Abstract: A retrospective analysis of 500 patient radiographs was conducted to measure the clinical correlation of cervical lordosis measurements and incidence of motor vehicle accident (MVA). Five hundred lateral cervical radiographs were selected at random from the practice of one of the authors (DLM). The C1-7 angle of the cervical curve was then measured by two blinded examiners. Inter-examiner reliability had a confidence interval of 95%. Eighty-two percent of patients who have had a MVA had an abnormal lordosis. The mean lordosis of patients who had been involved in a MVA was 26.1 degrees (SD 11.4), compared with 36.4 (SD 8.4) for those who had not been involved in a MVA. The results suggest a correlation of reduced cervical lordosis measurements following motor vehicle accident (MVA).

Key Indexing Terms: Cervical, lordosis, motor vehicle accident (MVA), neck pain.

INTRODUCTION

The purpose of this study was to measure the clinical correlation of cervical lordosis measurements and incidence of MVA. Five hundred patients aged between 25 and 50 years, inclusive, met a number of criteria in order to be included in the study.

Previous studies have focused on lordosis measurements in persons with no history of cervical spine injury. To our knowledge, no study has compared a history of MVA incidence with reference to the lordotic measurements involving a large sample of 500 subjects with the specific age requirements of 25-50 years of age.

In a survey of the literature, there remains a diverse range of views as to the significance of a “normal” cervical curve(1-30). Although many methods have been used to measure cervical lordosis, we have selected the C1-7 angle of the cervical curve in which the normal cervical curve measurement ranges from 30°-45° on the lateral radiograph(5,6,17,18,31).

This study correlates patient age, gender, occupation, presenting symptom, presence or absence of neck pain at the time of first visit, and the time since the MVA, if one had occurred. All of these variables were collected and associated with percentage of incidence.

This age specification is based on research by Gore(3) as he studied cervical lordotic curvature measurements and correlated an age dependant factor. He noted that young adults (20-25 years of age) generally had less lordosis than older adults. Also, the amount of disc narrowing correlated with the degree of lordosis only in subjects of 50 years of age and older.

METHODS

A retrospective study was conducted using files from the Macquarie Chiropractic Clinic. Five hundred 18 x 24 cm lateral cervical radiographs were selected. The radiographs were analysed by two blinded examiners. The first 500 radiographs were selected from the files and were numbered consecutively. Radiographs were included in the study only when the following criteria were met:

1. All landmarks including the inferior surface of C7 were clearly visible;
2. The patient records indicated whether or not the patient had a history of MVA;
3. The radiographs were taken since 1991, a period during which the same radiographer had taken all clinic radiographs;
4. The radiographs or patient records included patient gender and age and the patient was between 25 and 50 years of age.

Radiographs were excluded from the study in the presence of any of the following circumstances:

1. Pathologies such as congenital anomalies, neoplasms, and arthritis other than degenerative disease;
2. History of trauma noted in the last four weeks prior to the radiographs.

Three thousand, six hundred and seventeen patient files were examined. From this pool, 500 patient files were included and 3,117 patient files were excluded for the following reasons:

1. No radiographs taken (=2,049)
2. Radiographs taken prior to 1991 (=907)
3. Age less than 25 years or more than 50 years (=112)
4. Landmarks not clearly visible (=28)
5. Radiographs taken at another facility (=8)
6. Radiographs not available because they were released to the patient (=13)

The variables of gender, age, occupation, presenting symptoms, presence or absence of current neck pain, incidence or absence of MVA, and time since MVA were then correlated with cervical lordosis measurements and analysed (Table 2). Furthermore, occupations were analysed and allocated to different categories and presenting symptoms also were divided into categories.

