PATIENT PLACEMENT ERROR IN ROTATION AND ITS AFFECT ON THE UPPER CERVICAL MEASURING SYSTEM

Roderic P. Rochester, D.C.; Edward F. Owens, M.S., D.C.

ABSTRACT

Central to the theory and application of several chiropractic techniques is the assumed utility of x-ray analysis to measure with accuracy the position of the cervical vertebrae with respect to the skull. Yet, the validity of x-ray marking systems as a measure of the actual position of the vertebrae is still a matter of some debate. Early work has shown that upper cervical x-ray analysis needs to be accurate to within 1 degree to provide a useful pre-post measure of misalignment reduction. Interexaminer reliability studies have shown that x-ray analysis is in most cases repeatable enough to meet this goal. Another source of error in x-ray analysis for misalignment is that introduced by repositioning of the patient for the post adjustment radiographs. Repositioning errors could occur in which the patient has been displaced with respect to the central ray, or rotated.

This article is a presentation of the methods used to take the nasium radiograph in the Grostic Procedure of upper cervical chiropractic care, along with an analysis of the errors that might be introduced by rotational malposition of the patient for the radiograph.

A method was developed and tested for assessing the amount of patient to film rotation present on a nasium film. This method was used to assess the amount of rotation found in 20 of a practitioner's patient x-rays. A mathematical analysis was performed to calculate the amount of atlas plane line and altas laterality distortion that would be produced by patient to film rotation. Computer generated simulations of nasium x-rays with known skull to central ray rotations were used to test the algorithm produced and measure the amount of distortion in the atlas plane line and altas laterality induced by rotation.

The average amount of patient to film rotation found in a practitioner's records was 0.56 degrees (STD = 0.55 degrees). This amount of patient malpositioning was estimated to produce an average of 0.21 degrees artifact in the atlas plane line (STD 0.31 degrees). It was found that the distortion of the plane line depended on the amount of rotational malpositioning present and the tube tilt used to take the nasium film. Based on the model, the error in the atlas plane line reached a significant value (0.5 degrees) only when the patient to film rotation exceeded 1.5 degrees and the S-line was above 15 degrees. Based on measurement in this study the atlas laterality did not change significantly at 1.75 degrees of image rotation and a tube angle of 25 degrees. This amount of patient rotation is easily detectable by visual inspection of the nasium film and would probably necessitate retaking of the film in any event.

It was concluded that repositioning the patient for the post radiographic exam would not introduce significant error into the x-ray analysis, as long as proper procedure was followed to minimize rotation of the patient's skull with respect to the central ray.

Key Words: chiropractic, x-ray analysis, Grostic Procedure

INTRODUCTION

Central to the theory and application of several chiropractic techniques is the assumed utility of x-ray analysis to measure with accuracy the position of the cervical vertebrae with respect to the skull. Yet, the validity of x-ray marking systems as a measure of the actual position of the vertebrae is still a matter of some debate.

Grostic and DeBoer(1) were among the first to publish research findings to show that there was a reduction of atlas laterality following an adjustment. They reviewed 523 pre and post-adjustment x-rays from a chiropractor's office and compared the average atlas lateralities before and after the adjustment. The pre-adjustment average was 2.63 degrees and the post adjustment average was 1.40 degrees. This retrospective study was corroborated by a similar study carried out in New South Wales by Aldis and Hill (2). While these studies did show that chiropractic adjustment produced an average decrease in the atlas laterality, neither study was able to estimate the measurement error involved. There was also an uncontrollable bias in these studies since all the measurements were made by the chiropractor managing the patients' care.

Indeed, as Sigler and Howe pointed out, there are several possible sources of error involved with using x-ray analysis to determine adjustment factors and monitor upper cervical misalignment (3). The value of pre-post changes is determined to some extent by:

A) intra- and inter-examiner reliability of measurements,

B) repeatability of radiographic procedures, including patient positioning,

C) x-ray distortion inherent in radiographs,

D) the normal fluctuation of the atlas relative to daily activities.

As a first test of measurement error, Sigler and Howe carried out a reliability study of the atlas laterality measurement. They had two experts mark and re-mark ten films each for atlas laterality and found a range of error of 0.82 and 1.10 degrees. Based on these findings, Sigler and Howe concluded that upper cervical marking systems were not accurate enough to be relied upon for patient adjustment or the determination of alignment improvement.

In a letter to the editor of JMPT (4), the Sigler and Howe study was later criticized for using films of poor quality, not briefing the examiners on the objectives of the study and statistical problems in relation to their use of the Bartko formula.

Since that time, at least three studies have been carried out which refute the findings of Sigler and Howe. Jackson et al (5) found a mean standard error of only 0.41 degrees among six experts in a study of x-ray marking error. In a later study Jackson et al found a mean standard error of 0.47 degrees with three experts participating (6). In yet another study, Rochester found a mean standard error of 0.45 degrees with four doctors tested (7).

Keating and Boline published a paper comparing some of the above studies of x-ray marking error and compared it to Grostic and DeBoer's finding of an average reduction of 1.20 degrees in atlas laterality following an adjustment. To have adequate precision of the x-ray marking system, the 95% confidence interval (+/- 2 times the standard error of measurement) must be less than 1.20 degrees (precision criteria). They concluded that the measurement system is sometimes precise enough to detect small changes in atlas laterality (8).

