I.D.Gelalis*, G.N.Christoforou[1]*, Th.A.Xenakis*, L.G.Gilbertson, J.D.Kang****

THREE DIMENSIONAL ANALYSIS OF CERVICAL SPINE MOTION USING A COMPUTER ASSISTED MAGNETIC TRACKING DEVICE

**Department of Orthopaedic Surgery, University of Ioannina, Medical School, Ioannina, Greece*
***University of Pittsburgh Medical Center, Department of Orthopaedic Surgery, Pittsburgh, PA, USA*

Abstract

Background and Purpose. *The purpose of this study is to investigate the reliability and reproducibility of a magnetic tracking technique for the assessment of overall cervical spine motion (principal and coupled movements).*

Subjects and Methods. *Ten asymptomatic male volunteers with a mean age of 29.3 (range, 20-37 years) years were included in this study. Flexion, extension, left and right lateral bending and left and right axial rotation were measured using a magnetic tracking device mounted onto a custom head piece. A detailed statistical analysis was made to determine the inter-, and intra-observer reliability.*

Results. *High intra- and inter-observer reliability was found in flexion, extension, axial rotation, and lateral bending indicating that the testing routine is applicable for different examiners.*

Conclusions and Discussion. *The magnetic tracking device method described in our study is a reliable, reproducible method for three dimensional motion analysis of the cervical spine. The method is well suited for the clinical assessment of various degenerative and traumatic disorders. It may also supplement different therapeutic procedures and rehabilitation.*

Key words:
Three-dimensional motion analysis, Kinematics, Cervical spine, Magnetic tracking device

Introduction

Injuries and various degenerative conditions of the cervical spine are frequently associated with pain and limitation of mobility. Accurate methods for measuring cervical spine motion are therefore of great significance for baseline information and evaluating clinical outcomes. Many studies have reported on cervical spine motion assessment using different techniques, and have proposed variable norms of cervical range of motion, reflecting the difficulty of accurate measurement.

Radiographic techniques, such as conventional radiography, cineradiography, and stereoradiography, have been showed to be accurate and objective methods for the evaluation of the ROM of the cervical spine. [1-3] However the radiation exposure, equipment availability, expense and time consumption are the disadvantages of radiographic techniques.

Many studies have used different goniometric techniques to measure cervical range of motion. [7-11] Kadir et al. [12] used a head goniometer composed of a headgear with three calibration scales to measure degrees of motion in the cardinal planes. Tucci et al. [11] used a standard gravity goniometer with spirit level and scale calibrated in degrees which was mounted on a head adaptor. Ålund and Larsson described a clinical method for simultaneous recording of neck motion in three planes using electrogoniometric equipment. [7] Their technique showed good correlation ($P<0.001$) with radiographically determined flexion-extension occiput-C7 as well as lateral flexion C1-T1.

The purpose of this study is to present a noninvasive, reliable clinical method for three-dimensional analysis of overall cervical spine motion using a computer assisted magnetic tracking device.

[1]Contact Information:
Dr Georgios Christoforou
Email: giorgos_christoforou@yahoo.com
Phone: (+30)2651099682, 2651099688
Fax : (+30)265109968

Materials and Methods

Subject selection. Ten asymptomatic male volunteers, with normal physical status and no previous history of cervical spine surgery, cervical spine trauma or cervical pain, were included in this study. Mean age of the volunteers was 29.3 years (range, 20-37 years). All volunteers were engaged in sedentary and routine activities of daily living.

Instrumentation. Kinematic measurements were made using a magnetic tracking device (Figure 1). This device is a six degree-of-freedom measuring device consisting of a transmitter that creates a pulsed direct current (DC) magnetic field that is simultaneously measured by one or multiple receivers. From the measured magnetic field characteristics, each receiver independently computes its position and orientation. The overall rotational data are displayed in real time on a laptop computer. The technical specifications of this device include a positional range of 122cm, angular range of 180˚, static positional accuracy of 0.25cm RMS (root mean squared) and static angular accuracy of 0.5˚ RMS. A MRI compatible halo ring , composed of aluminum-magnesium alloy and modified by attachment of 8 positioning pads was used as a head mount for one sensor. A second receiver was attached on the chair's backrest.

