Perioperative Care of the Patient with Acute CNS Injury: Cervical Spine

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Every day, Anesthesiologists manipulate the neck, e.g. during endotracheal intubation and patient positioning. However, few understand the anatomy and biomechanics of the cervical spine (Cspine). This presentation will review the anatomy and motion of the normal Cspine and the movements that occur during routine direct laryngoscopy. I will then discuss some of the issues surrounding airway management in the patient with an unstable neck.

Anatomy

The Cspine can be divided into two portions: 1) the subaxial spine (below C2) and 2) the upper (or atlanto-axial) Cspine (the skull base, C1 & C2). Subaxial vertebrae are similar to normal vertebrae, having a distinct vertebral body, lamina, spinous processes, transverse elements etc. The vertebrae of the atlanto-axial spine are quite different. A few key structures should be noted. (a labeled lateral X-ray can be found on the next page)

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. Its most unusual feature is a long, thumb-like extension of the vertebral body, which extends upward to pass through the 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.

The C1/C2 unit is held together by an extensive set of ligaments. The most critical, from the standpoint of stability, is the transverse ligament (also known as the transverse portion of the cruciate ligament), which passes horizontally behind the odontoid process and anchors it to the inside of the anterior arch of C1.

The anterior atlanto-dental interval (AADI) is the space between the anterior aspect of the odontoid 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, in normal patients is typically less than 4mm in depth. Changes in the depth of the AADI with flexion and extension are an index of "atlanto-axial instability" (see below).