It is possible to compile the results from all of the reliability studies noted above in order to see how they compare to Keating and Boline's assessment of precision. In those studies a total of fifteen separate doctors have been tested for reliability. Figure 1 is a chart of the reliability of each film reader with respect to the 1.2 degree precision criterion. Twelve of the fifteen experts (80%) tested have a 95% confidence interval below the 1.20 degrees precision criteria. Hence, based on the inter-examiner reliability studies reported to date: The measurement system is precise enough to detect 1.20 degrees change in atlas laterality, for 80% of the experts tested.

While previous reliability studies tested only atlas laterality, Rochester (7) went further to test nine other aspects of the x-ray marking system for the Orthospinology (Grostic) procedure as well. Based on the same type of error analysis used by Keating and Boline, it was concluded that all aspects of the upper cervical marking system are sufficiently reliable to assess the magnitude of pre- to post-adjustment changes that are seen clinically.

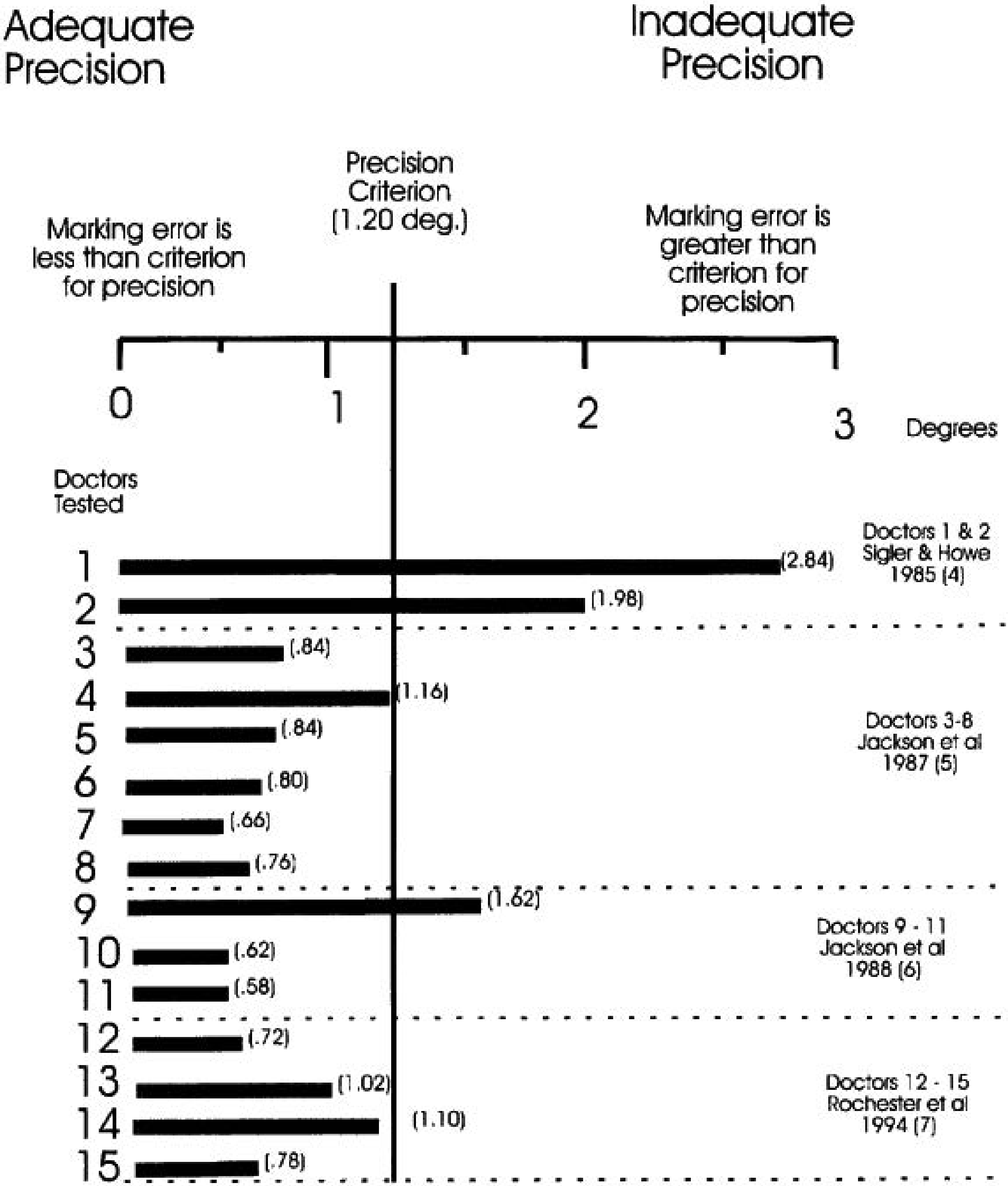


Figure 1.
Relationship between measurement error and precision of measurement of each doctor tested. Graph represents the intraexaminer 95% confidence intervals (+/- Std. Error of Measurements) compared with expected reduction in C1 laterally (precision).

