Acta of Bioengineering and Biomechanics
Vol. 13, No. 3, 2011

Original paper

Evaluation of dynamic formation of cervical spine column based on functional radiological studies in patients after cervical spine injury

JACEK MARTYNKIEWICZ, SZYMON FELIKS DRAGAN, KATARZYNA PŁOCIENIAK, ARTUR KRAWCZYK, MIROSŁAW KULEJ, SZYMON ŁUKASZ DRAGAN*

Department and Clinic of Orthopaedic and Traumatologic Surgery, Wrocław Medical University.

The purpose of this study was to evaluate cervical spine function, based on our own functional method of roentgenometric analysis in patients who suffered from cervical spine sprain injury. Study involved 72 patients who suffered from cervical spine whiplash injury. Conventional plain radiographs in all patients included three lateral views: maximum flexion, neutral (resting) and maximum extension. All views allowed roentgenometric evaluation of ligament instability of the lower cervical spine C5–C7 according to the White and Panjabi criteria. Furthermore, based on literature analysis and their own clinical observations, the authors proposed new classification of dynamic formation of cervical spine column. The dynamic formation of cervical column is evaluated based on pathomechanical chain of being between normal and unstable. Authors' own evaluation system in flexion views can be useful in diagnosis and treatment of this type of injury.

Key words: *cervical spine, injury, pathomechanism*

1. Introduction

Every year almost 60 thousand people are involved in traffic accidents, out of which almost 10% are fatal [1]. The outcomes and sequel of those injuries are treated mainly by orthopaedic surgeons. A modern safety means used in motor vehicles (e.g., multipoint seat belts, airbags) improved the protection of head and chest. However, cervical spine is one of those very important body regions that are still not protected. The use of seat belts caused the inertial forces affecting cervical spine in the indirect mechanism to be much greater [2]. This subsequently led to a higher incidence of acceleration–deceleration cervical spine injury (the so-called whiplash injury). In most cases there is no damage to bone tissue of cervical spine. There is no proof either of the higher incidence of ligament instability after such injuries [3]–[6]. Strictly defined criteria for diagnosing instability allow us to distinguish a group of results that are "controversial", i.e., image studies are not normal, but still do not meet the criteria of instability [7], [8].

This article evaluates cervical spine function, based on our own functional method of roentgenometric analysis in patients who suffered from cervical spine sprain injury.

2. Materials and methods

The study involved 72 patients who suffered from cervical spine whiplash injury (figure 1) and were treated in the Departament of Orthopaedic and Traumatology in Wrocław between 2003 and 2006. In this study, 34 men (47.2%) and 38 women (52.8%) aged between 24 and 66 (mean of 36 ± 10.1) participated. To

* Corresponding author: Szymon Ł. Dragan, Department and Clinic of Orthopaedic and Traumatologic Surgery, Wrocław Medical University, ul. Borowska 213, 50-556 Wrocław, Poland. Tel.: +48-71-734-32-00, e-mail: szymondragan@wp.pl

Received: July 26th, 2011
Accepted for publication: August 15th, 2011

verify the results the authors examined also the control group whose representatives have never suffered from any cervical spine injury and met all exclusion criteria. Control group consisted of 31 individuals: 14 men (42.5%) and 17 women (54.8%) aged between 23 and 78 (mean of 41 ± 16.5). Patients with diagnosed cervical spine fracture were excluded from the study. The first follow-up was held 6 months after injury at a minimum. The mean follow-up in the group under examination was 29.25 months.

