Cervical Spine Motion with Direct Laryngoscopy and Orotracheal Intubation

An In Vivo Cinefluoroscopic Study of Subjects without Cervical Abnormality


Background: Cervical spine kinetics during airway manipulation are poorly understood. This study was undertaken to quantify the extent and distribution of segmental cervical motion produced by direct laryngoscopy and oro-tracheal intubation in human subjects without cervical abnormality.

Methods: Ten patients without clinical or radiographic evidence of cervical spine abnormality underwent laryngoscopy using a #3 Macintosh blade while under general anesthesia and neuromuscular blockade. Cervical motion was recorded with continuous lateral fluoroscopy. The intubation sequence was divided into distinct stages and the corresponding fluoroscopic images were digitized. Segmental motion, occult through C5, was calculated for each stage using the digitized data.

Results: During exposure and laryngoscope blade insertion, minimal displacement of the skull base and rostral cervical vertebral bodies was observed. Visualization of the larynx created superior rotation of the occiput and C1 in the sagittal plane, and mild inferior rotation of C3–C5. C2 maintained near-neutral posture. This pattern of displacement resulted in extension at each motion segment, with the most significant motion produced at the occipitoatlantal and atlantoaxial joints (mean = 6.8° and 4.7°, respectively). Intubation created slight additional superior rotation at the occiput and C1, without substantial alteration in the posture of C2–C5. After laryngoscope removal, position trended toward baseline at all levels, although exact neutral posture was not regained.

Conclusions: This investigation quantifies the behavior of the normal cervical spine during direct laryngoscopy with a Macintosh blade. With this maneuver, the vast majority of cervical motion is produced at the occipitoatlantal and atlantoaxial joints. The subaxial cervical segments (C2–C5) are displaced only minimally. This study establishes a highly reliable and reproducible method for analyzing cervical motion in real time. (Key words: Equipment: cinefluoroscope; laryngoscopy. Intubation: oro-tracheal. Spine: cervical; motion.)

CERVICAL spine kinetics during airway manipulation are poorly understood. Direct laryngoscopy, the most commonly employed means of facilitating tracheal intubation, creates some degree of cervical spine extension in the course of aligning the oral, pharyngeal, and laryngeal axes.1,3,6 While it is generally acknowledged that motion associated with direct laryngoscopy occurs predominantly in the upper cervical regions,2,7,8 the magnitude and distribution of movement across these spinal segments have not been well characterized. Substantially less information is available about the motion behavior of the subaxial cervical spine during this maneuver.

A definitive characterization of cervical spine motion during direct laryngoscopy must address the following questions: (1) How much angular and translational motion occurs with this manipulation? (2) How is motion distributed across the cervical spine on a segment-by-segment basis? (3) How much motion is associated with each temporal phase of the direct laryngoscopy sequence (i.e., blade insertion, glottic exposure, endotracheal tube insertion, blade removal)? These requirements mandate the use of an imaging method capable of real-time visualization of the individual osseous elements that compose the craniovertebral junction and subaxial cervical spine. Previous studies of cervical motion during laryngoscopy have employed plain radiographic snapshots from which to calculate cervical displacement.2,7–12 However, because tracheal intubation via direct laryngoscopy is a dynamic process...
cess, transient but significant cervical displacement may be overlooked with static imaging techniques. Cinefluoroscopy satisfies all of the aforementioned criteria by affording continuous imaging of all cervical regions of interest throughout the intubation sequence.

A precise understanding of cervical spine kinetics with airway manipulation is of more than academic interest. Delineating the manner in which motion is distributed across the intact cervical spine during direct laryngoscopy may have predictive value in identifying subgroups of patients for whom such manipulation may be hazardous. This may be particularly relevant to patients with known or suspected cervical spinal abnormality, who often require tracheal intubation for airway protection, ventilatory assistance, and/or surgical anesthesia. For such persons, the optimal airway management strategy remains controversial.