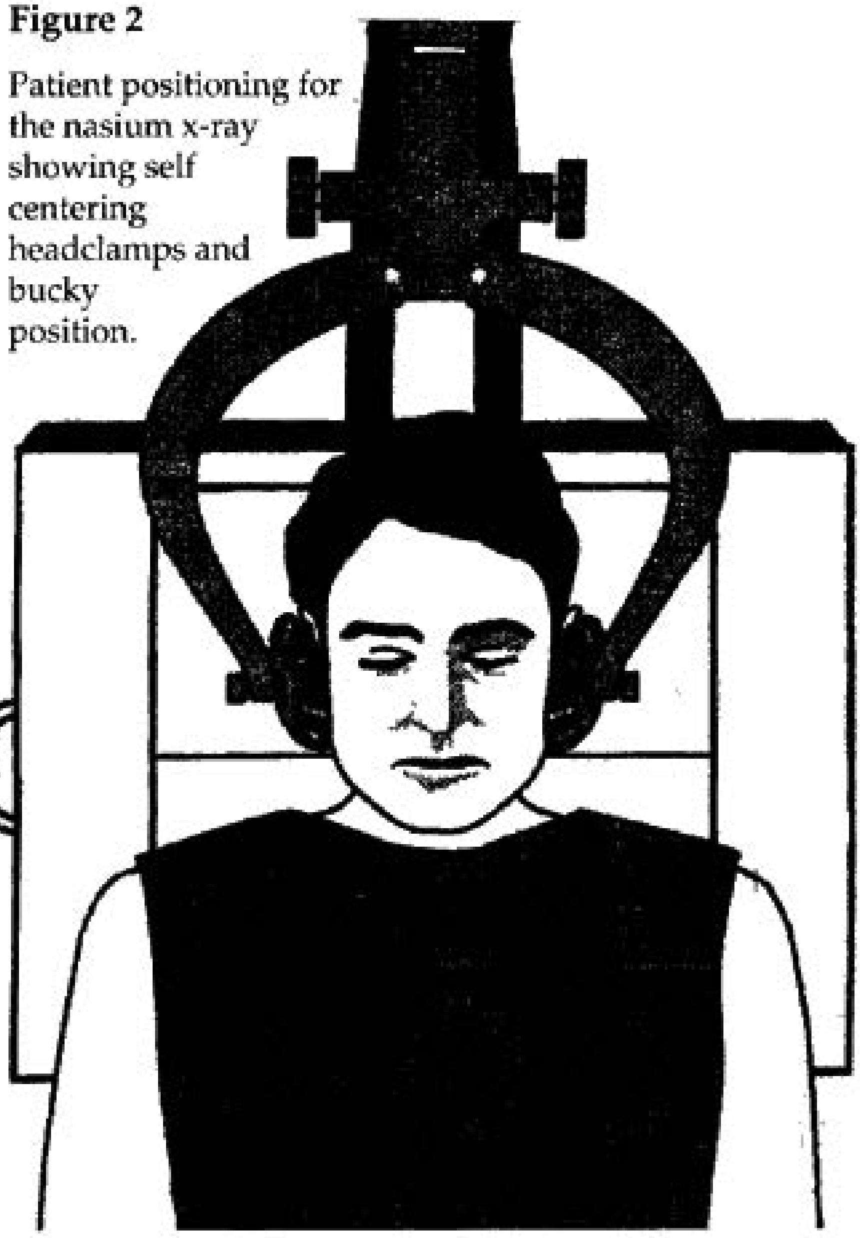
If the x-ray marking system is precise enough, then the next source of error that needs investigation is patient placement for the radiographs. Can a patient be x-rayed, and then, sometime later, positioned, and re-x-rayed with enough precision for the radiographs to be comparable?

Upper cervical techniques that rely on pre-post radiographs generally use special procedures to enhance the repeatability of x-ray positioning. In the Orthospinology (Grostic) technique, practitioners use a turntable chair, a tilting grid cabinet or bucky, an x-ray tube that tilts, and self-centering headclamps with an alignment rod to take the view as precisely as possible.

One important radiographic view used in upper cervical x-ray analyses derived from the Grostic Procedure is called the nasium view. It is an A-P projection that is taken with the x-ray tube tilted to pass along the S-line. The S-line is measured from the lateral cervical view and represents the best line of sight for resolving the inferior points of attachment of the posterior arch to the lateral masses (landmarks which are used to define the Atlas Plane Line). The tube angle will vary from patient to patient depending on the plane of the atlas seen on the lateral view.