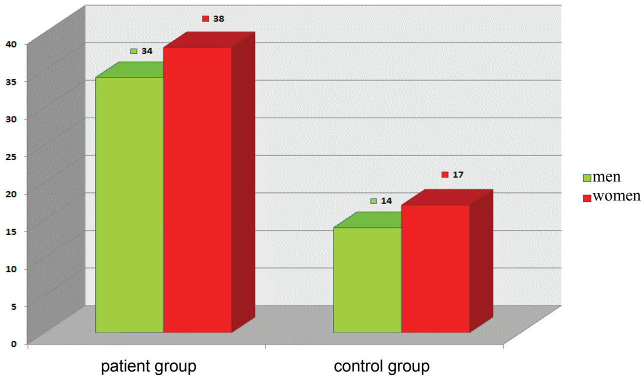

Fig. 1. Number of patients in both groups with sex distribution

Conventional plain radiographs in all the patients included three lateral views: maximum flexion, neutral (resting) and maximum extension [9], [10]. All views allowed the roentgenometric evaluation of:

- Ligament instability of the lower cervical spine C5–C7 according to the White and Panjabi criteria – anterior translation (A.T.) of more than 3.5 mm, regional angulation (R.A.) of more than 11° [7], [11].

Furthermore, based on literature analysis and our own clinical observations, the authors proposed [12]–[16]:

- New classification of dynamic formation of cervical spine column (called further in the text *the JM classification*):

For lateral flexion view (figures 2–5):

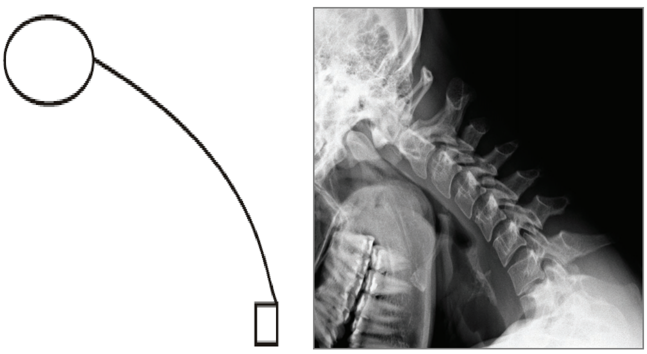

Fig. 2. *Type 1*. Arched anterior curve (our own material)

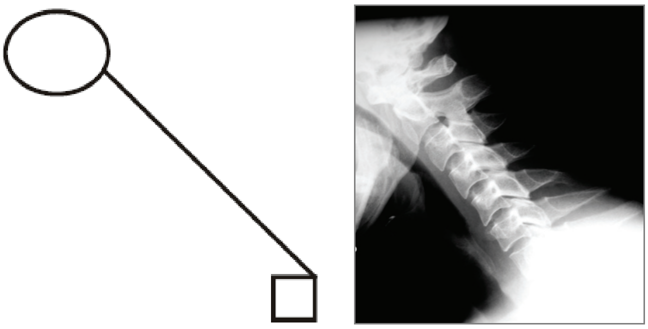

Fig. 3. *Type 2*. Simple anerior curve (our own material)

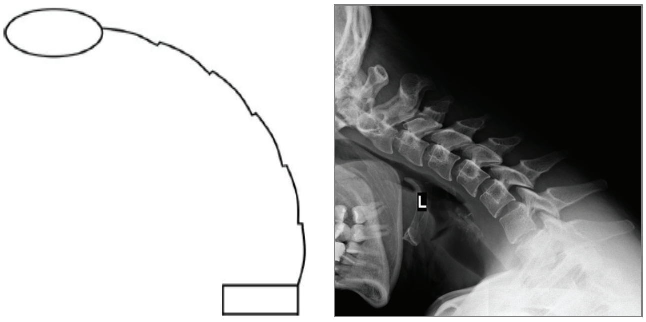

Fig. 4. *Type 3*. Anterior "stepping" curve: (our own material)
3.1 – does not meet the Panjabi and White criteria
3.2 – meets the Panjabi and White criteria

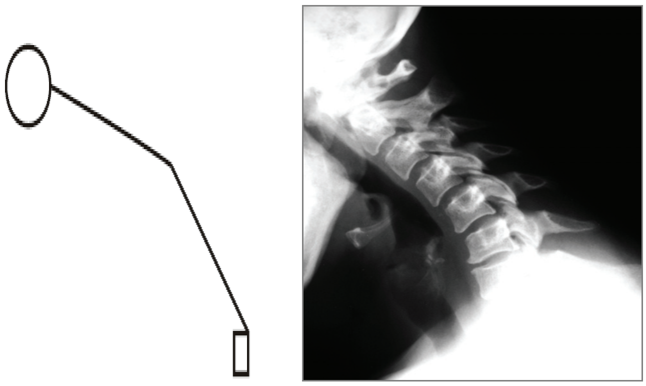

Fig. 5. *Type 4*. Angular curve (our own material)
4.1 – does not meet the Panjabi and White criteria
4.2 – meets the Panjabi and White criteria