Table 2: Percentage of patients with abnormal lordosis by variables collected

| Variable                        | %    | N    |
|---------------------------------|------|------|
| SEX                             |      |      |
| Male                            | 45   | (237)|
| Female                          | 50   | (263)|
| AGE (yrs)                       |      |      |
| 25-29                           | 49   | (127)|
| 30-34                           | 45   | (108)|
| 35-39                           | 54   | (84) |
| 40-44                           | 41   | (81) |
| 45-50                           | 49   | (100)|
| OCCUPATION                      |      |      |
| Professional/para-professional   | 48   | (268)|
| Clerical                        | 54   | (41) |
| Light manual including sales     | 42   | (76) |
| Medium-heavy manual              | 50   | (72) |
| Not in labour force              | 46   | (39) |
| Not elsewhere classifiable       | 50   | (4)  |
| PRESENTING SYMPTOM              |      |      |
| Lower back pain                 | 45   | (225)|
| Neck pain                       | 50   | (136)|
| Mid back pain                   | 36   | (22) |
| Shoulder pain                   | 45   | (31) |
| Headaches                       | 45   | (29) |
| Arm pain                        | 53   | (17) |
| Other                           | 60   | (40) |
| CURRENT NECK PAIN               |      |      |
| No                              | 43   | (155)|
| Yes                             | 50   | (345)|
| MOTOR VEHICLE ACCIDENT (MVA)    |      |      |
| No                              | 24   | (296)|
| Yes                             | 82   | (204)|
| TIME SINCE ACCIDENT (yrs)       |      |      |
| 0-1                             | 85   | (27) |
| 2-4                             | 88   | (50) |
| 5-9                             | 83   | (36) |
| 10-19                           | 79   | (58) |
| 20+                             | 73   | (33) |

The neutral lateral cervical radiographs were obtained using standardised positioning according to the following protocols:

1. The patient is positioned in the upright lateral standing position;
2. In patients with scoliosis, the patient was positioned such that the convex side of the scoliosis was placed adjacent to the film;
3. The shoulder is in contact with the cassette holder;
4. The head and neck are positioned in the true neutral position with the shoulders depressed as much as possible;
5. Full expiration at the time of exposure;
6. The central ray positioned at C4(6);
7. The source-imaging distance (SID) is 1.83 metres (72 inches).

The radiographer taking all the radiographs was fully trained in standardised methods of positioning, and every attempt was made to be precise in patient positioning.

All radiographs were arranged numerically. A large sample increased the power of the study and the statistical relevance of the results. A randomisation of subject study was made by both the examiners and the analysis was done independently. One examiner marked the lines and recorded cervical lordotic angle. The lines were left on the films and the second examiner checked and corrected the lines as deemed necessary and then re-measured the angles and recorded them.

Several methods of analysing cervical lordosis have been described(2,3,5-7,11,18,21,22,26,28,32-35). In this study the method of analysis for cervical lordosis is based on the C1-7 angle of the cervical curve(5,6,17,18,31). This procedure involves constructing a line intersecting the anterior and posterior tubercles of C1 (atlas plane line). A second line is then constructed through the inferior aspect of the C7 body. Two more lines are then drawn perpendicular to the first two lines. The angle of the intersecting lines formed is expected to fall within an arbitrary range of 30°-45° to be considered within normal limits. Less than 30° is considered hypolordosis, while more than 45° is considered hyperlordosis (Fig 1).

Figure 1: Diagram depicts the methods of drawing the C1-7 cervical angle:

Adapted from: MacRae J, Roentgenometrics in Chiropractic. Toronto: Canadian Memorial Chiropractic College, 1974.
RESULTS

Lordosis in each of the 500 patients was measured by two examiners, numbered 1 & 2. Table 1 shows the mean ratings of each examiner.

Table 1: Mean and standard deviation of lordosis rating by rater

|        | Mean | SD  |
|--------|------|-----|
| Number 1 | 32.0 | 11.0 |
| Number 2 | 31.9 | 11.0 |

1. Inter-Examiner Agreement

The normal range for lordosis is 30°-45° inclusive. For the 500 patients, measurement of lordosis showed a normal (i.e. classically bell-shaped) distribution (Table 2)

The mean magnitude of absolute differences in rating between examiner 1 and examiner 2 was 0.9° (“absolute” means ignoring the sign). No difference for any patient was greater than 3°, which is less than 10% of the mean rating of either examiner. The differences of larger magnitude (2° or 3°) occurred in patients with mid range lordosis as shown in Figure 2. As also shown in Figure 2, the differences were symmetrically distributed about zero which indicates that neither rate is systematically rating higher or lower than the other. This conclusion is supported by the mean signed difference being effectively zero at 0.04 with a 95% CI (-0.07, 0.14). The mean signed difference allows for + and - signs and is calculated by subtracting examiner 2 ratings from examiner 1. The confidence interval indicates that there is a 95% probability that the true mean difference between the two raters (the mean amount by which rater number 1’s ratings are greater than rater number 2’s) is between -0.07 and 0.14.