Figure 2

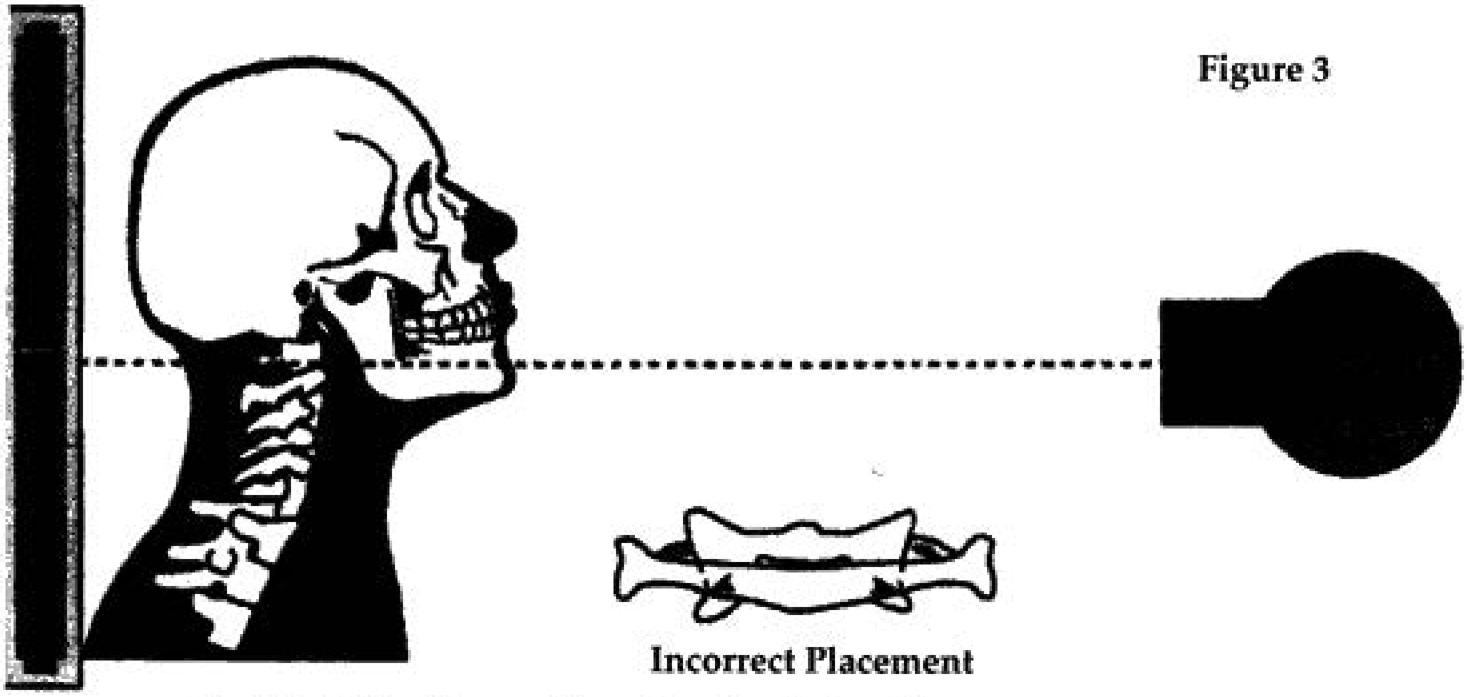
Patient positioning for the nasium x-ray showing self centering headclamps and bucky position.



For the nasium view, the patient is seated in a natural position in a turntable chair facing the x-ray tube. The patient is centered, by moving the turntable chair, without allowing the patient's head or shoulders to touch the grid cabinet. The grid cabinet is set at an angle to conform to the posterior aspect of the head and shoulders. The x-ray tube is set so that the central ray passes through the atlas, in the plane of the S-line and strikes the film at a point within one inch of its center.

Using the alignment rod, the chair is rotated so that the skull has no visible rotation and is centered to the film. Postural head rotation as compared to the thorax or head tilt is not removed manually. Next, the chair is moved back until the patient's head and shoulders touch the grid cabinet. The posterior aspect of the head

Figure 3



Incorrect Placement

1. Grid cabinet does not touch head and schoulders.
2. Chin elevated.
3. Central ray projects inferior to proper S-line, creating a low posterior arch, obscuring the inferior attachments.

should touch ahead of the shoulders if the grid cabinet angle is set correctly. The self centering head clamps are positioned to cover the atlas transverse processes. The headclamps are tightened, the tube angle, head rotation and central ray position are rechecked and the film is exposed. Figure 2 shows the position of a patient for a nasium radiograph, demonstrating the use of the self centering headclamps. Figures 3 and 4 show the inclination of the central ray and the appearance of the landmarks used in x-ray analysis of the Atlas Plane Line.

