ORIGINAL ARTICLES

CERVICAL SPINE GEOMETRY CORRELATED TO CERVICAL DEGENERATIVE DISEASE IN A SYMPTOMATIC GROUP

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ABSTRACT

Objective: To investigate whether a statistical correlation exists between lateral cervical geometry and cervical pathology, as identified on neutral anteroposterior (AP) and lateral radiographs within a symptomatic group; describe the cervical pathology and determine its location and frequency; and identify the subject's age, sex, and chief complaint.

Setting: Department of radiology at a chiropractic college.

Methods: One hundred eighty-six consecutive pairs of AP and lateral cervical radiographs were reviewed for pathology. A 5-category severity scale was used to describe degenerative joint disease, the most common pathological finding. The subject's age, sex, and symptoms were recorded. Geometric analysis was focused on vertebral position, alignment, and gravitational loading acquired from the neutral lateral cervical radiograph.

Results: Regression and discriminant analysis identified 5 geometric variables that correctly classified pathology subjects from nonpathology subjects 79% of the time. Those variables were: (1) forward flexion angle of the lower cervical curve; (2) gravitational loading on the C5 superior vertebral end plate; (3) horizontal angle of C2 measured from its inferior vertebral end plate; (4) disk angle of C3; and (5) posterior disk height of C5. Degenerative joint disease was the most common pathological finding identified within discrete age, sex, and symptom groups.

Conclusion: We identified 5 geometric variables from the lateral cervical spine that were predictive 79% of the time for cervical degenerative joint disease. There were discrete age, sex, and symptom groups, which demonstrated an increased incidence of degenerative joint disease. (J Manipulative Physiol Ther 2003;26:341-6)

Key Indexing Terms: *Cervical Vertebrae; Joint Diseases; Radiography*

INTRODUCTION

Cervical degenerative joint disease is a common physiological manifestation. However, the mechanisms contributing to its development are not well understood. Abnormal neutral geometry, such as kyphotic malalignment and unbalanced stress distributions, have been identified as some of the contributing factors to cervical degeneration.[1,2] Plain film radiography is often the initial means of evaluating degenerative joint disease in the cervical spine, and much controversy exists as to its clinical significance and prognosis.[3] In many instances, cervical joint degeneration produces intermittent neck pain, especially in middle-aged and elderly patients.[4] Pathomechanical alterations of cervical geometry and loading have also been reported in patients with and without degenerative joint disease who experienced severe neck pain.[5] Others have implicated cervical motion segment disorders and abnormal buckling configurations as etiologies of degenerative joint disease.[6,7]

The purpose of this study was to investigate whether a statistical correlation existed between cervical geometry obtained from the neutral lateral film and cervical degenerative disease as identified on anteroposterior (AP) and lateral radiographs within a symptomatic group. We noted both the location and frequency of cervical pathology and recorded the subjects' age, sex, and chief complaint.

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Method

The paired neutral lateral and AP cervical radiographs of 186 symptomatic subjects were reviewed for pathology by a diplomate of the American Chiropractic Board of Radiology (DACBR). The patient radiographs and histories were referred to the radiology department from the health centers of a chiropractic college and from chiropractic physicians to obtain a radiological interpretation. Inclusion criteria for this study required the identification of 29 osseous landmarks on the lateral film. These landmarks were employed in the geometric analysis. Ten common radiological pathologies were recorded. The list included discogenic spondylosis, uncovertebral joint arthrosis, apophyseal joint arthrosis, diffuse idiopathic skeletal hyperostosis (DISH), block vertebra, atlantoaxial osteoarthrosis, ankylosing spondylitis, fracture, rheumatoid arthritis, and surgical fusion. An 11th miscellaneous category describing all other pathologies was also included. A 5-category severity scale was used to grade the cervical degenerative joint disease. This was adopted from Kellgren and Lawrence[8] and has been reported as reliable and appropriate for epidemiological research.[9] The severity codes used were (A) none—no features of osteoarthritis; (B) doubtful—minute osteophyte, doubtful significance; (C) minimum—definite osteophyte, unimpaired joint space; (D) moderate—moderate diminution of joint space; and (E) severe—joint space greatly impaired with sclerosis of subchondral bone. Each diagnostic impression was recorded, including type of pathology, vertebral joint level, anterior or posterior cervical joint location, and the grade of joint disease severity. The subject's name, sex, age, and chief complaint were also recorded. This information was not available to the radiologist.