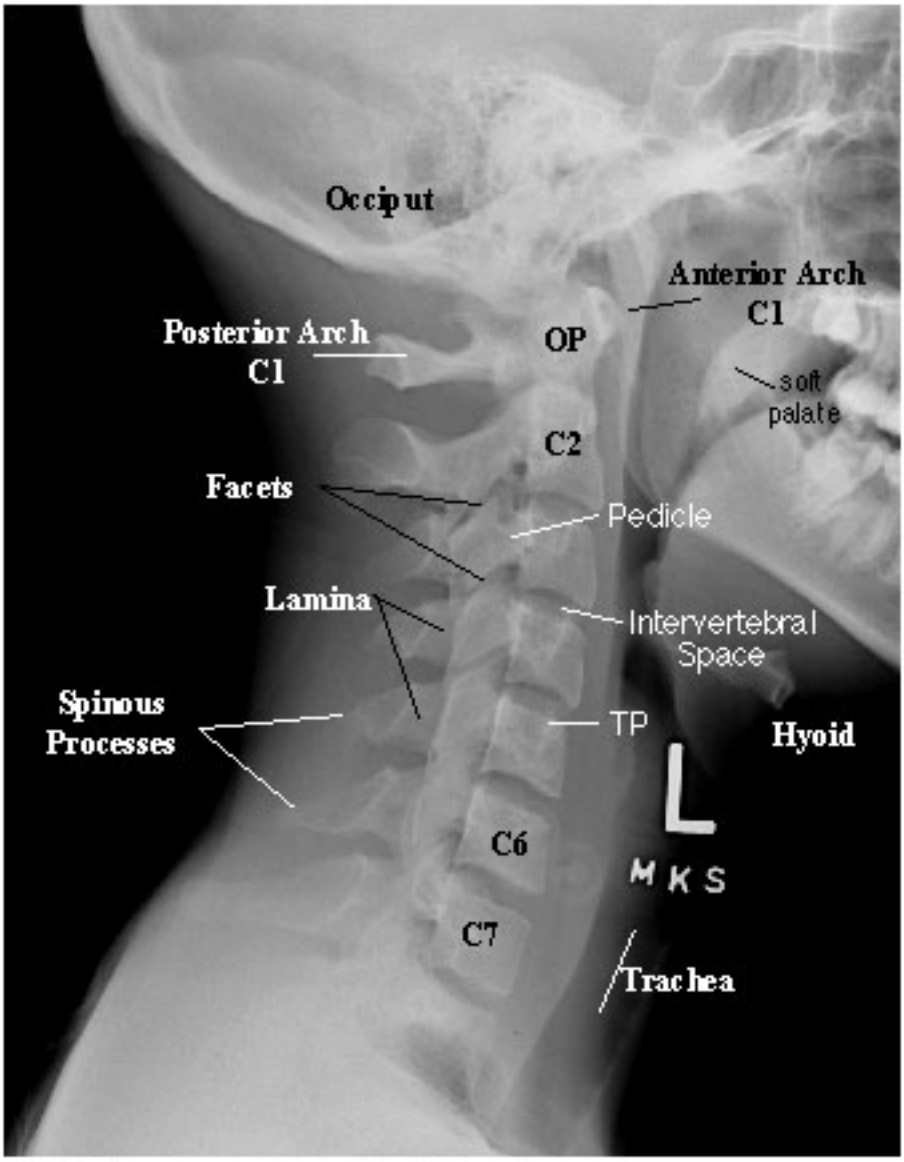
Motion

The cervical spine supports the head and permit motion in 3 dimensions without damaging the spinal cord. 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 (max down to max up):	130-140 degrees
Lateral bending (shoulder to shoulder):	85-90 degrees
Axial Rotation (max left to max right):	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, ≈20 degrees of extension (looking up) and only 5 degrees of flexion (looking down - both measured from a neutral position). 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. When someone turns their head from neutral to far right or far-left, more than half of this motion is occurring at C1-2. Watch someone with an O-C2 fusion; they can't rotate well.



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 (ligamentous?) 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

To place a tube via direct laryngoscopy, you must obtain a "line of sight" view between your eye and enough of the glottis to allow placement of the ET tube. The longstanding concept of "aligning the three-axis" has been questioned by Fred Adnet and colleagues (because we never need to look down the center of the trachea!), but even without this, a complex series of movements are required.

The primary force applied by the laryngoscopist is upward lift (and a little bit of angular force, even if we do tell people "don't pry). This force can be as high as 50-70N (40N is enough to lift 10lbs). Greater force is used in difficult laryngoscopies. This results in extension of the occiput-on-C1, combined with flexion at lower vertebrae (the fulcrum is probably at C7-T1). 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 the posterior arch of C1 touching the skull), with flexion below C2-C3. There are only minimal differences with the use of either straight or curved blades.

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 in patients with otherwise normal airways. 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 (see below). This is the "Catch-22" of all proposed methods used to "stabilize" the neck during intubation.

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/laxity 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.

Although the lifting motion associated with laryngoscopy has the potential for producing atlantoaxial subluxation, cord injury during laryngoscopy and intubation are rare. [There is at least one Case Report of marked C1/C2 subluxation produced by simply elevating a patients head with a pillow (to achieve the "sniffing position").] Nevertheless, it is recommended that all patients with severe RA have periodic flexion/extension x-rays prior to 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, although maybe only 10% of these patients are symptomatic. Some pediatricians recommended that all Down's patients have x-rays before age 5. Because of the anatomic abnormalities (as in rheumatoid arthritis) there is concern with any surgical procedure that requires direct laryngoscopy or extensive neck manipulation. However, while there are many cases of rotational subluxation (produced by extreme head rotation during tympanic membrane surgery) and some cases of injury during extreme extension (e.g. during tonsillectomy), we have been unable to find documented cases of Cspine injury that can be directly linked to laryngoscopy. However, extreme rotation and extension should be avoided if at all possible. The lack of data has triggered a great deal of debate about whether X-rays are need before surgery. Our recommendation is that children (and parents) should be carefully examined for any suggestion of cord compression, and that films be obtained only in patients with any symptoms, no matter how subtle.

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.

Instability: Trauma

Traumatic injuries are much more common at C5 and C6, although fractures are most often seen at C1 and 2. 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 (MILS, which is recommended by the American College of Surgeons as part of their Advanced Trauma Life Support-ATLS-guidelines) may reduce movement to some degree - at the expense of more difficult intubation. Our own cadaver studies suggest that MILS may not limit movement across a complete C4-5 fracture dislocation with ligamentous injury. In fact, immobilization of the upper spine may (theoretically) result in more movement of unstable structures lower in the neck, particularly if more force is applied to gain a laryngeal view.

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 uniformly 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, more importantly, the much more rigid 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.

Management Suggestions.

There are no easy answers regarding the management of the patient with severe cervical spine disease/damage and instability. If flexible fiberoptic laryngoscopy is possible it is probably indicated. If this is not possible, then the technique with which the anesthesiologist is most familiar is indicated. MILS is medico-legally advisable and has been widely used - 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. In other words, there are few "absolute" rules that apply to these patients; optimum management requires optimum medical judgment.

An excellent summary of these issues can be found in a recent review article by Crosby in the June 2006 issue of Anesthesiology.

Crosby ET Airway Management in Adults after Cervical Spine Trauma

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