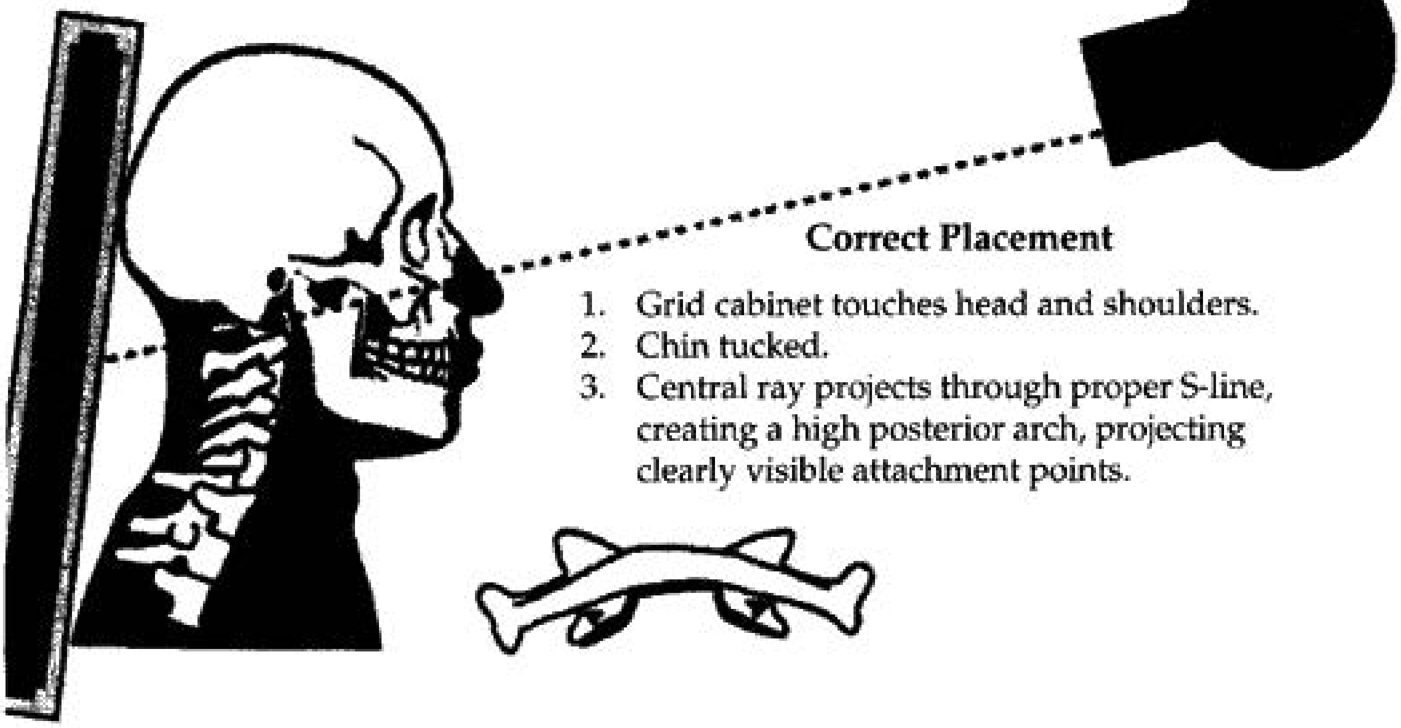
Most upper cervical doctors use filters or a split screen cassette to maximize the sharpness of the various densities of structures. They use a thicker filter or slower screen for the upper portions of the film so the skull surfaces are very sharp, a medium filter or screen for the upper cervical area and a thin filter or faster screen for the lower cervical area.

This type of x-ray procedure has been in use since the early 1950's, when Travis Utterback, working with John F. Grostic, D.C., developed the self centering head clamps for use in the Grostic Procedure. The developers of the Grostic Procedure no doubt felt that pre-post repeatability was good enough for clinical use, however; there have been no reports of an error analysis for x-ray positioning methods.

It would be easy enough to set up a blinded experiment to test this hypothesis, however, it would involve submitting the participants to repeated radiation exposures, without intervening treatment. As pointed out by Keating and Boline (8), such an experiment should not be done on humans, due to the hazards of radiation.

A safer, more ethical approach would be to analyze the problem logically and mathematically to assess the possible effects of

Figure 4



patient positioning on x-ray repeatability. Patient positioning error can be broken down into two subdivisions: location of the patient with respect to the central ray, and postural changes that may affect head tilt or vertebral alignment.

This paper will address the first source of error, that of patient to film placement. If the patient is in the same anatomic position, then patient placement compared with the film could have two separate components: the image could be displaced vertically or horizontally with respect to the central ray, or the patient may be rotated with respect to the film plane.

When the pre image is higher or lower on the film than the post, it would make little difference in the comparison of the images as long as the x-ray equipment and self centering head clamps are aligned properly, the central ray was aimed through the atlas at the angle of the S-Line, and all of the structures that are necessary for the measurement process are visible. Any distortion that takes place, due to divergent rays, penumbra, etc. would be equally distributed, not affecting the measuring process.

A greater contribution to positioning error would be due to patient rotation. Rotational malpositioning could create an apparent change in the measurement of the atlas plane line, mainly because the plane in which the atlas would be rotating during patient placement is not necessarily the same as the plane of the incident x-rays. Even though the central ray may pass through the atlas, because of the tube angle the atlas may appear tilted on the nasium film.

During patient placement, the patient's head rotation is removed with respect to the film by turning the chair in which the patient is seated and not by having the patient turn their head. If the image of the skull on the film has rotation, it is because the examiner did not remove all of the rotation with the turn table chair. Geometric projection distortion occurs when the patient's S-Line angle and thus the tube angle are not parallel to the floor and image rotation is present on the x-ray film. This distortion could affect the Center Skull Line, Atlas Plane Line (APL), C2 spinous and lower angle measurements. For this reason, in the upper cervical work, films that have "noticeable" image rotation are to be retaken.

It was the first goal of this paper to assess the typical amount of patient rotation malpositioning found in the nasium x-rays of a chiropractor's records. Next, we intended to demonstrate geometrically what effect the rotational malpositioning would be expected to have on the x-ray analysis results.