The radiographs were prepared for digital analysis by identifying 29 osseous landmarks on each lateral cervical radiograph (Fig 1). For levels C3-C7, the points selected were the 4 corners of the vertebral body at the intersection of the vertebral end plates with the anterior and posterior body margins. For T1, the points selected were the anterior and posterior superior vertebral end plates. For C2, 1 point each on the anterior and posterior inferior vertebral end plate and a point at the superior intersection of the pedicle and body were selected. For C1, 1 site marked on the vertical midpoint of the anterior arch, most anterior position of the arch, and 1 site at the posterior arch midpoint of the interlaminar junction were selected. For the occiput, 1 point was selected at the anterior intersection of the skull and occipital condyle and 1 at the posterior intersection of the skull and occipital condyle. The spatial coordinates of these osseous landmarks were obtained using a Numonics Digitizer Model 2200 (Montgomeryville, Pa). The point identification and grid marking have been shown to be reliable and accurate in vertebral measurement.[10-12]

Thirty-five geometric measurements (Table 1) were calculated and sorted for each of the lateral cervical radiographs using the Spinal Analysis System (Weldon Springs, Mo) and Alpha 4 database (Burlington, Mass) software programs. Distribution values for the geometric variables were analyzed using Statgraphics (Rockville, Md) Statistical Software v4.0. These variables were subjected to regression and discriminant analyses to differentiate between the pathology and nonpathology groups.

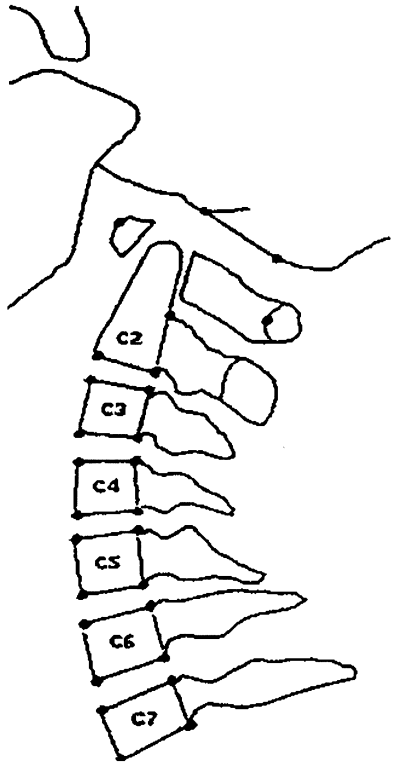

Fig 1. *Digitizing points.*

Results

General

The sample population of 186 subjects consisted of 125 female subjects and 61 male subjects. The mean age was 38.1 ± 13.7 years. Seventy-two subjects (38.7% of the sample), 49 female subjects and 23 male subjects, had at least 1 level of degenerative joint disease; more than half of these subjects also had a second level. On average, the degenerative joint disease was classified as *moderate*. Of those with degenerative joint disease, 91.6% had discogenic spondylosis, 68% had uncovertebral arthrosis, and 20.8% had apophyseal joint arthrosis. Of those with anterior joint disease (disk or uncovertebral), 13% had concomitant posterior joint involvement (apophyseal).

Cervical Geometry and Spine Pathology

Thirty-three of the 35 lateral cervical geometric and loading variables demonstrated normal distributions with P values $< .01$. Only the radius of curvatures fell outside of a