Procedure. All subjects were seated in a wooden chair, and their shoulders were restrained with straps so that their torso maintained contact with the chair's backrest. Their

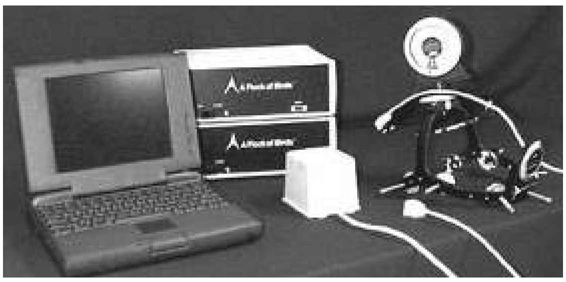

Figure 1. *Spinal Kinematic assessment system, consisting of (magnetic tracking system transmitter, recievers, and control units), laptop computer, and modified halo apparatus with magnetic receiver*

arms rested freely on their sides and their feet were positioned flat on the floor. The head-piece was placed on each subject's head, 1 cm above the ear tips and stabilized in this position by tightening the positioning pads. The positioning pads provide stabilization of the head-piece and reduced random movements of the head-piece due to subject's hair and scalp. The transmitter was positioned a distance of 10 cm behind the receiver attached to the chair (Figure 2).

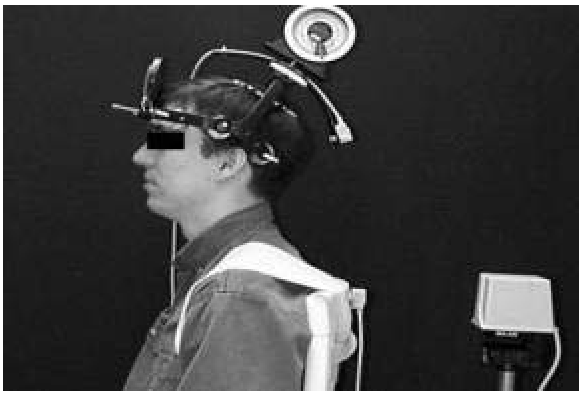

Figure 2. *Subject performing cervical spine flexion maneuver while wearing the cervical spine measurement apparatus. Note the subjects' torso is restrained, to reduce torso move-*

Subjects were examined in relaxed sitting position and were initially instructed to sight on a single point on the wall, defining their neutral position. The range of motion maneuvers were obtained by asking the subjects to move their head maximally in the following rotational degrees of freedom: flexion, extension, right lateral bending, left lateral bending, right axial rotation, and left axial rotation. Each subject was instructed to minimize the coupled motions and to return to his neutral position after each maneuver. Each subject was encouraged to perform maximum excursion for each maneuver without excessive effort. During each maneuver the examiner observed the real time data displayed on the computer screen to ensure the quality of the test.

Reliability was tested by examining each subject two times on different days (at the same time of day) by two investigators who performed the measurements independently. The subject's active range of motion was recorded by each observer three times in each of the six degrees-of-freedom. The values were measured and reported as the average value of the three trials. The data from each motion was analyzed using Microsoft Excel 5.0 .

Interclass coefficient study was made to express the reliability of the measurements. The reliability coefficient and probability value were calculated for inter-observer variability (comparing the results from the two examiners) and for intra-observer variability (comparing the results from the two different tests of each examiner). All statistics were calculated on a personal PC running the SAS Version 6.08 statistical software . Poor reliability was defined for reliability coefficients between 0 and 0.4, fair and good reliability between 0.4 and 0.75, and high or excellent reliability over 0.75.

Results

The means and standard deviations obtained with the magnetic tracking device were 130.1^0 and 17.2 for flexion-extension, 79.8^0 and 12.1 for total lateral bending, and 137.7^0 and 15.8 for total axial rotation respectively.

Inter-observer variability.