METHODS

Measuring Patient Rotation from the Nasium X-ray: Patient rotation on an x-ray film was determined by digitizing points on the lateral and nasium x-ray sets and calculating a rotation angle based on trigonometric relationships. The medial portion of the eye orbit (medial orbital ridge at the lacrimal bone) is easily identified on the nasium film and was used as the chief landmark on that film. The distance between the bilateral medial orbital ridge points and the lateral skull surface was measured for each nasium film using a digitizer tablet and computer software. This value, as well as the distance in the z-axis plane between the odontoid and lacrimal bone measured from the lateral film was used to calculate image rotation according to the following formula:

Image Rotation = ARCSIN([-(A-B)/2]/R)
(Equation 1)

Where "A" is the distance from the medial orbital ridge and the lateral skull surface on the right side, "B" is the same measurement on the left side, and "R" is the distance from the dens to the lacrimal bone as seen on the lateral x-ray. A positive value for image rotation represents clockwise rotation, i.e. image rotation to the right on the nasium film.

Twenty randomly selected nasium films from the active patient files of the first author were analyzed for radiographic image rotation. The results were tabulated for use as an estimate of the amount of image rotation expected in a typical upper cervical x-ray.

In addition, an algorithm was developed, based on the amount of patient rotation and the S-line at which the film was taken, to calculate the degree to which patient rotation could affect the inclination of the atlas plane line. Again, based on trigonometry, it can be shown that the equation for rotation induced artifact is:

Delta Plane Line = ARCSIN[(tan H * tan S)]
(Equation 2)

Where "H" is image rotation and "S" is the S-line/tube angle in degrees. The above relation was derived by considering how anterior and posterior movement of bilateral atlas landmark points due to rotation would produce apparent atlas tilting as the points pass above or below the central ray.

Using Computer simulated x-rays to test the algorithm. The rotation algorithm was tested for accuracy against known rotations in a computer model. The model used is a digitized skull and cervical skeleton (Viewpoint DataLabs, Orem, Utah) that is manipulated using 3D Studio animation and rendering software (AutoDesk, Inc.) operating on a 486-DX2 MS-DOS compatible computer. 3D Studio is used to position the model in front of simulated cameras and lights that represent the viewpoint of the central ray used for a nasium radiograph and mimic the projection distortion inherent in radiographs. The "view angle" or tube angle was set at twenty-five degrees (the S-line angle measured from a lateral view of the model). Test films were generated by rotating the whole skull/cervical spine model with respect to the central ray and rendering the view to a graphics file with pixel resolution 2560 x 1920. The graphics file was then printed and sent to the first author for analysis. The model itself is perfectly symmetrical and was staged with correct relative positioning of the skull, atlas and lower cervical spine, i.e.; atlas laterality and the lower angle were equal to 0 degrees.

Five simulated nasium radiographs were produced in this way, with model to central ray rotation varying from 0 to 10 degrees. The examiner, who was blinded to the amount of rotation each image represented, then analyzed the simulated films for skull image rotation, central skull line angle, atlas plane line angle, C2 spinous and lower angle measurements. The examiner analyzed the simulated film with the computer digitized upper cervical measurement program, "The DOC!" (Roderic P. Rochester, D.C., 530 S. Main Street, Woodstock, Georgia 30188) without placing pencil marks on structures. This allows unbiased re-reading of the films. The examiner analyzed each film six times for a total of thirty readings. Once all data was compiled, the input rotation amounts were then compared to the measured rotation amounts to obtain an accuracy accounting. Also observed were any measured differences in Atlas Laterality (the angle formed by the central skull line and atlas plane line), C2 Spinous and Lower Angle components. These measured amounts were then compared to the "distortion" predicted by the mathematical algorithm.

RESULTS

Typical patient to film rotations:

Table 1 shows the factors that were measured from twenty actual patient x-rays. The average calculated image rotation was 0.56 degrees (SD = 0.55 degrees). The average S-line angle in degrees of these twenty films was 17.7 degrees (SD = 7.7 degrees), the average chord angle (the angle formed between the y-axis and a vector connecting the tip of the odontoid to the posterior- inferior aspect of the body of C7 on the lateral view), was 11.7 degrees (Std. Dev. 2.5 degrees).

Accuracy of image rotation calculation:

Table 2 shows a comparison between the actual image rotation in the computerized model and the image rotation measured from simulated x-rays of the model. The average actual image rotation of the five films is 4.550 degrees. The average standard error between the actual rotations and the measured rotations is 0.681 degrees representing a 14.97% error.

Accuracy of atlas laterality artifact algorithm:

Table 3 displays the object rotation, the calculated artifacts and measured distortion of the plane lines and atlas lateralities for the five computer simulated films. For example, film three has an image rotation of 0.50 degrees that results in a measured plane line distortion of 0.28 degrees. The measured atlas laterality distortion, however, was zero degrees, suggesting that this amount of image rotation does not affect the measuring of atlas laterality. The average of the pre-

Film #	Rotation	S-Line Angle	Chord Angle	Plane Line Distortion
1	R0.42	21.00	13.75	0.16
2	R1.04	25.00	08.00	0.49
3	0.00	25.00	08.00	0.00
4	R2.55	29.00	16.00	1.41
5	L0.43	29.00	16.00	0.24
6	0.00	29.00	16.00	0.00
7	R0.43	18.75	13.00	0.15
8	R0.43	18.75	13.00	0.15
9	L0.43	18.75	13.00	0.15
10	R0.50	11.50	11.00	0.10
11	R0.50	11.50	11.00	0.10
12	0.00	11.50	11.00	0.00
13	R0.25	11.50	11.00	0.05
14	R0.63	14.00	13.00	0.16
15	R0.84	14.00	13.00	0.21
16	R1.10	23.50	09.00	0.48
17	R0.73	23.50	09.00	0.32
18	0.00	06.50	09.50	0.00
19	R0.40	06.50	09.50	0.05
20	R0.61	06.50	09.50	0.07
Average	0.56 deg	17.74 deg	11.66 deg	0.21 deg
Std. Deviation	0.55 deg	07.51 deg	02.52 deg	0.31 deg

Table 1:

Twenty nasium films and their image rotation, S-line Angle, Chord Angle and estimated plane line distortion.