Table 1. *Thirty-five geometric measurements*

Description	Mean ± SD	*P* value
Angle between occiput and C1	7.4°E ± 7.3	<.001
Angle between C1 and C2	22.3°E ± 6.8	<.001
Angle of C1 to horizontal	17.9°E ± 8.2	<.001
Inferior end plate angle of C2*	4.6°E ± 8.3	
C2/C3 disk angle	4.2°E ± 4.5	<.001
C3/C4 disk angle*	5.2°E ± 4.7	<.001
C4/C5 disk angle	3.2°E ± 4.2	<.001
C5/C6 disk angle	3.3°E ± 3.4	<.001
C6/C7 disk angle	3.7°E ± 3.1	<.001
C7/T1 disk angle	2.8°E ± 2.9	<.001
Anterior disk height		
C2/C3	5.0 mm ± 1.2	<.001
C3/C4	4.9 mm ± 1.2	<.001
C4/C5	4.5 mm ± 1.3	<.001
C5/C6	4.2 mm ± 1.2	<.001
C6/C7	4.5 mm ± 1.3	<.001
C7/T1	4.3 mm ± 1.1	<.001
Posterior disk height		
C2/C3	3.8 mm ± 0.8	<.001
C3/C4	3.4 mm ± 0.9	<.001
C4/C5	3.6 mm ± 0.9	<.001
C5/C6*	3.2 mm ± 0.9	<.001
C6/C7	3.3 mm ± 0.9	<.001
C7/T1	3.4 mm ± 0.6	<.001
Inferior end plate angle of C4	20.9° F ± 7.9	<.001
Inferior end plate angle of C7	26.1° F ± 9.7	<.001
Superior end plate angle of T1	28.7° F ± 9.4	<.001
Cervical radius of curvature: 3 points anterior body C2, C5, C7	9.8 cm ± 103.8	.22
Flexion or extension angle of radius of curvature	13.1° F ± 6.1	<.001
Upper radius of curvature: 3 points anterior body C2, C3, C4	3.6 cm ± 50.7	.04
Flexion or extension angle of upper radius or curvature	15.3° F ± 10.1	<.001
Lower radius of curvature: 3 points anterior body C5, C6, C7	20.1 cm ± 60.2	<.001
Flexion or extension angle of lower radius of curvature*	6.8° F ± 10.4	<.001
Jackson angle: intersection angle of tangent lines drawn off posterior body of C2 and C7	18.9° E ± 12.3	<.001
Location of line intersection of Jackson angle	mid =C4 ± 1 vertebra	<.001
Gravity line originating on C2 at body pedicle junction referenced to posterior superior body C5*	10.5 mm A ± 7.1	<.001
Posterior superior body C7	25.3 mm A ± 11.8	<.001

F, Flexion; *E*, extension; *A*, anterior.
*Pathology variable.

normal distribution and P values $< .01$. This was due to the nature of a radial measurement. All the variables were subjected to regression and discriminant analyses to determine whether subjects could be correctly classified into pathology and nonpathology groups. The linear discriminant stepwise method was used to estimate the Fisher and nonstandardized function coefficients. The F values used in the stepwise calculations were 3.84 for entry and 2.71 for removal from the discriminant function. The function coefficients did not change by estimating the coefficients with the "leave-out-one" classification method. It should be pointed out that the eigenvalues of the final discriminant function were statistically significant ($\alpha = 0.05$) and that no data outliers were identified. All calculations were performed using the SPSS 10.0 statistical software (SPSS Inc, Chicago, Ill). It should be noted that the same sample was used to estimate both the correct pathology classification percentage and the parameters of the discriminant function.

We could correctly classify the pathology group from the nonpathology group 79% of the time based on the following 5 variables (Fig 2): (1) forward flexion angle of the lower cervical curve, (2) gravitational loading on the C5 superior vertebral end plate, (3) horizontal angle of C2 measured from its inferior vertebral end plate, (4) disk angle of C3, and (5) posterior disk height of C5.

Pathology

Discogenic spondylosis and uncovertebral arthrosis were the most common pathological findings (Table 2). Column

