Cineradiographic Studies of the Normal Cervical Spine

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• **By considering the cervical spine as several segments with relatively different motions, an understanding of the total possible motions of the cervical spine can be more easily attained.**

Reversal of the cervical lordosis is a normal part of the flexion action and can result from positioning of the patient for radiographic studies.

The effect of standing or sitting postures, and methods of initiating flexion of the neck should be considered in the evaluation of routine flexion and extension studies.

Evaluation of individual cervical segments may be accomplished by the use of different methods of initiating flexion.

APPLICATION of cineradiographic methods to studies of the motion of the cervical spine has supplied information for detailed evaluation and review of the movements of the various joints involved.

General considerations: The function of the cervical spine utilizes a complex combination of motions. By studies of the cervical spine segment by segment, each of which has certain motions, it can be seen that the total possible motion of the cervical spine entails an interrelation of individual segmental motions.

The cervical spine consists of five segments showing the "usual" motions, and two transitional vertebrae (the first and the seventh) which may share the motion of the other cervical vertebrae but may also show motion corresponding to that of the next adjoining area. Thus, in the atlas, motion may be observed corresponding to that of the axis, or it may function independently, its motion resembling that of the occiput. It thus simulates a washer or bearing between the skull and the spine, its motion corresponding more closely to that of the skull than to that of other cervical segments. The seventh cervical vertebra shows less motion than the other cervical vertebrae and thus acts more like the thoracic vertebra. If the seventh vertebra becomes sufficiently fixed by disease, by cervical ribs or by long transverse processes, the sixth cervical vertebra may assume its function. The actions of the atlas, however, are sufficiently specialized so that its function cannot be satisfactorily assumed by the other cervical segments. This is particularly true of rotation.

From the standpoint of function, the central cervical segments, the second to the sixth, may be subdivided into *upper* (the second and third), *mid* (the fourth and fifth) and *lower* (the sixth) segments. In such a subdivision the next subjacent intervertebral disc is considered as part of that segment. In a healthy adult the midcervical segment is considered the most active. It has been generally accepted as fact that motion at the fourth and fifth cervical vertebrae (including the disc between the fifth and sixth) is greater than in other portions of the cervical spine. The increased function here has been considered the cause for early development of degenerative changes at this point. The lower cervical segment and the upper cervical segment are approximately equal in function. The difference in mobility between the cervical segments is more apparent in flexion than in extension—that is, the curve of the cervical spine in full extension is smoother than the curve when the spine is in flexion. In flexion, posterior bowing is most pronounced at the midcervical segment, with this segment developing a reversed lordosis when produced by causes other than disease of the spine.

Buetti-Baüml[1] studied the motions of the cervical spine from angles formed by lines drawn along the posterior aspects of vertebral bodies examined in the flexed and extended attitudes. The postulations as to segmental mobility described in the preceding paragraphs agree with his data. In the present study, in order to duplicate the muscle action in the group studied, it became evident that the following factors had to be controlled.

Position: The first group of patients had routine static films in a sitting position but cineradiographs were obtained with the patient in a standing position. The next group of patients, therefore, was studied in both sitting and standing positions by routine films and cineradiographs. Review of the static films showed that in the standing position the amount of extension was reduced and flexion appeared to occur at a lower level. Thus, when standing, the amount of posterior bowing of the midcervical segment produced by flexion was less pro-