For lateral extension view (figures 6–9):

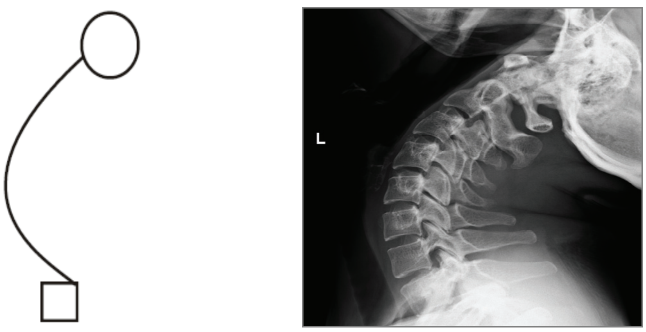

Fig. 6. *Type 1*. Arched posterior curve (our own material)

Fig. 7. *Type 2*. Simple posterior curve (our own material)

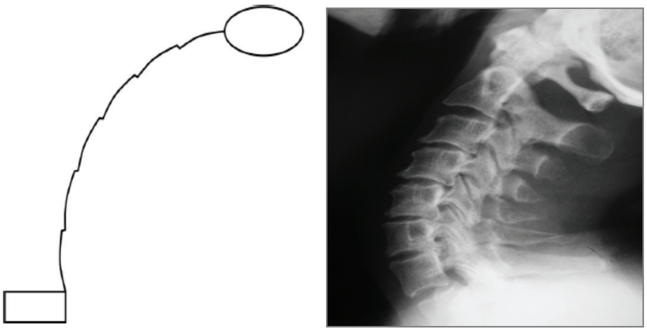

Fig. 8. *Type 3.* Posterior "stepping" curve (our own material)

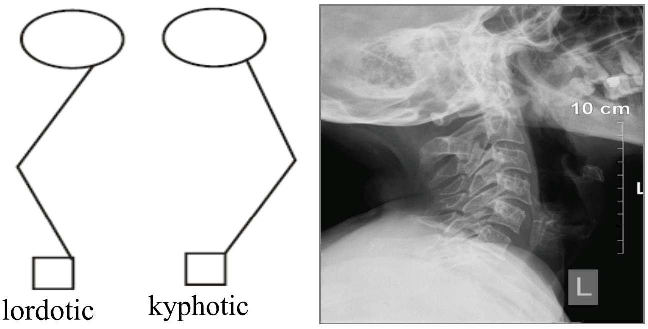

Fig. 9. *Type 4.* Angular curve (our own material)
4.1 – does not meet the Panjabi and White criteria
4.2 – meets the Panjabi and White criteria

Patients from both groups were examined in the same way. Functional assessment included standarised NDI (*Neck Disability Index*) questionnaire [17], [18]. For results – see table 1.

Table 1. NDI questionnaire and severity of symptoms (white background) and groups according to the author (grey background)

0–4 pts	no pain	group 0
5–14 pts	mild	group 1
15–24 pts	moderate	group 2
25–34 pts	heavy	group 3
Above 34 pts	severe	group 4

Data was analysed statistically with STATISTICA programme, version 7.0. All the parameters analysed in all patients' groups were subjected to preliminary assessment which gave mean values, standard deviation, median and minimum and maximum values. Nonparametrical alternatives of the *t*-Student test were used to calculate the relevance of the results obtained in the groups being compared. The relationship between the parameters chosen was checked using the Goodman–Kruskal index. Statistical significance was taken at $p < 0.05$.