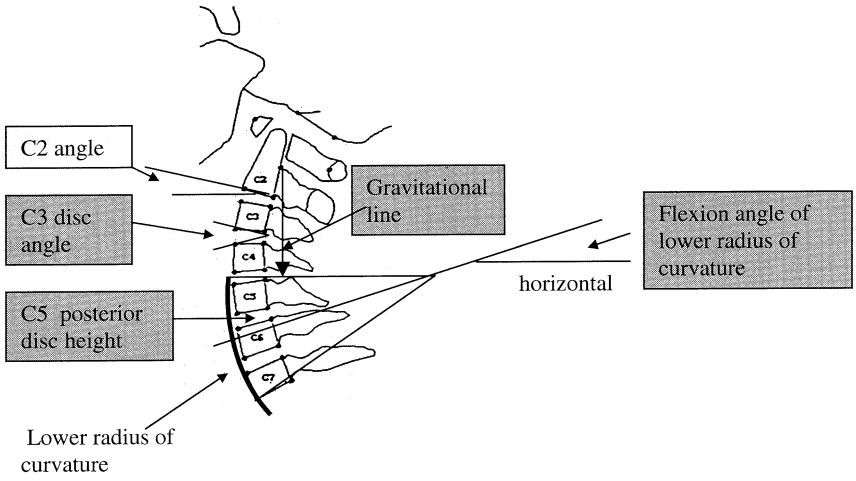

Fig 2. *Five geometric variables correlated with degenerative joint disease.*

Table 2. *Frequency of radiographic pathology*

ID	Pathology	Subjects	Total with pathology (%)	Multiple levels of pathology
1	Discogenic spondylosis	66	91.6%	62.0%
2	Uncovertebral arthrosis	49	68%	46.9%
3	Apophyseal degenerative disease	15	20.8%	60.0%
4	DISH	3	4.1%	100.0%
5	Congenital block	2	2.7%	50.0%
6	Atlantoaxial osteoarthrosis	4	5.5%	0.0%
7	Ankylosing spondylitis	0	0.0%	0.0%
8	Fracture	1	1.3%	100.0%
9	Rheumatoid arthritis	0	0.0%	0.0%
10	Surgical fusion	2	2.7%	0.0%
11	Other	3	4.1%	33.3%

DISH, Diffuse idiopathic skeletal hyperostosis.

5 (% with multiple levels of pathology) indicates the percentage of subjects with a second level of pathology.

Age

Degenerative joint disease was found to be correlated with age; 6% in ages 15 to 30 (n = 60), 25% in ages 31 to 40 (n = 60), 75% in ages 41 to 50 (n = 32), 83% in ages 51 to 60 (n = 24), and 100% in the age group greater than 61 years (n = 10).

Location

The most common site of degenerative joint disease was identified at C5-6 (39%, n = 28), followed by C4-5 (24%, n = 17), C6-7 (22%, n = 16), C3-4 (11%, n = 8), C2-3 less than 1%, C7-T1 less than 1%, and occiput-C1 0%.

Age and Gender

We observed an 80% increase in the incidence of degenerative joint disease in male subjects 31 to 40 compared to female subjects of the same age group (Fig 3). There was also an 81% increase in degenerative joint disease in female subjects 51 to 60 compared to male subjects of the same age group. We found an equal incidence of degenerative joint disease in male subjects and female subjects 41 to 50 and greater than 60 years old.

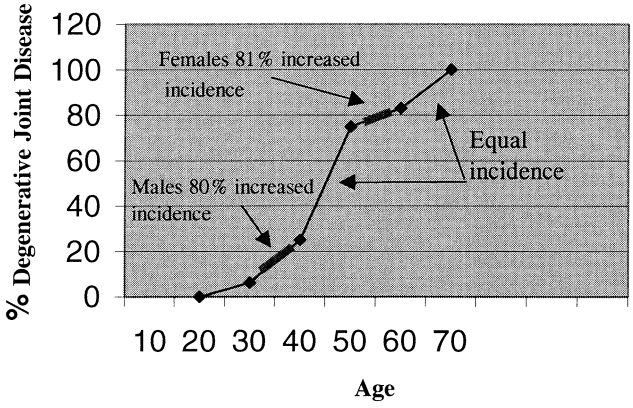

Fig 3. *Gender and age correlated to degenerative joint disease.*

Table 3. *distribution of symptoms*

Symptoms	Populations *	Gender ratio (F:M)	Degenerative disease (%)	Gender ratio degenerative disease (F:M)	Increased degenerative disease
Headache	14%	4:1	30%	3:1	25% M
Neck stiffness	23%	1.8:1	40%	2.5:1	38% F
Neck Pain	52%	2:1	40%	2.5:1	25% F
Upper extremity Paresthesia	15%	3:1	64%	5:1	66% F
Thoracic pain	14%	3:1	44%	2:1	33% M
Shoulder pain	11%	2.6:1	60%	3.3:1	27% F
Radiation	4%	3:1	44%	6:1	200% F

F, Female; *M*, male.
*N = 186.