The reliability coefficients of the examiners' results were computed for each motion test. The correlation between the examiners' results in flexion and extension was high with reliability coefficients of 0.89 and 0.94.There were no significant differences between the results in right and left lateral bending and the reliability coefficients were also high. (Table 1)

Table 1.

Inter-observer variability. Reliability coefficients (R) and probability values (p-value) for the magnetic tracking device

	Magnetic tracking device
Flexion	R=0.89 (P=0.19)
Extension	R=0.94 (P=0.09)
Right Lateral Bending	R=0.80 (P=0.26)
Left Lateral Bending	R=0.78 (P=0.51)
Right Axial Rotation	R=0.89 (P=0.53)
Left Axial Rotation	R=0.82 (P=0.82)

Intra-observer variability.

High reliability was obtained from the repeated measurements from each examiner in flexion and extension and axial rotation. From the measurements of the first examiner, fair to good reliability was shown in right lateral bending, in left lateral bending and high reliability coefficients in all remaining measurements. The results from the second examiner revealed fair to good reliability only in right lateral bending (R=0.67, P>0.05), and high reliability in the remaining degrees-of-freedom. (Table 2)

Table 2.

Intra-observer variability. Reliability coefficients (*R*) and probability values (*P*-value) for the magnetic tracking device used by both examiners

	Examiner 1	Examiner 2
	Magnetic tracking device	
Flexion	R=0.89 (P=0.06)	R=0.91 (P=0.26)
Extension	R=0.92 (P=0.69)	R=0.96 (P=0.001)
RLB	R=0.57 (P=0.68)	R=0.67 (P=0.66)
LLB	R=0.68 (P=0.91)	R=0.82 (P=0.26)
RAR	R=0.87 (P=0.68)	R=0.75 (P=0.87)
LAR	R=0.80 (P=0.48)	R=0.90 (P=0.34)

RLB=Right Lateral Bending, LLB= Left Lateral Bending
RAR= Right Axial Rotation, LAR= Left Axial Rotation

Discussion

Despite the availability of numerous instruments for measuring cervical range of motion, clinicians are looking for easier to use, safer and more accurate and reliable devices. *In-vivo* measurements require techniques which are not too invasive or too complex to perform and that are comfortable for the subject. The purpose of the present study was to investigate the reliability of a noninvasive method for the analysis of cervical spine motion using a magnetic tracking device.

The current study has shown that the assessment of the cervical range of motion can be performed simply and with high intra- and inter-observer reliability in flexion, extension, axial rotation, and lateral bending. The high interobserver correlation indicates that the testing routine is applicable for different examiners. The fair to good intraobserver variability in lateral bending that we found might be a result of additional combined movements of axial rotation and flexion/extension occurring during the performance of lateral bending, and also a result of the different experience level of the examiners. Intra-observer repeatability was found to be high during the second day test. Each examination consisted of a trial of three tests in each motion. To reduce random movements of the head sensor caused by the subject's hair and scalp, we used a MRI compatible halo ring on which we attached the sensor. Some goniometric and inclinometer devices measure both cervical and thoracic motion, whereas other methods eliminate thoracic motion, thus measuring true cervical motion. [6,7,9,10,14,17,18] In our study to minimize thoracic spine motion, the subjects' shoulders were strapped to the chair thus reducing the involvement of the thoracic spine motion and measuring cervical spine motion.

The electromagnetic technique described here has the advantage of simultaneous assessment of the overall coupled motions occurring in cervical spine motion as the data is displayed in real time on a computer screen. Various movements contributing to the complex motion pattern of the cervical spine seems to be a characteristic of each individual. Rotation and lateral bending in the lower cervical spine are coupled because of the inclination of the intervertebral joints and the function of the uncovertebral joints. [2,6,20]

Conclusions

In conclusion, our study demonstrates that the magnetic tracking device is a reliable, noninvasive, reproducible method to measure cervical range of motion.

The method described here is well suited for the assessment of various degenerative and traumatic (soft tissue injuries) disorders of the cervical spine. It could also be performed in the evaluation of postoperative results in cervical spine surgery as a function of time and in the evaluation of the influence of different therapeutic procedures postoperatively. The results of this method could serve to standardize or customize rehabilitation.

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