3. Results

Lateral resting view did not show any pathological values of anterior shift to meet the White and Panjab instability criteria. Lateral functional view in flexion showed pathological values of anterior shift at C4–C5 level in two cases in patient group, and did not show any substantial difference as compared with the control group ($p = 0.867$). Two cases of pathological values of A.T. parameter were found as well at the level of C5–C6 and again the comparison with control group was statistically insignificant ($p = 0.867$).

Based on lateral functional views in flexion in the patient group, most cases, i.e., 20 (27.7%) patients and 22 (30.5%) patients were classified into type 2 of JM classification (simple curve) and type 3 (stepping curve), respectively. In the control group, most individuals, i.e., 15 cases (48.5%), presented type 1 (arched curve) (table 2). The statistical analysis of the incidence of JM parameter in lateral functional view in flexion revealed that the distribution of this parameter in the patient and control groups was statistically insignificant ($p = 0.156$).

Table 2. JM classification for both groups in lateral flexion view

	JM			
	1	2	3	4
Patient group at last follow-up	19	20	22	11
Control group	15	7	7	2

In lateral functional views in extension, the number of the patients was similar, most individuals from both groups were identified as type 1: 52 cases in patient group (72.2%) and 29 cases in control group (94.5%). Statistical analysis of the incidence of JM parameter for functional extension view showed that the distribution of this parameter in the patient and control groups was statistically insignificant ($p = 0.156$) (table 3).

Table 3. JM classification for both groups in lateral extension view

	JM			
	1	2	3	4
Patient group at last follow-up	52	6	10	4
Control group	29	0	1	1

Both groups were evaluated based on the symptoms of NDI. In the patient group, the symptoms were classified mainly into mild and moderate ones, as they applied to about 77% of patients. Heavy and severe symptoms were declared by 7% of patients. In the control group, almost 88% of individuals had no complaints or they suffered from mild symptoms only (table 4).

Table 4. Number of individuals in NDI groups

	NDI index			
	No pain NDI = 0	Mild NDI = 1	Moderate NDI = 2	Heavy NDI = 3
Patient group	12 (16.7%)	39 (54.2%)	16 (22.2%)	2 (2.8%)
Control group	13 (41.9%)	14 (45.2%)	2 (6.5%)	2 (6.5%)

The study showed higher values of NDI parameter in post-injury group and the difference was statistically significant ($p < 0.001$) (figure 10).

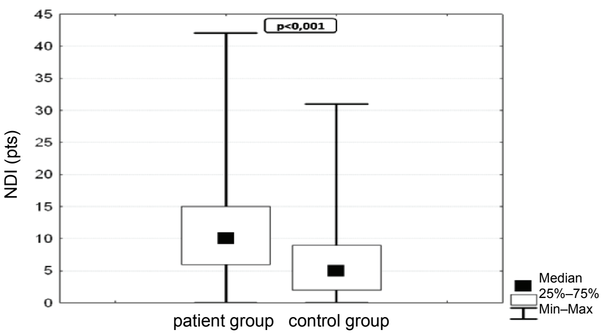

Fig. 10. NDI values for patient and control groups

NDI and JM classification for functional view in flexion were found to be statistically significantly correlated. The Goodman–Kruskal correlation index between JM parameter for functional flexion view in the last follow-up and NDI in the patient group was 0.280. Statistical analysis proved a significant correlation between those two parameters ($p = 0.017$). The positive values of correlation index means that an increase in JM values in functional flexion view correlates with an increase in NDI (table 5).

The Goodman–Kruskal gamma correlation index between JM parameter in functional extension view in the last follow-up and NDI in the patient group was 0.275. Statistical analysis did not show any significant correlation between those two indexes ($p = 0.063$), although it was close to statistical significance (table 6).