Direct laryngoscopy affords a rapid and reliable means of securing an airway and is generally the technique of choice when cervical spine stability is not in question. This procedure is familiar to most practitioners, requires no complex equipment, and provides direct visualization of the glottis. Despite these attributes, many clinicians are reluctant to use this technique in the face of potential cervical spine instability, because of the risk of precipitating secondary neurologic injury. For such scenarios, alternative methods of airway manipulation have been advocated.

Blind nasotracheal intubation may require less cervical motion but is less dependable and more time consuming than direct laryngoscopy, and is associated with a number of complications, including epistaxis, vomiting, aspiration, and retropharyngeal laceration. Fiberoptic laryngoscopy may facilitate tracheal intubation with little or no cervical motion, but has several inherent limitations: (1) the patient must be cooperative or fully anesthetized; (2) specialized equipment and expertise are required; (3) excessive secretion, blood, vomitus, and anatomic distortion may complicate the procedure; and (4) time-consuming nature generally renders it unsuitable in many emergency situations.

Additional, both blind nasal and fiberoptic-assisted intubation are relatively contraindicated in the apneic patient.

Currently, there are few objective data that guide the clinician in the appropriate airway management of patients with known or suspected cervical abnormality. The purpose of this investigation, thus, was twofold: (1) to develop a method to facilitate the analysis of segmental cervical motion in real time during airway manipulation; and (2) to quantify the magnitude and distribution of such motion during direct laryngoscopy and orotracheal intubation in human subjects without cervical abnormality.

Materials and Methods

Subjects

Ten adults, ASA physical status 1 or 2 were enrolled in the study. There were six men and four women. Mean subject age was 47.1 yr (range 25–75 yr). All enrollees were scheduled to undergo elective neurosurgical procedures requiring general anesthesia, all of which were unrelated to the cervical spine. Potential subjects with clinical and/or radiographic evidence of cervical abnormality were excluded from the trial.

The study was conducted in accordance with guidelines set forth by the University of Iowa Hospitals and Clinics Committee for Use of Human Subjects in Research and the Human Use Subcommittee for Radiation Protection. All subjects gave informed written consent before participating in the trial.

Preoperative Clinical Assessment

Preoperative head and neck mobility was found to be clinically unrestricted in all subjects. The relative ease of direct laryngoscopy and orotracheal intubation for all subjects was predicted using the classification scheme described by Mallampati et al.

Nine of the ten subjects (90%) exhibited Mallampati class I oropharyngeal views, whereas in the remaining person a class II view was seen.

Intubation Protocol

A routine direct laryngoscopy and orotracheal intubation sequence was employed in all cases. The patient was placed supine on the operating table with the occiput resting on a foam pad 3-cm thick. The head and neck were maintained in neutral posture throughout induction, as confirmed by direct visualization and lateral fluoroscopy. General anesthesia was induced with 3.0–5.0 mg/kg intravenous thiopental, and neuromuscular blockade was achieved with vecuronium. Patients’ lungs were ventilated with an isoflurane/N₂O mixture by mask. Care was taken to avoid manipulation of the head and neck at this stage. Oral/nares airways were used as needed to maintain adequate ventilation.

After the disappearance of the fourth twitch of the train-of-four, direct laryngoscopy was performed using
a #5 Macintosh blade. No effort was made to fully expose the glottis during laryngoscopy; exposure was limited to that necessary to allow passage of the endotracheal tube through the vocal cords under direct vision. Orotracheal intubation was accomplished with auffed endotracheal tube, measuring 7.0–7.5 mm ID. Wire-reinforced tubes were used to improve visualization of fluoroscopic images.

All intubations were performed by an experienced faculty anesthesiologist. In every case,atraumatic tra-
cheal intubation was accomplished on the first attempt. Nine intubations (90%) were described as "easy," as was predicted by the preoperative Mallampati I classification of these subjects. The remaining intubation, in the person denoted preoperatively as Mallampati Class II, was described as "slightly difficult." No intubation required longer than 15 s to accomplish. Throughout the intubation sequence, the occiput maintained contact with the foam pad. Because the purpose of this investigation was to define the extent of cervical motion that occurs during a routine direct laryngoscopy and orotracheal intubation sequence, no attempt was made to restrict cervical motion in any way during airway manipulation.