Film #	1	2	3	4	5	Average
Rotation (actual)	L 4.500	L 1.750	R 0.500	R 9.250	L 6.750	4.550 deg.
Rotation (measured)	L 5.597	L 1.591	R 0.572	R 9.831	L 6.821	4.882 deg.
Std.Error	1.243	.252	.110	.936	.865	.681 deg.

TABLE 2:
Comparison of actual rotation to rotation measured on simulated nasium x-rays. The measured rotations were based on digitized data and a calculation described in the text.

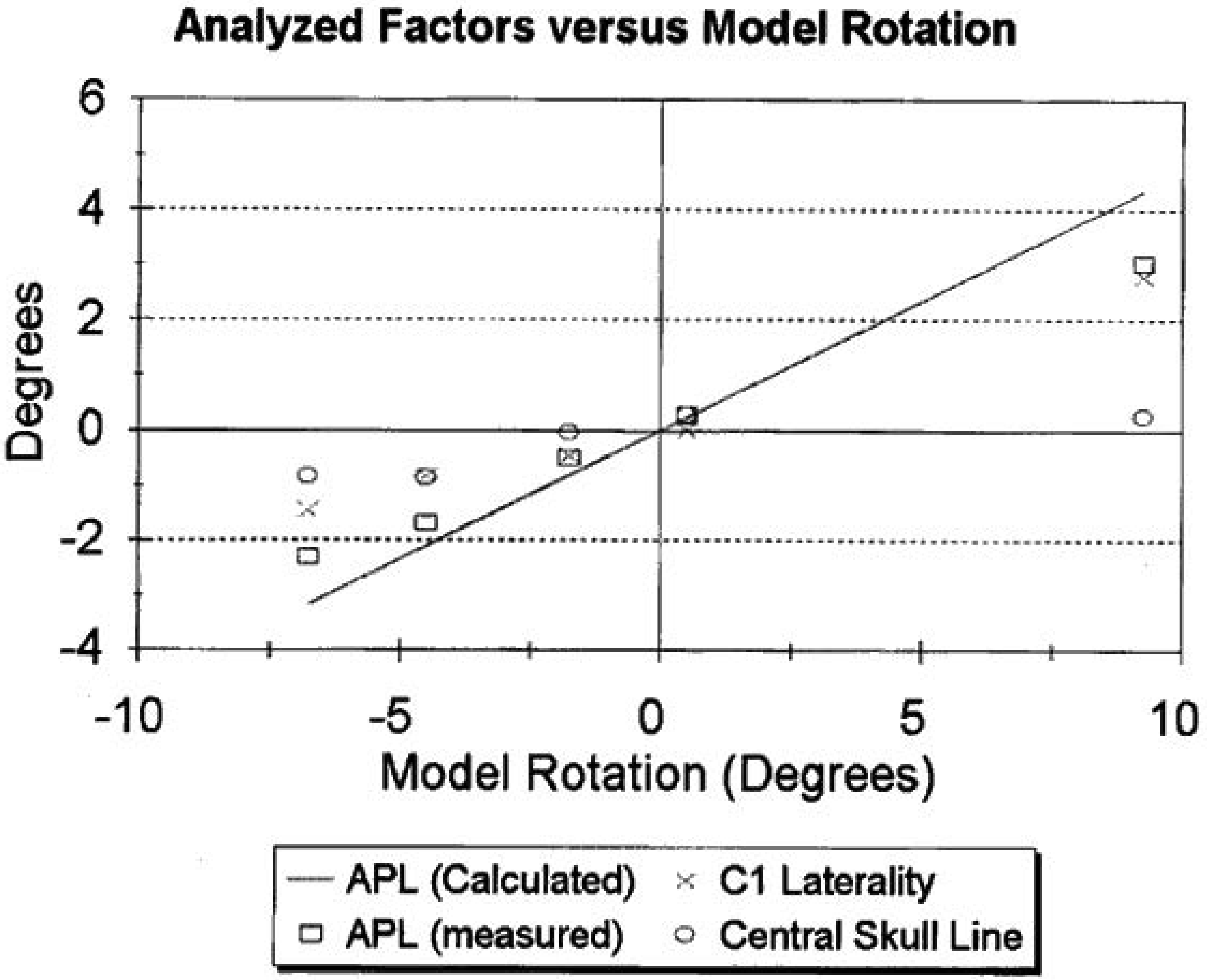
Film #	1	2	3	4	5	Average
Plane Line (measured)	- 1.69	- 0.51	0.28	3.05	- 2.30	1.565 deg.
Plane Line (predicted)	-2.10	-0.82	0.23	4.35	-3.16	2.134 deg.
Std. Error	0.414	0.318	0.219	1.058	0.768	.555 deg.
Central Skull Line	-0.86	-0.05	0.28	0.26	-0.84	0.456 deg.
Cl Lat.	- 0.83	- 0.46	0.00	2.79	- 1.46	1.108 deg.
C2 Spinous	0.96	0.00	- 0.21	-5.50	2.96	1.925 deg.
Lower Angle	1.08	0.08	- 0.21	-2.37	1.42	1.033 deg.
Image Rotation	- 4.50	- 1.75	0.50	9.25	- 6.75	4.550 deg.