Table 5. Correlation between JM classification in lateral flexion view and NDI values in patient group

Patient group		JM – in flexion				
		1	2	3	4	Total
NDI	0	5	3	4	0	12
	1	11	12	8	8	39
	2	3	3	8	2	16
	3	0	1	1	0	2
	4	0	1	1	1	3
	Total	19	20	22	11	72

Table 6. Correlation between JM classification in lateral extension view and NDI values in patient group

Patient group		JM – in extension				
		1	2	3	4	Total
NDI	0	10	0	1	1	12
	1	29	4	5	1	39
	2	10	2	3	1	16
	3	1	0	1	0	2
	4	2	0	0	1	3
	Total	52	6	10	4	72

The Goodman–Kruskal gamma correlation index between JM parameter in functional view in flexion and NDI for the control group was –0.014. Statistical analysis did not prove any significant correlation between those two parameters ($p = 0.938$). The Goodman–Kruskal gamma correlation index between JM parameter in functional extension view and NDI for control group was –0.294. Statistical analysis did not show any significant correlation between those two parameters ($p = 0.548$).

4. Discussion

A sprain injury of cervical spine subsequently leads to disturbances in dynamic formation of cervical column in flexion. Individuals suffering from such an injury more often present its symptoms and complaints. The authors proposed their own classification (JM) which was based on clinical observations. There is no correlation between JM classification and NDI value for lateral extension view; however, statistical analysis has proved to be a correct research path, and JM classification for extension view needs further research. Dynamic formation of cervical spine column is the total of force directions of individual motor units during the movement in sagittal plane. Only type 4 refers to one motor unit. Straight axis of the spine, i.e. type 2 of JM classification, is referred to as a “string sign" in clinical terminology and is the first type of pathologic dynamic formation of the spine column. Literature defines this type as an "apprehension" sign (muscle tension) in patients during the acute phase [19]. A prolonged muscle tension testifies to an increased coherence of motor units; however, it does not identify the cause of this process. The muscle tension disorders appear very unlikely to be responsible for JM of types 3 and 4; it is more probable that they are caused by ligament and capsular disorders. Panjabi's study shows that whiplash mechanism causes injury within the anterior column of spine (anterior longitudinal ligament, disc), i.e., the injury to the structures that are stretched and squeezed (disc), being responsible for ligamentous restrictions of cervical spine extension [20]–[22]. Currently, there is no objective diagnostic method for verifying patient's complaints and symptoms. The use of MRI did not yield the expected results [23], [24]. According to WILMING and PATJAN [25] normal results of MRI studies in patients who suffer from cervical spine sprain injury are caused by still poor efficiency of this method. There are still no objective prognostic factors. So far, the most important prognostic factors include symptoms emerging just after the injury and general severity of injury according to QTF (Quebec Tasc Force) [26]–[28].

5. Conclusion

Whiplash injury causes dynamic disorders in individual motor units which subsequently affect cervical spine formation in sagittal plane. The dynamic formation of cervical column is evaluated based on pathomechanical chain of being between normal and unstable. Authors' own evaluation system in flexion views can be useful in diagnosis and treatment of this type of injury.

References

[1] DYTMAN M. i wsp., *GUS: Transport – wyniki działalności w 2006 r.*, Główny Urząd Statystyczny, Warszawa, 2007.

[2] JAKOBSSON L., LUNDELL B., NORIN H. et al., *WHIPS – Volvo's whiplash protection study*, Accident Analysis and Prevention, 2000, 32, 307–319.

[3] BRADY W., MOGHTADER J., CUTCHER D. et al., *Use of flexion-extension cervical spine radiography in the evaluation of blunt trauma*, Am. J. of Emergency Medicine, 1999, 6, 504–508.

[4] HOFFMAN J., WOLFSON A., TODD K. et al., *Selective cervical spine radiography in blunt trauma: methodology of the National Emergency X-Radiography Utilization Study (NEXUS)*, Annals of Emerg. Med., 1998, 32, 461–469.

[5] HOFFMAN J.R., MOWER M.R., WOLFSON A.B. et al., *Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma*, N. Eng. J. Med., 2000, 343, 94–99.

[6] MOWER W., CLEMENTS C., HOFFMAN J., *Anterior subluxation of the cervical spine*, Emergency Radiology, 2001, 8, 194–199.