Data Acquisition, Processing, and Analysis

In all cases, the entire laryngoscopy and intubation sequence was monitored with continuous lateral fluoroscopy of the cervical spine (OEC model 9400, OEC Diasonics, Salt Lake City, UT). This technique afforded real-time visualization of the skull base, craniovertebral junction, and rostral cervical spine (through C5–C6). Cervical segments caudal to the C5–C6 vertebral interspace could not be consistently seen, because the shoulders obscured these regions. The fluoroscope was stationary throughout the entire intubation sequence; the tube-to-subject and subject-to-image intensifier distances were likewise held constant for all examinations. Fluoroscopic images were recorded on videotape using a VHS-formatted videocassette recorder (Panasonic AG-1730, Matsushita Electrical, Osaka, Japan) interfaced with the image intensifier.

Images were then captured and digitized from videotape with a "frame grabber" (IP Lab Spectrum, version 2.3 1c, Signal Analysis, Vienna, Virginia). Once digitized, the images were analyzed with the National Institutes of Health Image 1.55 graphics analysis software (The National Institutes of Health, Bethesda, MD). The full complement of fluoroscopic images for all subjects were analyzed de novo by two independent observers in a blinded fashion, with one observer repeating the analysis a second time, to assess both the reliability and reproducibility of the method.

To facilitate comparisons between subjects, the intubation sequence was subdivided into seven distinct stages (Fig. 1). The baseline stage was denoted by the head and neck in neutral position prior to any manipulation. The preinsertion phase comprised any head/neck motion that occurred before the appearance of the laryngoscope blade in the oral cavity. L1 was delineated by the passage of the laryngoscope blade into the oropharynx. As the blade was advanced into the vallecula and a ventral lifting force vector was applied, L2 was defined. The radiographic appearance of the endotracheal tube in the posterior oropharynx marked the tube stage. Advancement of the vocal cords into the trachea completed the intubation sequence. Postintubation was defined as the laryngoscope blade from the oropharynx taken to identify the extremes described in each stage.

Localization of a given structural landmark (e.g., vertebral body) in two dimensions was performed by using a straight line intersecting two radiographic points (Fig. 2). For C2–C5, these points were taken at the vertex of the angle formed by the anterior and inferior borders of the vertebral body and the vertebral endplate, and the second, applied to the lateral process. The position of the anterior vertebral body was passed through the anterior angulation of the cervical spine with respect to a fixed horizontal line intersecting the spinal axis. The position of the anterior angulation was identified in similar fashion, applied to the lateral process of the cervical spine. The position of the posterior angulation was used as the anterior skull base, in the opisthion serving as the anteroposterior result line (Chamberlain, 1961), as modified for locants with respect to the head orientation. All subsequent radiographic measurements were performed in this position.

Registration of each bony landmark was performed before any manipulation of the head and neck in neutral posture. Three-dimensional images were used to establish reference points for each structure. The reference points were identified on the lateral projection of the cervical spine. The resulting images were then analyzed for the seven stages described above. The analysis was repeated for each subject, with the exception of the baseline stage.

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Fig. 1. Digitized lateral fluoroscopic images of the cervical spine from a representative subject depicting various stages of direct laryngoscopy and intubation. (Note: the preinsertion stage, radiographically similar to the L1 stage, has been omitted for the sake of brevity.)
the tube stage. Advancement of the tube through the vocal cords into the trachea defined the intubation phase. Postintubation was delineated by removal of the the laryngoscope blade from the oropharynx. Care was taken to identify the extremes of cervical motion manifested in each stage.

