Cervical Spine Anatomy and Function for the Anesthesiologist

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OBJECTIVES

To review the basic anatomy and biomechanics (motion) of the normal cervical spine, with specific attention to the changes seen during laryngoscopy and endotracheal intubation. In addition, a variety of topics related to the management of patients with Cspine instability and pathology will be reviewed.

CASE PRESENTATION

Anesthesiologists manipulate the cervical spine every day (during endotracheal intubation and patient positioning) and deal frequently with cervical spine disease. Nevertheless, few anesthesiologists understand the anatomy and biomechanics of the cervical spine. This presentation will review the anatomy and motion of the normal Cspine and movements that occur during routine direct laryngoscopy and intubation. I will also discuss several relevant disease states, including Down syndrome, rheumatoid arthritis and trauma.

Anatomy

The neck can be conceptually divided into two portions: 1) the subaxial spine (below the “axis” of C2) and 2) the upper (or atlanto-axial) Cspine (which includes the skull base). The vertebrae of the subaxial spine are anatomically similar normal vertebrae, having a distinct vertebral body, lamina, spinous processes, transverse elements etc. The vertebrae of the upper Cspine are quite different. It′s almost impossible to describe their structure in words, or adequately show them in 2-D images, but a few key structures should be noted.

C1 (the Atlas): C1 is a ring, with large superior and inferior articular surfaces, which interact with the skull base above and C2 below, respectively. It has no vertebral body and no spinous process.

C2 (the Axis): A very unusual structure. It′s most unusual feature is a long, thumb-like extension of its vertebral body, which extends upward to pass through the anterior arch of C1. This is the dens or the odontoid process, which can be considered embryologically as the body of C1.

The odontoid process (OD) is located just behind the anterior arch of C1. It′s actually quite easy to feel the tubercle on the anterior arch of C1 as a midline bump/ridge high in the back of your throat.

The anterior atlanto-dental interval (AADI) is the space between the anterior aspect of the odontoid (the dens) and the back of the anterior arch of C1. A reciprocal space, termed the posterior atlanto-dental interval (PADI), extends from the back of the odontoid to the anterior aspect of the posterior arch of C1. The spinal cord is passes through the PADI. Since C1 is a rigid ring, if the AADI gets larger, the PADI must get smaller. The AADI is easily seen on lateral X-rays and changes in its size with flexion and extension is an index of “atlanto-axial instability” (see below).

Motion

The cervical spine supports the head and to permit motion in 3 dimensions without damaging the spinal cord. The three axes of motion are flexion/extension (floor to ceiling), lateral bending (shoulder-to-shoulder), and axial rotation (turning side-to-side). There is some general reduction in mobility with age, but in normal, middle aged individuals, our maximal head-shoulder ranges of motion are as follows.

Flexion/extension: 130-140 degrees
Lateral bending: 85-90 degrees
Axial Rotation: 160-170 degrees

This motion is not distributed uniformly along the entire Cspine. A few points are relevant.

O-C1 joints/ligaments are “tight” and allow little motion (remember this later): there is minimal axial rotation, only 5-10 degrees of lateral bending, approximately 20 degrees of extension and only 5 degrees of flexion (measured from a neutral position). Basically, the only normal movement at O-C1 is extension. This means that the space between the skull base and the posterior arch of C1 can get small - but it can′t get larger. If, on a lateral X-ray, you see the posterior arch of C1 touching the skull base, the film was taken in maximum extension.

There is more freedom of motion at C1-C2. A great deal of rotation occurs at C1-C2, with the odontoid process as the pivot point: when you turn someone′s head to the side, nearly all the motion is at C1-C2. Watch someone with an O-C2 fusion. They can′t rotate very well. Flexion and extension are roughly equal at C1-C2 (about 10 degrees of each from neutral).

At C2-C3 and below, motion is more uniformly distributed; however, maximal motion occurs at C4-C5-C6, an observation that coincides with the much more common occurrence of injury at these levels.