[7] WHITE A.A., PABJABI M.M., *Clinical biomechanics of the spine*, 2nd ed., Phipadelphia, J.B. Lippincott, 1990.

[8] KNOPP R., PARKER J., TASHJIAN J., GANZ W., *Defining radiographic criteria for flexion–extension studies of the cervical spine*, Annals of Emerg. Med., 2001, 38, 31–35.

[9] CASSAR-PULLICINO V.N., *Spinal injury optimizing the imaging options*, Eur. J. of Radiol., 2002, 42, 85–91.

[10] DAFFNER R., SCIULLI R., RODRIGUEZ A., PROTETCH J., *Imaging for evaluation of suspected cervical spine trauma. A 2-year analysis*, Injury, 2006, 37, 652–658.

[11] CANALE T., BEATY J. et al., *Campbell's Operative Orthopaedics*, 11th edition, Mosby, 2008.

[12] PANJABI M., NIBU K., CHOLEWICKI J., *Whiplash injuries and the potential for mechanical instability*, Eur. Spine J., 1998, 7, 484–492.

[13] PANJABI M., ITO S., PEAERSON A. et al., *Cervical spine curvature during simulated whiplash*, Clinical Biomechanics, 2004, 19.

[14] Van GOETHEM J., BILTJES I., van den HAUWE L. et al., *Whiplash injuries: is there a role of imaging?* Eur. Journal of Radiology, 1996, 22, 30–37.

[15] Van GOETHEM J., MEAS M., OZSARLAK O. et al., *Imaging in spinal trauma*, Euro. Radiol., 2005, 15, 582–590.

[16] SIEVERS K., RIEDIGER H., *Stellenwert der radiologischen verfahren in der Diagnostik des HWS-Schleudertraumas*, Manuelle Medizin, 1999, 37, 79–84.

[17] STERLING M., *A proposed new classification system for whiplash associated disorders – implications for assessment and management*, Manual Therapy, 2004, 9, 60–70.

[18] KAALE B., KRAKENES J., ALBREKTSEN G., WESTEK K., *Whiplash-associated disorders impairment rating: Neck Disability Index score according to severity of MRI findings of ligaments and membranes in the upper cervical spine*, Journal of Neurotrauma, 2005, 22, 466–478.

[19] DZIAK A., *Bóle szyi, głowy i barków*, wyd. I, Medicina Sportiva, Kraków, 2001.

[20] PANJABI M., ITO S., PEARSON A. et al., *Injury mechanisms of the cervical intervertebral disc simulated whiplash*, Spine, 2004, 29, 1217–1225.

[21] ITO S., IVANCIC P., PANJABI M., CUNNINGHAM B., *Soft tissue injury threshold during simulated whiplash*, Spine, 2004, 29, 979–987.

[22] IVANCIC P., PEARSON A., PANJABI M., ITO S., *Injury of the anterior longitudinal ligament during whiplash simulation*, Eur. Spine J., 2004, 13, 61–68.

[23] BORCHGREVINK G., SMEVIK O., HAAVE I. et al., *MRI of cerebrum and cervical column within two days after whiplash neck sprain injury*, Injury, 1997, 28, 331–335.

[24] RONNEN H., de KORTE Ph., BRINK P. et al., *Acute whiplash injury: is there a role for MR imaging? – a prospective study of 100 patients*, Radiology, 1996, 201, 93–96.

[25] WILMING J., PATIJAN J., *MR imaging of alar ligament in whiplash-associated disorders: an observer study*, Neuroradiology, 2001, 43, 859–863.

[26] LOVELL M., GALASKO C., *Whiplash disorders – a review*, Injury, 2002, 33, 97–101.

[27] SCHOLTEN-PEETERS G., VERHAGEN A., BEKKERING G. et al., *Prognostic factors of whiplash – associated disorders: A systemic review of prospective cohort study*, Pain, 2003, 104, 303–322.

[28] HARTLING L., BRISON R., ARDERN CH., PICKETT W., *Prognostic value of the Quebec classification of whiplash – associated disorders*, Spine, 2001, 26, 36–41.