Localization of a given structure (i.e., occiput or cervical vertebrae) in two dimensions was defined by a straight line intersecting two readily defined reference points (fig. 2). For C2–C5, the first point was placed at the vertex of the angle formed by the anterior cortex of the vertebral body and the inferior vertebral end plate, and the second, applied to the tip of the spinous process. The position of the atlas was defined by a line passing through the anterior and posterior arches. The spatial orientation of the reference lines was calculated with respect to a fixed horizontal baseline parallel to the spinal axis. The position of the skull base (occiput) was identified in similar fashion, with reference points applied to readily identifiable anatomic landmarks. Most often, the posterior margin of the hard palate was used as the anterior skull base reference point, with the opisthion serving as the posterior landmark. The resultant line (Chamberlain’s line\(^46\)) was obvious in most persons. However, owing to variations in anatomy and fluoroscopic visualization, alternative reference points were occasionally required. The exact anatomic landmarks employed for localization in a given subject are of minimal importance; it is critical, however, that the identical structures are consistently identified in all subsequent radiographic images of that person.

Registration of each bony element in space was undertaken before any manipulation with the head and neck in neutral posture. These baseline measurements served as reference values against which all subsequent cervical motions were quantified. Spatial localization of each structure was repeated at multiple time points throughout the laryngoscopy and intubation sequence corresponding to the seven stages of intubation previously defined. All measurements were compared to the baseline neutral orientation of that element, and positional values denoted as “degree change” from baseline.

Individual motion calculations derived from each subject were pooled and a composite data set was created for each of the seven stages. Means and extreme values for each stage were documented. With these data, cervical spinal motion during direct laryngoscopy and intubation was described in two ways. First, the alterations in position that each osseous unit (i.e., skull base or cervical vertebrae) experienced during airway manipulation were described independently of adjacent structures, yielding a value for the absolute rotational movement of that object in space. This affords an understanding of the precise behavior of each anatomic structure at any point throughout the procedure. Second, the degree of extension or flexion that occurred between adjacent vertebrae was calculated. This latter approach enables an appreciation for the response of individual “motion segments” (consisting of two adjacent vertebrae, the intervertebral disc, and connecting ligamentous tissue\(^51\)) as the airway is manipulated.

Results

Reproducibility of the Methods

The methods employed to analyze cervical motion in this investigation were found to be precise and highly reproducible. The image-analysis software facilitated quantification of rotational displacement of a given bony element with a resolution of 0.01°. Intraobserver variability averaged 0.37° (range 0.0°–0.7°) per calculation. Measurement discrepancies between observers were similar in magnitude (mean 0.48°, range 0.0–
0.9°). Thus, this technique allowed consistent discrimination of cervical motion to within 1° of rotation.

Rotational Displacement in the Sagittal Plane
Calculating the rotational displacement of each osseous element in the sagittal plane describes the principal motion experienced by that anatomic unit, independent of adjacent structures. Cervical spine motion in the coronal (lateral bending) and axial (axial rotation) planes was not measured in this study. However, motion in these planes should be minimal because the primary force vector applied with laryngoscopy lies in the sagittal plane. Review of the fluoroscopic data confirmed that the occiput maintained contact with the headrest at all times. While this was not the consequence of a deliberate effort by the laryngoscopist, this finding facilitated motion analysis by preserving the validity of the horizontal reference plane, thereby minimizing the potentially confounding influence of head/neck elevation during airway manipulation. Additionally, because the ligamentous structures in all subjects were intact, the degree of anteroposterior translation (listhesis) also was negligible (≤1.0 mm at any given level). Thus, the vast majority of motion experienced by each vertebra occurred in the sagittal plane and was rotational in nature. Rotation of the anterior vertebral body cortex toward the skull base was defined as “superior rotation.” This direction was arbitrarily assigned (+) numeric values. “Inferior rotation” denoted caudal rotation of the anterior cortex, represented by (−) values (fig. 5).