Symptoms and Gender

The patient symptoms reduced to 7 categories, which accounted for 96% of the subject population (Table 3). Column 1 indicates the symptom; column 2 is the percentage of the sample population with the particular symptom (patients are counted more than once if they reported multiple symptoms); column 3 is the gender ratio (F:M) of the symptom group; column 4 is the percentage of symptom group with degenerative joint disease; column 5 is the gender ratio of the symptom group with degenerative joint disease; and column 6 is a comparison of the gender ratio with pathology (column 5) to the gender ratio of the symptom group. Column 6 identified whether there was a pathology gender bias.

Discussion

We hypothesized that a correlation may exist between cervical geometry and the presence or absence of cervical degenerative joint disease. Our results identified 5 geometric variables that in a linear combination are predictive 79% of the time of the presence of degenerative joint disease. These variables have the individual and combined effect of anterior head translation. However, the weighted significance of the individual variables within the linear equation describing the likelihood of pathology demonstrated the combined effect was more complicated than simple additive translation.

Anterior head translation, resulting from diminished or buckled cervical configurations, produces abnormal loading, increased mechanical stress, and unbalanced pressure gradients onto the anterior cervical column.[7] These unbalanced pressure gradients, when directed on the skeleton, are known to cause remodeling as described by Wolff's law. Pressure gradients are also associated with the generation of biopotentials, including piezoelectricity and streaming potentials.[14] These local electromagnetic fields affect the orientation and deposition of bone. Subsequently, metaplasia of fibrocartilaginous tissue into osteophytes and other degenerative findings will occur as physiological responses.[15]

The gender ratio of our 186 subjects was 2.05:1 female subjects to male subjects. The gender ratio within the degenerative joint disease group was 2.13:1. From this data, female subjects had a 4% increased likelihood of degenerative joint disease compared to male subjects. However, our data demonstrated that the age of onset of degenerative joint disease was gender-dependent. Male subjects displayed an 80% increase in the incidence of degenerative joint disease in the age group of 31 to 40 as compared to female subjects of the same age group; female subjects demonstrated an 81% increased incidence of degenerative joint disease in the age group 51 to 60 as compared to male subjects. These results might suggest that in male subjects 31 to 40, adverse mechanical factors are dominating, while in female subjects 51 to 60, hormonal factors are dominating. Only 2 of the 8 subjective complaints, upper extremity paresthesia and shoulder pain, presented with a significantly higher incidence of degenerative joint disease, 60% and 64%, respectively, and these were female-dominant findings.

Our study has important limitations. One is that the same sample was used to estimate both the correct pathology classification percentage and the parameters of the discriminant function. A study needs to be conducted using only the parameters of the discriminate function. This would confirm the reliability of the discriminant function. Another limitation is the small sample size. Clearly, a larger sample needs to be collected across a broader range of cervical pathology, cervical geometry, and age. This would provide a better understanding of the statistical correlation with respect to the frequency of cervical degenerative joint disease, symptoms, and gender. Ultimately, this improved design would enhance our confidence in the stated conclusions. In addition, the utilization of bone densitometry and magnetic resonance imaging in a future study may identify early increases in bone density associated with pathomechanically induced unbalanced pressure gradients.

Conclusion

This study correlated cervical geometry and pathology. We reported (1) in combination, 5 biomechanical variables that correctly classified subjects into pathology and nonpathology groups 79% of the time; (2) the presence of a

gender bias in the incidence of degenerative joint disease in specific age ranges, male subjects 31 to 40 and female subjects 51 to 60; (3) an increased incidence of degenerative joint disease associated with upper extremity paresthesia and shoulder pain; and (4) C5-6 was the most frequent location of cervical degenerative joint disease. If the correlation of the 5 geometric variables with joint pathology is supported by further study, the opportunity to predict risk factors for cervical degenerative joint disease is available using cervical radiography.

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