Observing the standard deviation of differences between examiners for individual patients, 95% of the difference will lie within two standard deviations of the mean difference. As mentioned above, the mean signed difference is 0.04, i.e. effectively zero. The standard deviation of differences is 1.17 so that 95% of differences in ratings between individual patients in the population from which this sample is drawn are predicted to lie in the range -2.31 to 2.38. This is a small range considering the range of lordosis measurements recorded in the study (Figure 2).

2. Patient Data

As the difference between examiners was small and not biased toward a particular examiner (i.e. the mean difference was effectively zero), the remainder of the analysis uses the average of the two examiners’ rating calling this measure just “lordosis” (Table 2).

3. Multivariate Analysis

The effect of MVA on lordosis both unadjusted and adjusted (controlled) for other variables collected was modelled using logistic regression. The outcome variable was dichotomous, indicating whether or not each patient had abnormal lordosis. An odds ratio greater than one for MVA indicates that having had a MVA is associated with greater probability of abnormal lordosis.

Figure 3 shows lordosis by years since MVA in comparison with patients who have not been involved in a MVA. The odds ratio for MVA for each model fitted is shown in Table 4. The odds ratio for time between accident and first attendance for treatment is illustrated in Table 5.
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Figure 3: Lordosis by year of MVA and for patients with no MVA

Each sunflower is positioned at the X and Y mean for the cases it represents. One sunflower petal = one case, and so on.

Table 4: Odds ratio for MVA

|                | OR   | 95% CI       |
|----------------|------|--------------|
| Unadjusted     | 14.3 | (9.2, 22.3)  |
| Controlling for: |     |              |
| sex+age       | 14.5 | (9.3, 22.8)  |
| sex+age+occupation | 14.6 | (9.3, 22.9)  |
| sex+age+symptom | 15.0 | (9.5, 23.8)  |
| sex+age+neck pain |    |              |

Base: all patients

Table 5: Odds ratio for time between accident and first attendance for treatment (controlled for sex and age)

| Time (yrs) | OR   | 95% CI       |
|------------|------|--------------|
| 2-4        | 1.3  | (0.3, 5.2)   |
| 5-9        | 0.9  | (0.2, 3.4)   |
| 10-19      | 0.7  | (0.2, 2.5)   |
| 20+        | 0.5  | (0.1, 2.0)   |

Base: patients who had a MVA

DISCUSSION

No extreme values for the distribution of lordosis were observed. As can be seen from the statistics in Table 3 describing lordosis distribution, the mean (32.2) is quite close to the lower bound of the normal range (30). This indicates that just under half the patients in the study had abnormal lordosis which were less than the lower bound of the normal range. The percentages in Table 2 are the percentages of subjects in the given category who had abnormal lordosis.

Of the variables collected, having been involved in a MVA is most strongly associated with abnormal lordosis.

Eighty-two percent of patients who had been involved in a MVA had abnormal lordosis. The mean lordosis of patients who have been involved in a MVA is 26.1 (SD 11.4) compared with 36.4 (SD 8.4) for those who have not had a MVA. Figure 3 shows lordosis by years since MVA in comparison with patients who have not been involved in a MVA. This contrasts with the studies by Gore (3, 36) who found no relationship between cervical curve, injury, or degenerative changes in the cervical spine. Gore (36) studied 205 patients over a 10-year period and concluded there was no clinical correlation between a hypolordotic or kyphotic cervical spine and pain, degenerative changes or injury.

The unadjusted (not controlled for additional variables) odds ratio for MVA is 14.3 as shown in Table 4. This is consistent with the substantially increased incidence of abnormal lordosis in patients who had been involved in a MVA evident in Table 2. The confidence interval for this odds ratio means that there is a 95% probability that the true odds ratio lies in the range 9.2 to 22.3. This is consistent with a very small chance that the true odds ratio is in fact as low as one and suggests that even the smallest likely odds ratio in the population (9.2) is still large by any standard.

The remaining variables do not show strong association with abnormal lordosis (Table 2).
The odds ratio for MVA in Table 2 is very stable at between 14 and 15 when adjusted for the control variables. This indicates that none of the control variables - gender, age, occupation, symptom and neck pain confounds the relationship between MVA and lordosis. Moreover, none of these variables had statistically significant association with abnormality of lordosis in their own right. This contrasts the findings of Jochumsen(2). Jochumsen(2), who concluded 56% of patients with neck pain as a result of trauma had hypolordosis or kyphosis of the cervical spine versus the control group’s 36%. Jochumsen studied 500 patients but did not specify age restriction which affects the findings directly and is a limitation of that study. He concluded the following:

1. Patients with a straightening of the cervical curve are more disposed to cervical symptoms than patients without straightening.
2. Trauma to the neck is not the main or only cause of straightening of the cervical curve.