Rotational motion data are summarized in table 1 and depicted in figure 4. The preinsertion stage was associated with 1.7° and 2.2° of mean superior rotation of the skull base and C1, respectively, with minimal displacement of C2 through C5. During L1, slightly greater superior rotation of the skull base (mean = 2.3°) and C1 (mean = 2.9°) was noted. Motion remained barely perceptible in the more caudal cervical levels. L2 created additional rotational displacement at all levels. Superior rotation predominated at the skull base (mean = 9.9°) and C1 (mean = 3.1°). C2 retained a near-neutral posture. Inferior rotation was experienced by C3–C5. During the tube stage, further superior rotation occurred at the skull base (mean = 11.2°) and C1 (mean = 4.6°), without substantial change in the rotation of the caudal levels. This posture was maintained at all levels during intubation. After laryngoscope removal (postintubation), the position of all structures tended toward baseline, although neutral posture was not regained at any level.

Segmental Cervical Motion
The degree of motion experienced by each visualized segment (flexion/extension) is presented in table 2 and shown in figures 5 and 6. Extension of a given motion segment is denoted by positive numeric values; flexion is indicated by negative values. This is contrary to standard convention in the spinal biomechanical literature, where flexion and extension are represented by positive and negative numeric values, respectively. However, previous investigations of cervical motion during airway manipulation have used positive values to signify extension.21–22 We have adopted the latter (nonstandard) convention to avoid confusion when analyzing studies of similar focus.

During preinsertion and L1, minimal segmental motion was noted. Substantially more motion was produced at all cervical segments during the L2 phase. Extension occurred at all segments, and was of greatest magnitude at O–C1 (mean = 6.8°) and C1–C2 (mean = 4.7°). All motion segments remained extended throughout the tube and intubation stages. Again, the O–C1 interspace exhibited the greatest degree of motion. During the postintubation phase, a lesser degree of extension persisted across all motion segments.

Discussion
This study demonstrates that direct laryngoscopy produces extension of the cervical spine, which is most
Table 1. Summary of Rotational Cervical Motion Data

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Preinsertion</th>
<th>L1</th>
<th>L2</th>
<th>Tube</th>
<th>Intubation</th>
<th>Postintubation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>Skull base</td>
<td>1.7</td>
<td>-3.1 to 7.7</td>
<td>2.3</td>
<td>-3.0 to 4.0</td>
<td>9.9</td>
<td>1.5 to 17.1</td>
<td>11.2</td>
</tr>
<tr>
<td>C1</td>
<td>2.2</td>
<td>-1.9 to 6.3</td>
<td>2.9</td>
<td>-2.3 to 5.7</td>
<td>3.1</td>
<td>-1.7 to 7.6</td>
<td>4.6</td>
</tr>
<tr>
<td>C2</td>
<td>0.7</td>
<td>-2.2 to 3.3</td>
<td>0.9</td>
<td>-2.5 to 2.8</td>
<td>-1.6</td>
<td>-3.1 to 2.5</td>
<td>-0.8</td>
</tr>
<tr>
<td>C3</td>
<td>0.1</td>
<td>-2.4 to 3.4</td>
<td>0.2</td>
<td>-2.6 to 3.7</td>
<td>-2.9</td>
<td>-8.1 to 3.6</td>
<td>-1.2</td>
</tr>
<tr>
<td>C4</td>
<td>0.0</td>
<td>-2.6 to 3.2</td>
<td>0.3</td>
<td>-2.6 to 2.9</td>
<td>-5.0</td>
<td>-14.9 to 4.4</td>
<td>-5.6</td>
</tr>
<tr>
<td>C5</td>
<td>-1.1</td>
<td>-3.3 to 3.4</td>
<td>-1.2</td>
<td>-3.6 to 4.0</td>
<td>-6.3</td>
<td>-18.8 to 0.9</td>
<td>-6.5</td>
</tr>
</tbody>
</table>

Values are given as degrees.

(+) values = superior rotation; (−) values = inferior rotation; Baseline = neutral position prior to manipulation; Preinsertion = head/neck positioning prior to introduction of laryngoscope blade; L1 = laryngoscope blade into oropharynx; L2 = laryngoscope blade into vallecula; Tube = endotracheal tube in oropharynx; Intubation = endotracheal tube in trachea; Postintubation = removal of laryngoscope blade.

