Cervical disc prolapse in rear-end automobile collisions: Injury mechanism unique to occupant and head restraint geometry

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Introduction
Anecdotal evidence has subjectively linked rear-end automobile collisions to causation of cervical disc trauma, however the injury mechanism has not been reported. Adams and Hutton (1982) have indicated that a coupled loading of flexion and compression from an external source are needed to effect disc prolapse. Two case studies of C5/6 disc prolapse following rear-end impacts are presented. In both of these cases, a unique combination of occupant restraint geometry, and head/neck dynamics resulted in the compression/flexion injury mechanism being produced in the cervical spine.

Methods
This investigation involved a review of rear-end impact case studies, live human and dummy rear-end head/neck kinematics, and cadaveric studies on cervical disc injury biomechanics. The two case studies investigated involved rear end collisions of minivans by other vehicles. In both cases, the injured party was a female driver of the minivan. The impact dynamics of both accidents were determined from accident reconstruction using photographs, property damage estimates, and vehicle specific crash test data. These accidents were compared to results from human volunteers and anthropometric devices (ATD’s) subjected to rear end impacts. Investigation of the seat and head restraint geometries, along with occupant anthropometric characteristics, exposed loading conditions that could lead to disc injury.

Results
Case One involved a 35 year-old female (160cm 54.5kg) driver of a 1995 Plymouth Voyager passenger van that sustained a rear-end collision imparting a speed change of 16kph to her vehicle. She was wearing a three-point seat belt and braced for the collision by pushing on the steering wheel and pushing her head and neck into the integrated seat back and head restraint (Figure 1).

Figure 1. Integrated seat back and head restraint design used in typical passenger van front seats.
Her clinical presentation was of neck pain radiating to both shoulders with subsequent complaints of tingling, numbness and dyesthesias of the left thumb and index finger with occasional symptoms in the right upper extremity. Neurological findings of tenderness and spasm of the cervical musculature, decreased cervical ROM, muscle weakness and loss of sensation combined with EMG and MRI studies led to a diagnosis of C5/6 disc extrusion. Surgery exposed a large, exuberant, extruded disc fragment on the right side extending from the midline into the foramen.

Case Two involved a 30 year-old female (155cm 63.5kg) driving a 1995 Ford Windstar passenger van that sustained a rear-end impact and subsequent speed change of approximately 12 kph. Clinical symptoms of neck and back pain, muscular pain and spasm, headache, nausea, and numbness in her fingers led to a MRI, which demonstrated a large disc extrusion at C5/6 producing cord deformity. Surgery noted an explosive herniation with fragmented disc material and damaged posterior longitudinal ligament.

Discussion

Military aviators (Schall, 1989), parachutists (Makela and Hietaniemi, 1997; Rose, 1984), and American football players (Torg et al., 1991) have sustained cervical disc injury following exposure of a flexed cervical spine to compressive (axial) loading. This injury occurs as the head is flexed forward in a chin to chest fashion. Either direct head contact or inertial loading of the head leads to the axial compressive load. Cadaveric studies by Adams and Hutton (1982) have established compression/flexion loading causes traumatic disc prolapse (protrusion, extrusion or herniation). Furthermore, head impacts onto padded surfaces produce large neck forces and more frequent injuries and cervical spine tolerance has been shown to be lower in females (Nightingale et al., 1997). During rear-end impacts, the head translates in a transverse plane rearward relative to the torso, contacting the head restraint which then accelerates the head forward (Siegmund et al, 1997). Therefore, in most cases there is no opportunity for significant cervical spine compression. However, the seated height of these two subjects (13th percentile and 40th percentile females respectively; Health Statistics, 1965) placed the occupants’ opisthocranion below the top of the head restraint. Further examination of the unique integrated seat geometry revealed the superior border of the metal frame of the head restraint protruded forward 3cm (Plymouth) and 4 cm (Ford) (Figure 2a) with respect to the lower border. Rear-end occupant dynamics include an upward ramping effect of the torso relative to the seat back as well as straightening of the lordotic and kyphotic curves (McConnell et al., 1993; Warner et al., 1991). In the two cases presented in this paper, the head translated rearward pocketing into the padded head restraint, which was then trapped superiorly by the seat frame structure resulting in cervical compression as the torso ramped and the spine straightened (Figure 2b).

Figure 2. Cut-away of seat back and head restraint upholstery and padding exposing frame geometry and superior border permitting head pocketing.
Cervical x-ray studies have demonstrated rearward translation causes relative flexion from C2 through C6 (Figure 3). Therefore, the resultant injury mechanism is compressive loading to a cervical spine segment already in flexion, or compression to a segment that then buckles in flexion resulting in disc prolapse. The circumstances surrounding the injury mechanisms in these two cases stress the importance of individual occupant and vehicle variables in the design of vehicle safety features and in the determination of occupant injury biomechanics.

**Figure 3. Rearward translation and flexion of cervical spine.**

**References**
- National Center for Health Statistics, Series 11, Number 8, 1965.