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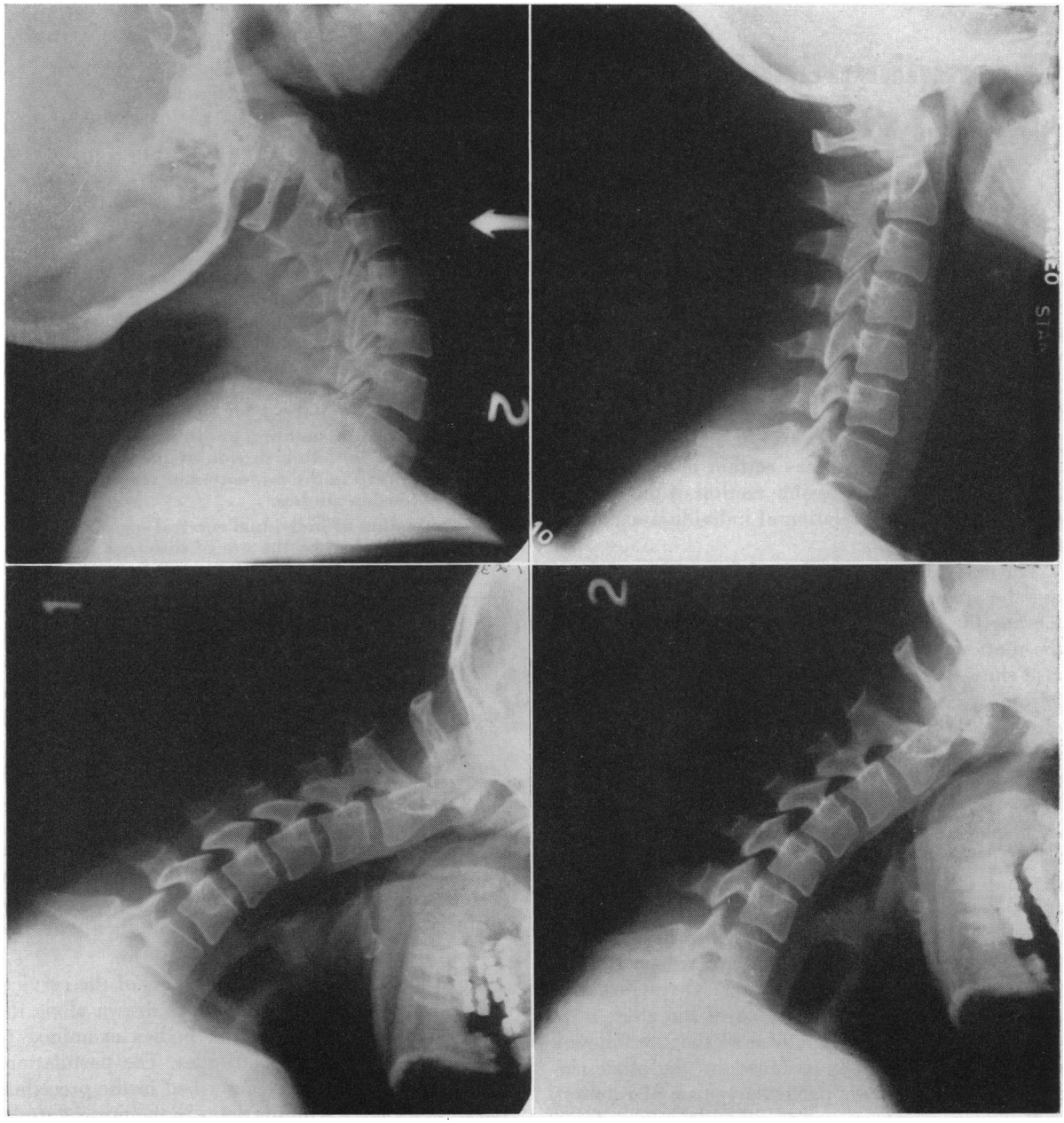

Figure 1.—Flexion and extension studies in a normal 30-year-old woman. *Upper left,* cervical spine in controlled extension. *Upper right,* cervical spine in neutral standing position. *Lower left,* cervical spine in controlled flexion, using chin-motion 1 (described in this article). *Lower right,* cervical spine in controlled flexion, using chin-motion 2.

nounced than when sitting. The degree of glide between the vertebral bodies was also curtailed in the standing position, particularly in extension. This differential motion was more easily demonstrated on the static films than on the cineradiographs but, until appreciated, made correlation between the static and moving films difficult in some cases.

Method of initiating flexion: Comparison between two sets of films made on the same person on the same day showed, in the two instances, a different curve of the cervical spine. In the first study the neck had been flexed and the chin then pulled in, whereas on the second set of films, the chin had been pulled in first, and the neck then flexed. A series of patients were examined in which the patient first flexed the neck without moving the shoulders, and with the head semi-extended. When the maximum range of such motion was attained, the chin was pulled in. This will be referred to hereafter as chin-motion 1. Films were next made with the patient's chin pulled in to the greatest extent, and the neck flexed to the maximum (chin-

motion 2). These studies were made in both standing and sitting positions.