Table 2. Summary of Segmental Cervical Motion Data

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Preinsertion</th>
<th>L1</th>
<th>L2</th>
<th>Tube</th>
<th>Intubation</th>
<th>Postintubation</th>
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</thead>
<tbody>
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<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
<td>Range</td>
<td>Mean</td>
</tr>
<tr>
<td>O-C1</td>
<td>-0.5</td>
<td>-1.6 to 2.1</td>
<td>-0.6</td>
<td>-1.7 to 1.2</td>
<td>6.8</td>
<td>3.2 to 10.5</td>
<td>6.6</td>
</tr>
<tr>
<td>C1-C2</td>
<td>1.5</td>
<td>0.3 to 3.4</td>
<td>2.0</td>
<td>0.2 to 4.3</td>
<td>4.7</td>
<td>1.4 to 8.8</td>
<td>5.4</td>
</tr>
<tr>
<td>C2-C3</td>
<td>0.6</td>
<td>-1.1 to 3.0</td>
<td>0.7</td>
<td>-0.9 to 2.9</td>
<td>1.3</td>
<td>-0.7 to 3.3</td>
<td>2.4</td>
</tr>
<tr>
<td>C3-C4</td>
<td>0.1</td>
<td>-2.0 to 1.8</td>
<td>-0.1</td>
<td>-1.3 to 0.4</td>
<td>2.1</td>
<td>0.6 to 4.1</td>
<td>1.6</td>
</tr>
<tr>
<td>C4-C5</td>
<td>1.1</td>
<td>0.3 to 2.5</td>
<td>1.5</td>
<td>-0.3 to 2.6</td>
<td>1.3</td>
<td>-0.8 to 3.5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Values are given as degrees.

(+) values = extension; (−) values = flexion; Baseline = neutral position prior to manipulation; Preinsertion = head/neck positioning prior to introduction of laryngoscope blade; L1 = laryngoscope blade into oropharynx; L2 = laryngoscope blade into vallecula; Tube = endotracheal tube in oropharynx; Intubation = endotracheal tube in trachea; Postintubation = removal of laryngoscope blade.
pronounced at the occipitoatlantal and atlantoaxial joints. The subaxial segments experience far less displacement. This motion distribution is predicted by the anatomy of the craniovertebral junction. The occipitoatlantal joint is responsible for the majority of the flexion/extension motion experienced by the cervical spine. The lower cervical segments contribute less substantially to this type of motion because head extension is integral to direct laryngoscopy, it is not surprising that motion occurs preferentially at the occipitoatlantal joint.

The degree of motion noted in this region was less than we had anticipated, however. Extension at O–C1 averaged less than 7° at the point of greatest excursion. The atlantoaxial articulation experienced a maximal mean extension of 5.4° throughout the laryngoscopy

![Graph of mean rotational displacement (in degrees) of the skull base and cervical vertebrae during each stage of direct laryngoscopy and orotracheal intubation.](image)

![Graph of mean segmental cervical motion (in degrees) produced by direct laryngoscopy and orotracheal intubation at various stages throughout the intubation sequence.](image)

![Graph of distribution of individual representative stages in the intubation of the cervical spine.](image)
sequence. The average extension capacity of the normal occipitoatlantoaxial complex is approximately 30° (range 25°–45°). Roughly two thirds of this motion (i.e., 20°) occurs at O–C1; the remaining one third takes place at C1–C2. Thus, while direct laryngoscopy is often purported to create extreme cervical motion, in fact only a fraction of the extension capacity of the craniovertebral junction is required to complete the maneuver.