TABLE 3:
Mean measurements of computer simulated nasium radiographs with known amounts of image rotation. Each film was read six times. "Average" is the absolute mean of all 30 readings.

dicted plane line distortion was 2.29 degrees for the five simulated x-rays, while the measured distortion averaged 1.57 degrees (standard error = 0.56 degrees).

Figure 5 shows selected portions of the data from Table 3 in a graphical format. The calculated or measured factors are plotted with respect to the rotation of the cervical model. The solid line represents the calculated APL expected for given values of object rotation, based on equation 2. From the graph, it can be seen that the relationship between the calculated APL and model rotation is very nearly linear in the range of -10 to 10 degrees. The measured APL follows the calculated APL but tends to underestimate it. The Central Skull Line, on the other hand, is not closely related to model

Figure 5



rotation, and does not appear to behave symmetrically.

Atlas Laterality is measured as the acute angle formed by the Central Skull Line and the Altas Plane Line. The average measured atlas laterality was 1.11 degrees compared to the average plane line distortion of 1.57 degrees. While the central skull line is also distorted by rotation, apparently, it is affected in such a manner as to reduce the net distortion of the atlas laterality measurement. In other words, geometric distortion tends to shift the central skull line in the same direction as the atlas plane line, and reduces the effect of the distortion on atlas laterality.

Calculated atlas plane line artifact:

Using our algorithm to calculate the effect of patient to film rotation it is estimated that the average error between the atlas plane line on the nasium film and the patients' actual atlas position was 0.21 degrees (standard deviation .31 degrees) and results in no measurable difference in atlas laterality.

DISCUSSION

An algorithm was developed and tested which can be used to calculate the amount of artifact induced in the atlas laterality measurement by patient to film rotation during placement for the nasium radiographic view. Further, it is possible to measure, on a nasium radiograph, the amount of patient to film rotation that was present during the taking of the film. Based on a sample of radiographs from a doctor's files, it was shown that patient repositioning had no significant effect on the atlas laterality measurement.

The algorithm shows that the amount of artifact in atlas laterality depends on the amount of skull rotation and on the angle of the central ray used to take the nasium film. It is expected that a tube angle of zero degrees (S-Line of 0) would result in no measurable difference in atlas plane line even for high magnitudes of rotation. Based on the model, the error in the **atlas plane line** reaches a significant value (0.5 degrees) only when the patient to film rotation exceeds 1.5 degrees and the S-line is above 15 degrees. Based on measurement in this study the **atlas laterality** did not change significantly at 1.75 degrees of image rotation and a tube angle of 25 degrees. This amount of patient rotation is easily detectable by visual inspection of the nasium film and would probably necessitate retaking of the film in any event.

The typical amount of patient to film rotation detected in a doctor's patient files was 0.56 degrees, well below the amount needed to produce a significant change in atlas laterality. Further, experts in upper cervical work use a simple technique to minimize tube angle. Tucking the chin for the nasium film reduces the tube angle by as much as ten degrees and produces an acceptable nasium film. Owens and Hoiriis in a 1990 study found a mean of 13.56 degrees for the S-line angle using computer assisted digital analysis of 115 radiographs (9).

Based on this work, it is recommended that when high S-lines are present, the patient's chin should perhaps be tucked for the taking of the nasium radiograph. Minimizing the tube angle in this manner would help limit the error that might be induced by patient to film rotation and make pre-post film taking more reliable. It is not known to what extent tucking the chin might affect upper cervical alignment, however.

Based on this study and the results of recent reliability studies, it should be accepted that neither measurement error, nor patient to film positioning error could account for the magnitude of pre to post changes typically seen by upper cervical practitioners. This suggests that changes in atlas laterality on the order of 1 degree or more, measured from pre and post nasium x-rays represent actual changes in the relative positioning of the skull and atlas.

It still, however, remains to be demonstrated whether the changes in atlas/skull relationship are due to the chiropractic adjustment, or simply to changes in patient posture. Further study is still hampered by the problems associated with exposing patients to unnecessary radiation.

CONCLUSION

This study demonstrates that the source of error of image rotation on the nasium film would be expected to have little or no effect on the measurement of atlas laterality when considering the amount of image rotation normally seen in patient films.

It is also concluded that something other than x-ray marking error or image rotation error is responsible for the 1.20 degrees of change in atlas laterality following an adjustment, reported by Grostic and DeBoer (1).

ACKNOWLEDGMENTS

Sincere appreciation is extended to Dr. John D. Grostic, The Sid E. Williams Research Center at Life College, Roger K. Rochester and Jeff Howard for their contributions to this study.

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