguments in favour have been historic in nature. Opponents to enlocation of spines rurally, prior to arrival at a spinal centre argue that lack of appropriate imaging can further worsen cord compression by pressure applied from a clot or remnant of the intervertebral disk. Most rural centres in WA are equipped with a CT scanner but not a MRI scanner. In total, there are 70 emergency departments in WA outside metropolitan Perth (Figure 1), Out of these 60 have x-ray facilities, 10 have CT facilities and 3 have MRI scanners. All CT scanners are capable of soft tissue views to visualize haematomas and disk matter that could cause cord compression. All scanners are also linked to the statewide PACS system making the images available to the spinal surgeons at RPH.
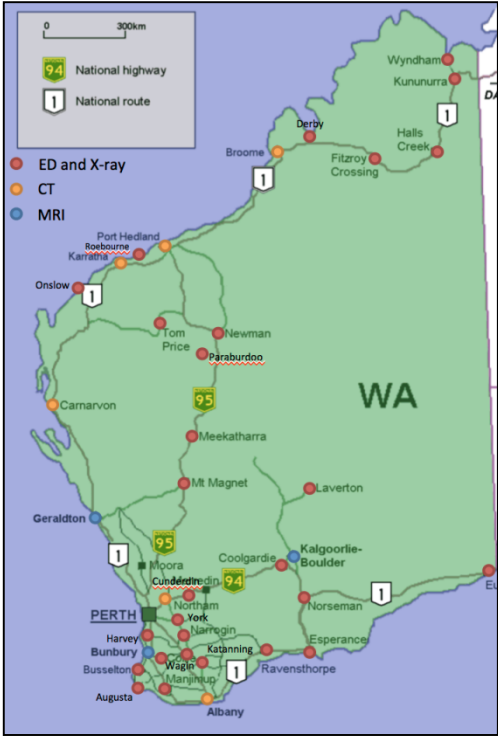

Figure 1- EDs, Xrays, CTs and MRI in WA

Currently, patients who suffer facet joint dislocation in Rural WA are transferred to RPH prior to enlocation. From a logistical viewpoint, a patient who suffers a spinal injury in a rural area has to wait for ambulance services to attend to the scene of trauma and transport the patient to the rural hospital. RFDS transport from the rural centre to

RPH itself takes several hours. During this time, the secondary injury to the spinal cord can be progressing and the window of opportunity available for recovery diminishes. As the data suggests, this final outcome in rural patients is worse than their urban counterparts. Once the patient arrives to RPH Emergency department or Operating tertres, the reduction is achieved with either the use of Gardner Wells tongs or open reduction, depending on the clinical case and the fixation method used. In major rural centres in WA, the existing infrastructure and training of local medical officers is sufficient to diagnose, apply traction and attempt to reduce facet joint dislocations.

The different variables were correlated using Pearsons correlation. Strong correlation was observed between the initial ASIA score and the final ASIA score in both the rural and urban population. In the urban population, a strong correlation was observed between the degree of listhesis and the ASIA scores at the origin and the final. Initial ASIA score is an indicator of the injury to the spinal cord. Low ASIA scores of A, B or C are suggestive of trauma to the spinal cord. Even upon reversal of the pressure effect caused by facet joint dislocations, the neurological deficit is unlikely to return. Patients with a good ASIA score at the scene of the injury (such as ASIA D or E) are less likely to have spinal cords injuries are are therefore more likely to have good final ASIA scores. This has been observed repeatedly in both the rural and urban groups. Enlocation time has been shown the beminimise secondary insult to the spinal cord. This has been demonstrated scientifically and statistically with a strong correlation observed between enlocation times and the final outcomes. Therefore to minimise prejudicial outcomes in patients, we believe minimising the secondary insult to be the key factor. This would mean attending to patients with an ASIA score of A, B or C and attending to rural patients who have a significantly higher enlocation time.

The current standards in Western Australia have been effective in the past at funnelling this devastating injury from a remote area to an area of excellence. In more recent years, due to the rapid increase in population and exponential growth of business within the mining sector, there has been an aggressive expansion in the facilities in rural WA in terms of the number of emergency departments and the available imaging and medical equipment. Some of these rural centres also have functioning orthopaedic and trauma

operating facilities. We propose that rural patients who have an initial ASIA score of A, B or C undergo traction prior to transport to RPH. Patients with an ASIA score of D and E can be transported without the need for traction.

Conclusion

This study confirms the challenges of management of these injures in a large geographical area where current services are confided to a single centre. Generally, facet joint dislocations with a delayed reduction had a poorer outcome in terms of final neurological function. We plan to draw up a protocol for enlocation of ASIA A,B,C rural injuries such that appropriate early traction and attempted enlocation van be undertaken in the rural hospital setting.

Chapter 5

Recommendations and Conclusion

1. Post facet joint dislocation, primary insult is irreversible but secondary insult may be reversed. The time frame is unknown but the earlier decompression have had better results

2. Closed reduction with axial traction has been shown to be an effective method of achieving decompression prior to open reduction and internal fixation

3. MRI scanning a pre-reduced facet joint in awake patients with facet dislocation is not mandatory and should not delay enlocation.

4. Patients who are unconscious or in whom closed reduction fails should be transferred to decompressed surgically as a priority

Chapter 6

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