The effect of the two different head motions (Figure 1) was to produce an accentuation of the midcervical reversed lordosis when chin-motion 2 was used. With chin-motion 1, greater flexion in the lower cervical segment and less reversal of the normal midcervical lordosis was observed. On the cineradiographs it was seen that chin-motion 1 caused the head to go into relative extension, straightened the midcervical lordosis and resulted in early flexion at the cervicothoracic junction. As flexion continued, there was gradual development of the expected reversed lordosis in the midcervical segment. This lordosis, however, became pronounced only after the chin had been fully drawn in.

With chin-motion 2, the first change was that of backward motion of the lower cervical segment, which produced straightening of the lordosis at this level, and a forward movement of the upper segment. By forcibly pulling in the chin, it was possible to produce a sharp posterior angulation of the midcervical segment. As the flexion action continued, the lordotic reversal in the lower cervical segment progressed and the sharp angulation lessened. The total flexion in the lower cervical segment with this particular motion was less than that seen with chin-motion 1.

When chin-motion 1 was used to produce flexion in the sitting position, the curve which the spine developed approximated that seen in the films taken in standing position. A greater reversal of the lordosis still occurred, however, in the sitting position.

By utilizing these various motions, it is possible to study almost selectively the potential motion of the individual cervical segments.

Specific consideration: As a patient ages, there is general reduction in the segmental and total motion of the cervical spine. If focal degenerative changes are present, one segment may lose its major action and other segments assume its function. In childhood, the upper cervical segment is more active because of the position of the scapula and clavicle. As these bones descend, the midcervical segment assumes the greatest action. Later the motion once more becomes proportionately greater at the higher levels as decreased function from degeneration affects the mobility of the midcervical segment. The total motion pattern of the cervical spine of any one person is rather characteristic of that person. This is reflected in the varying forms of the spinous processes, the shaping of vertebral bodies and the varying muscular development. Thus, there is no one average motion that can be ascribed to the cervical spine but rather a range of normal motions. In one person, elongated transverse processes of the seventh cervical vertebra caused restriction of the flexion action in the lower cervical segment when studied in the standing position. This restriction was not as apparent in the sitting position. Such elongated processes may require the same consideration applied to a transitional lumbosacral vertebra.

INDIVIDUAL JOINT MOTION

In his report on cineradiographic studies of the cervical spine, Fielding[2] described in detail the various motions possible. Only a brief résumé of such motions will be given here.

Occipito-atloid: Only flexion and extension are observed at this joint. The degree of these motions as related to total cervical spine motion depends upon the position in which the head is held. The motion occurs independently or in combination with atlanto-axial motion. Evaluation of this joint can be accomplished by observing a nod motion with rather strong extension component. The posterior arch of the atlas can be observed in some persons to nestle in the impression on the occipital bone when the head is fully extended.

Atlanto-axial: This joint allows most of the rotation of the head, other cervical segments coming into action only in extreme rotation. Flexion and extension can be observed separately or in conjunction with occipito-atloid motion, as in the nod. In extension and flexion the anterior arch of the atlas can be observed to move up and down on the dens. Fielding reported a telescoping action of the atlas on the dens during rotation owing to the comparative form of the articulating facets. This action was not observed in the present study but may not have been adequately demonstrated.

The importance of the transverse ligament-dens relationship was observed in three patients with congenital fracture of the odontoid. In these patients, a reverse curve of the midcervical segment could not be produced in extreme flexion. Flexion of the head occurred almost entirely in the atlantal-axial joint with only a straightening of the midcervical lordosis.