Potential Study Limitations
This investigation was designed to analyze the motion behavior of the intact cervical spine in response to direct laryngoscopy under relatively ideal conditions. Thus, the degree of segmental motion reported herein may indeed represent the lower limit of that achievable with the technique. All intubations were performed by an experienced anesthesiologist in a controlled, operating room atmosphere. Less-accomplished laryngoscopists, unfamiliar with the procedure or the anatomy, may induce more cervical motion when securing the airway in this manner. Suboptimal conditions in the field may render laryngoscopy difficult, and thus may influence the degree of motion associated with the technique. Furthermore, because laryngeal exposure was limited to that necessary for tracheal tube passage, these data may underestimate the amount of cervical motion induced by more extensive glottic visualization. Neuromuscular blockade, used in all subjects, facilitated ventral soft tissue displacement during laryngoscopy and thus may have reduced the need for cervical extension to achieve adequate laryngeal exposure.

All patients composing the study population were predicted to be good candidates for direct laryngoscopy, and all proved to be relatively easily intubated. Additional cervical extension would be anticipated in persons who pose more of a challenge to the laryngoscopist. Age may influence the magnitude and distribution of cervical motion resulting from direct laryngoscopy, although this was not evident in the current study. While small sample sizes precluded meaningful statistical analyses of the various age subgroups, we observed no data to suggest that the motion behavior of the aged cervical spine differed substantially from that exhibited by younger persons during the procedure.

Previous Studies of Cervical Motion with Airway Manipulation
Other investigators have attempted to quantify cervical motion associated with airway manipulation. The
conclusions that may be derived from these studies are limited by one or more of the following concerns: (1) segmental motion was not analyzed, (2) only a limited region of the cervical spine was studied; and/or (3) static plain films, or “snapshots,” were obtained at one or two time points during the maneuver rather than continuous imaging.

Majernick et al. studied cervical motion during direct laryngoscopy in 16 anesthetized volunteers. They found that this technique resulted in “significant cervical motion,” which was reduced by manual in-line stabilization but not by use of a Philadelphia collar. No difference in motion was noted between laryngoscopes with straight or curved blades. Using similar techniques, Gajraj et al. found no difference in cervical spinal movement during orotracheal intubation with the Belascope and Macintosh laryngoscopes in 20 anesthetized subjects. Unfortunately, neither study evaluated true segmental cervical motion, and thus interpretation of the reported motion data per se is difficult.

Horton et al. studied the disposition of cervical vertebrae during direct laryngoscopy in ten awake subjects, employing a single radiograph obtained at full glottic exposure. Cervical extension was documented at the atlantoaxial joint, with minimal movement of the lower cervical segments. Motion at the occipitotantal joint was not evaluated. Using similar methods, Fitzgerald et al. compared cervical spine excursion during direct laryngoscopy and blind oral intubation in 12 anesthetized patients. While the blind orotracheal method created less extension than did direct laryngoscopy, both techniques produced the greatest excursions at the atlantoaxial joint. Unfortunately, the lack of baseline neutral radiographs with which to compare cervical alignment at full glottic exposure renders the reported numeric motion values questionable. Certainly, the mean atlantoaxial extension measurements of 25° and 35° reported in these respective studies seem excessive; most investigators have noted an extension capacity of ~10° at this motion segment. Findings of the current study are more in accordance with these motion ranges, with a mean extension value of 5.4° noted at this articulation.

Hastings and Wood quantified head extension during direct laryngoscopy with an external angle finder affixed to the head of 31 anesthetized subjects. Without stabilization, head extension averaged 10° ± 5° at arytenoid cartilage exposure and 15° ± 6° at “best view” of the glottis, values similar to the sum of all segmental motion occurring in the corresponding stage of the current study. Head extension was reduced by head immobilization but not by in-line traction. While this measurement technique is incapable of assessing segmental motion, it appears to accurately characterize gross head movement during airway manipulation.