Lateral bending (head on shoulder) is the result of roughly 5-10 degrees of motion per segment below C2

Movement with Intubation

Since the 1940′s, we′ve read about the idea that to visualize the glottis and introduce an endotracheal tube, it is necessary to “align the pharyngeal and laryngeal axis”. More recent work by Frederic Adnet and colleagues has clearly shown that this is a fallacy and was based on some erroneous (falsified?) observations (although it is probably true if you are interested in passing a rigid bronchoscope). Nevertheless, to place a tube via direct laryngoscopy, you still must be obtain a “line of sight” view between your eye and enough of the glottis to allow placement of the ET tube. This requires a complex series of movements.

The primary force applied by the laryngoscope is upward lift (toward the ceiling). This force can be as high as 50-70N (enough to lift the head off of the pillow). This results in extension of the occiput and the O-C1 interspace (with the posterior arch of C1 touching the skull). The lift also results in flexion at lower vertebrae. Data collected during a large series of cinefluoroscopic studies of the Cspine during laryngoscopy indicates that direct laryngoscopy with a Mac 3 blade results in near-maximal extension at O and C1, with flexion below C2-C3.

Any intervention that impedes this motion (upper extension, lower flexion) will make it more difficult to visualize the glottis, although cervical fusions below C4 do not usually create clinical problems. Conversely, surgical O-C1-C2 fusion makes it extremely difficult (impossible) to successfully perform a DL. External “stabilization” methods (traction, manual stabilization, collars etc) may reduce movement during DL - but they will also make visualization more difficult.

You cannot stabilize the neck without impeding the laryngeal view!

Instability at C1-C2: Rheumatoid Disease and Down Syndrome
Instability is defined as excessive translational or rotational motion of any vertebrae. Instability can occur anywhere - and may be exceptionally difficult to diagnosis. Because of the unique motion associated with DL, atlanto-axial instability is of particular interest. Such instability means that the odontoid process is no longer firmly held against the back of the anterior arch of C1, due either to disruption/destruction of the transverse ligament (as seen in severe rheumatoid arthritis or Down syndrome), or from damage to the odontoid process itself (e.g. fracture across the base of the odontoid).

In patients with severe/longstanding RA, there is destruction of multiple joints in the neck and to the transverse ligament. Roughly 30% of patients with severe disease will have some instability at C1-C2, although surgical correction is needed in relatively few. It is recommended that all patients with severe RA have periodic flexion/extension x-rays, certainly prior to any surgery. What is the radiologist looking for on these flexion/extension films? They are specifically looking for evidence that the AADI is increasing with flexion (as the skull-C1 unit slides anteriorly on C2, and the anterior arch of C1 moves away from the odontoid); if the AADI increases to 5 or more millimeters, instability is typically judged to be present.

Similarly, roughly 15% of patients with Down Syndrome have laxity in the transverse ligament. It is recommended that all Down′s patients have x-rays at ages 3, 12 and 18, before any surgical procedure that requires DL or extensive neck manipulation (e.g. tonsillectomies, PE tubes), or prior to engaging in vigorous sports (there is enormous debate about the required frequency of such films, or the need for them in very young children - particularly children so young that ossification of the bones in the upper Cspine is incomplete).

To reiterate: The mechanical problem with AA instability relates to a) the fact that C1 is relatively firmly affixed to the base of the skull and b) C1 is a rigid ring. If the transverse ligament is damaged, lifting the skull and C1 with a laryngoscope will result in an increase in the AADI and a reciprocal decrease in the PADI. In other words, C2 remains “fixed” while C1 slides anteriorly, with the cord becoming compressed/trapped in the space behind the odontoid (small arrows, below).