General cervical motion—zygapophyseal: During flexion from the neutral position, the zygapophyseal joints showed the greatest change. This variation occurred when the intervertebral discs were undergoing alteration in shape, the change being from that of a wedge with its greatest width anteriorly, to a parallel form. The fulcrum of motion at this time appeared to be shifting from a point approximately at or slightly behind the posterior aspect of the vertebral body, to a point approximately at the midpoint of the body. As flexion continued, upward and forward glide of the zygapophyseal joints was

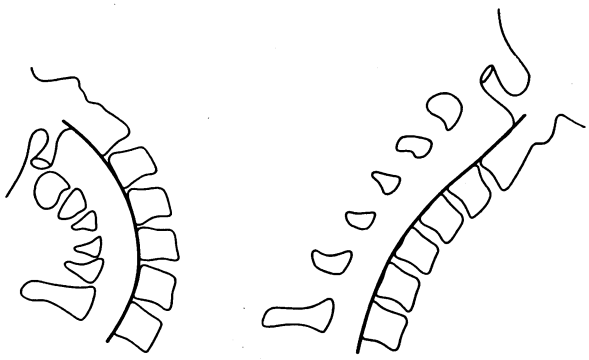

Figure 2.—Diagram of cervical spine in flexion and extension. A smooth curve is produced along the posterior aspects of the vertebral bodies in extension. The curve traced along the posterior aspect of the vertebral bodies when the neck is flexed shows the form of a bow rather than an arc. This reflects the varying degree of participation of the cervical segments in the flexion action.

observed until there was only minimal apposition of the superior surface of the inferior facet with the inferior surface of the superior facet. The second and third cervical facets, which tend to be smaller and asymmetric, showed less pronounced motion in adults. At the extreme of flexion, the facets tended to be angled on each other. This allowed the spinous processes to spread. Widening of the superior segment of the zygapophyseal joints was produced by continued extension after the maximum range of downward glide was reached.

Intervertebral discs: The intervertebral discs showed two motions during flexion—anterior glide of one vertebral body on the adjoining body, and change in shape of the intervertebral disc. As the head moved from the neutral to flexed position, the anterior height of the intervertebral disc decreased and the posterior vertical dimension widened. The forward glide developed later in the course of the flexion. The combination of these two actions resulted in a rocking motion. The overriding of the anterior inferior margin of one vertebral body on the anterior superior surface of the next inferior body would account for the frequently seen notch or irregularity of the inferior body. In maximum flexion, the discs in the midcervical segment were wider in the posterior than in the anterior dimension. This was more evident and constant in the midcervical segment. This difference in mobility produced a curve along the posterior surfaces of the vertebral bodies which was smooth but shaped like a bow rather than a semi-circle (Figure 2).

As extension occurred, there was downward and posterior glide of the zygapophyseal joints until the impingement of the spinous processes limited further extension. If extension was forced after the zygapophyseal joints completed maximum slide, further opening of the discs appeared. This resulted from some further leverage of the discs, with the zygapophyseal joints acting as the fulcrum.

Combined motion: The cervical spine actually functions by combinations of the above motions. When a patient suffering from pain in the cervical area places his head in the position accentuating pain, he tends to swing the head in circles. Cineradiographs recorded during this motion demonstrate a combined flexion-extension and rotary motion with upward and forward glide of the zygapophyseal joints of one side, and a downward and backward glide of the opposite side. The changes of the discs observed in flexion and extension can be observed at the same time. Side-to-side bending is limited in the cervical area; thus, narrowing of the lateral margins of the discs is not as pronounced a phenomenon.

Equipment used: A commercial model Westinghouse Cine Fluorex unit was used in all these studies. Radiation exposure was measured at the skin surface by means of a Victoreen rate meter, and for an average person measured approximately 3.4 roentgens per minute in the central beam. This was delivered to an area measuring approximately 5 by 5 inches with the field defined by the lead shutter of the unit. The total duration of exposure for the average patient was approximately four minutes. Since the equipment used will not measure a rate of less than six milliroentgens per minute, male gonadal exposure rate was not measurable.

COMMENT

Cineradiography permits the study of diseases of the spine which relate to abnormal function as well as to anatomic distortion. The spine can be evaluated in a more physiologic manner. In addition, patients who for physical reasons are unable to maintain proper position for static film study can be examined by this method. Those positions and movements which produce symptomatology can be recorded as they occur, and evaluated as to underlying disturbance.

To date 80 examinations of the kind herein described have been conducted. Flexion and extension studies with routine methods were also obtained in most of these patients.

Various diseases affecting the cervical spine have been studied and will be reported subsequently.

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