Similar methods were used to quantify the degree of head extension produced by the Bullard (Girton ACMI, Stamford CT), Macintosh, and Miller laryngoscopes in 35 anesthetized volunteers. No difference between the Macintosh and Miller blades was documented (head extension = ~11° for both). Eight of these patients were evaluated with static radiographs obtained at baseline and laryngeal exposure. “Best view” laryngoscopy with the Macintosh blade produced extension at O-C1 (mean = 13°, range 5°-22°), with less motion occurring at the more caudal segments. These results are in rough concordance with those of the current study, both in the magnitude and the distribution of cervical motion. Because we attempted to obtain only the minimal laryngeal exposure necessary for endotracheal tube passage, the degree of O-C1 extension is predictably less than that noted by Hastings et al.

In the only previous study to employ continuous imaging techniques, Hauswald et al. examined cervical spinal motion during various airway manipulations in cadavers fitted with cervical collars. Mask ventilation created significantly more anteroposterior translation of the intact cervical spine than direct orotracheal, blind nasotracheal, or fiberoptic intubation techniques. Differences in vertebral body translation produced by these latter techniques were not significant; flexion-extension motion was not assessed.

Implications for the Patient with Cervical Spine Injury

The current investigation characterizes the motion behavior of the intact cervical spine during direct laryngoscopy and orotracheal intubation. Throughout the maneuver, motion occurs preferentially at the occipitoatlantal and atlantoaxial articulations, and is predominantly extension in nature. The subaxial segments experience far less motion. Displacement at all levels is maximal during visualization of the glottis and endotracheal tube insertion. While these findings are provocative, a great deal of caution must be exercised when attempting to extrapolate these data to the cervical spine-injured patient. Indeed, the kinematics of the unstable cervical spine in response to airway manipulation may vary considerably from the intact state.
CERVICAL SPINE MOTION DURING DIRECT LARYNGOSCOPY

Previous investigations using cadaveric specimens indicate that an injured cervical motion segment may exhibit hypermobility in response to various airway maneuvers. Studies that delineate the manner in which motion is distributed over segments adjacent and remote to the level of injury have not been performed. Thus, the extent to which a given injury influences composite cervical motion during airway manipulation is unknown.

The relative risk of direct laryngoscopy to the patient with cervical spinal abnormality is dependent on many factors. Among these are: (1) type of injury (i.e., bony fracture vs. ligamentous incompetence), (2) anatomic location of the lesion (i.e., anterior vs. posterior, subaxial vs. craniovertebral junction); and (3) severity of structural compromise. When considering the manner in which motion is distributed across the intact cervical spine, one may speculate that injuries involving the rostral segments may possess a greater potential for spinal cord injury than those affecting the subaxial spine. Similarly, direct laryngoscopy may be more hazardous to patients with cervical instability that is exacerbated by head/neck extension rather than by flexion maneuvers. Finally, severe destabilizing injuries involving all three vertebral load-bearing columns (anterior, middle, posterior) may confer a greater risk of secondary injury than those affecting only a single structural element. These hypotheses are suggested by the current data, they are as yet unproven.

Several retrospective clinical studies have suggested that direct laryngoscopy is as safe as any other airway management technique, even when unstable cervical injuries are present. However, at least two cases of quadriplegia after laryngoscopy in patients with unrecognized cervical spinal injuries have been reported, and others have been acknowledged. While the incidence of such a catastrophic event is low, it is certainly not inconsequential. Therefore, until conclusive data are amassed that clearly delineate the role of direct laryngoscopy in the treatment of selected cervical spine-injured patients, a conservative approach to the airway management of all patients with known or suspected cervical spinal abnormality is warranted.

Further Investigation

An accurate characterization of the segmental motion behavior exhibited by the intact cervical spine during direct laryngoscopy is only the initial step in defining the consequences of this technique for patients with cervical instability. Further study is necessary to delineate specific types of cervical injury that confer an increased risk of secondary neurologic morbidity from airway manipulation. The magnitude and distribution of motion created by all standard airway management techniques must be assessed to determine the relative safety of each when spinal stability is impaired. The efficacy of orthoses and stabilizing maneuvers in restricting cervical motion also must be reevaluated using cineradiographic imaging and reliable motion-analysis techniques. This research is ongoing at our institution.

References

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