Bussieres(37) suggests 45-85% of patients who have suffered a whiplash injury resulting from a MVA will continue to experience neck pain after five years. Pedersen(7) concluded that cervical hypolordosis may be a normal variant and not necessarily related to a history of trauma. His study involved patients between the ages of 20-59.

Rechtman et al(22) concluded abnormalities associated with a loss of the cervical lordosis, decreased movement or flexibility relates to a whiplash injury, strain, sprain, fracture, dislocation, disc herniation, or soft tissue disturbance.

Plaugher et al(35) suggest the upper cervical spine can show an apparent increase in the cervical lordosis if a kyphotic cervical posture is present.

Kettner(8), Foreman(4) and Cramer(38) suggest a lack of cervical lordosis indicates a ligamentous injury or hypertonicity of the cervical anterior musculature. Hellisiwell(23) concluded that a loss of cervical lordosis results from variations on radiographic positioning. Kettner(8) suggests a chin depression of one inch will straighten the cervical spine curve in 70% of the population.

Jackson (20) explains a loss of cervical lordosis indicates a cervical spine disorder. She states that in 78% of patients with a history of trauma to the cervical spine, will have a loss of the normal cervical curve and that a cervical curve reversal will result in 20% of these cases.

Gay(1) concludes that an altered cervical curvature is of little prognostic significance. Macnab(19) concludes a loss of cervical lordosis is of some prognostic significance but may be due to a lowered chin position.

Fineman et al(11) studied 330 patient radiographs aged 17-75 years and another 129 patient radiographs to determine the lordotic measurements. He concluded a lowered-chin position changed a lordotic cervical curve to a kyphotic curve, a straightened cervical curve may be a normal finding, or may be associated with a cervical spondylisis deformans.

There was, however, a clear effect of time between accident and first attendance for treatment on the probability of lordosis (p<0.0001). Compared to patients who had less than one year between their accident and first attendance for treatment, there was a monotonic decrease in the probability of lordosis with increasing time as shown by the odds ratio (Table 5).

Following are two plausible hypotheses to explain the effect of elapsed time on lordosis as shown in Table 5:

1. The healing time effect: as time since an accident increases, abnormal lordosis resulting from the accident tends to correct itself naturally.
2. The accident severity effect: the patients in whom the most severe lordosis is caused by MVAs are the patients who seek chiropractic treatment soonest after their accident.

We recognise several limitations of this study. First, we chose to use the C1-7 angle of cervical curve method of measurement. We selected this method above several other methods because it is a relatively simple procedure to perform and it appears to be the most widely used method in chiropractic. However, this method does not assess if there are areas of hypolordosis which may give a false lordosis impression. That is, a normal value may be made if the atlas is hyperextended on the axis (C2), even though the remaining cervical spine has a greatly reduced lordosis.

Second, only one examiner marked the radiographs which was corrected by the second examiner only if examiner number 2 saw an obvious error in the marking procedure. This is not consistent with real life experience and may have affected inter-rater reliability. Further studies could remove these lines between each examiner making their assessments.

Third, because we employed a retrospective design, we did not control precisely for head tilt or correct for head tilt, which might affect lordosis measurements. Measuring Chamberlain’s line (platobasal line) could help determine if the radiograph was well positioned as in a well positioned film it should be horizontal.
Finally, neither the severity of MVA and injury nor the mechanism of injury was considered in our analysis.

CONCLUSION

The results of this study suggest a correlation between having been involved in a MVA and an abnormal lordosis. Eighty-two percent of patients with a history of MVA had a diminished lordosis. The significance of a “normal” lordosis of the cervical spine is controversial, but this study does reveal an association between the two variables.

The other variables studied including gender, age, occupation, presenting primary symptom and neck pain did not appear correlated to an abnormal lordotic measurement. Further research is needed to address the variables in a prospective large sample over many years duration.

Further studies are also necessary to address any potential relationship with the time period between the MVA and the first attendance to the chiropractic clinic. More evaluation is necessary to understand if there any causal link between the MVA and first chiropractic treatment, with a resultant smaller the abnormality of the cervical curve. A prospective study is needed to address this specific issue.

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