Instability: Trauma

Traumatic injuries are much more common at C5 and C6. One of our greatest worries is the failure to diagnose an injury in a neurologically intact individual. This has resulted in a series of “rules” about when Cspine diagnostic studies are needed in patients with blunt trauma (ALL patients with penetrating trauma require films). The general “rule” is that films are needed when any one of 5 criteria are met:

1) Neck pain
2) LOC at the scene of injury
3) Any neurologic abnormality or symptoms
4) Intoxication
5) Distracting severe pain

The value of these rules has been confirmed in a huge prospective study of over 30,000 emergency patients with blunt trauma (See Hoffman et al in the reading list below). Of those patients with one or more of the above-noted criteria, serious Cspine abnormalities were found in about 2%. Conversely, abnormalities were found in only 0.03% of patients (1 of 4,309) with no such symptoms (and there were no sequelae in that patient). The problem, of course, is that positive findings are still uncommon; 100 X-rays or CT scans are needed to detect 2 serious injuries; 4000 films would need to be obtained to find an injury in asymptomatic patients.

Cspine injuries pose three problems for the anesthesiologist. 1) management of the patient with a known injury, 2) management of the patient in whom no films were ever obtained, due to surgical urgency and 3) the patient in whom films have been taken, but whose neck, for a variety of medical or bureaucratic reasons, has not been “cleared”.

Some might argue that patients in all three categories should simply be managed by flexible fiberoptic laryngoscopy and intubation; no neck motion would ever be required. Unfortunately, this is not feasible in many situations, and it may also be unwise (same size fits all?). We are commonly confronted by the combative or intoxicated patient with a full stomach in whom an awake fiberoptic intubation is not feasible, or the emergent patient (often with other injuries) where rapid intubation is required but a fiberoptic scope is not available (or its use is inappropriate). We are constantly asking “in which patient is it acceptable to do a DL and is there anything that can be done to minimize the risk of Cspine injury during such a DL.”

There has been a reasonable amount of work concerning the impact of “stabilization” techniques including soft collars, hard (Philadelphia) collars, manual external stabilization, axial traction (hand-held or with Gardner-Wells tongs), and complete halo-vest (4 post) fixation. It is impossible to review this literature entirely. However, a few points are worth mentioning.

Soft and hard collars are of minimal (no?) value in preventing Cspine motion during DL, certainly motion of the upper Cspine. They also seriously limit mouth opening.

Manual in-line stabilization may reduce movement to some degree - at the expense of more difficult intubation.

Axial traction also reduces extension at 0-C1 - but again impedes visualization. More important, even small amounts of traction may a) distract a complete injury and b) actually augment AP translational motion at the injury segment.

Near perfect stabilization can be achieved with halo-fixation. However, intubation via DL may be impossible.

What about alternative airway management techniques? There has been great interest in the use of airway management methods that do not require Cspine movement - or at least which don′t require the same motions as DL. These include the esophageal Combitube, the LMA, the ILMA. lightwands, WuScopes, Bullard laryngoscopes etc. There is relatively little information available regarding the use of these in the presence of severe Cspine injuries. It is probably incorrect to assume that, since head extension/flexion is not required for placement, that these devices are safe. For example, inflation of the large pharyngeal cuff of the Combitube exerts pressure against the vertebral bodies of C2, C3 and/or C4, depending on placement. Similarly, insertion of the LMA or ILM results in pressure against C2/C3. Manipulation of the ILM to facilitate ET insertion also may (theoretically) create problems. Unfortunately, while we know of cases in which DL results in spinal cord injury, experience with these alternative methods is extremely limited - and hence no data exists to determine whether or not they offer advantages. Each of these methods may be deemed appropriate in certain situations - but beware of the unfounded belief that they are “better” than any other method.

SUMMARY COMMENTS

There are no easy answers regarding the management of the patient with severe cervical spine disease/damage. If fiberoptic laryngoscopy is possible (using either a flexible scope, Bullard/Wu scope or other method) it is probably indicated. If this is not possible, then the technique with which the anesthesiologist is most familiar is indicated. Manual in-line stabilization is probably medico-legally advisable - but will not prevent motion of a severely disrupted spine and is not of proven benefit. Moreover, all stabilization methods make DL/intubation more difficult; anything that limits extension of the upper spine and flexion below C2 will make visualization more difficult.

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