CLINICAL BIOMECHANICS OF CERVICAL SPINE

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- Cervical Spine is divided into 3 regions because of kinetic, kinematic and clinical findings.
- 1)Upper Cervical Spine →Co-C1-C2
- 2)Middle Cervical spine →C3-C5
- 3)Lower Cervical spine →C5-T1

- Vertebrae have 6 degrees of freedom,translation along and rotn about each of 3 orthogonal axes.

THE OCCIPITAL – ATLANTO – AXIAL COMPLEX (Co-C1-C2)

- The occipital – atlanto – axial jt.s are the most complex jt.s of the axial skeleton, both anatomically and kinematically
- There is controversy about some basic biomechanical characteristics.

CRANIOVERTEBRAL VERTEBRAE

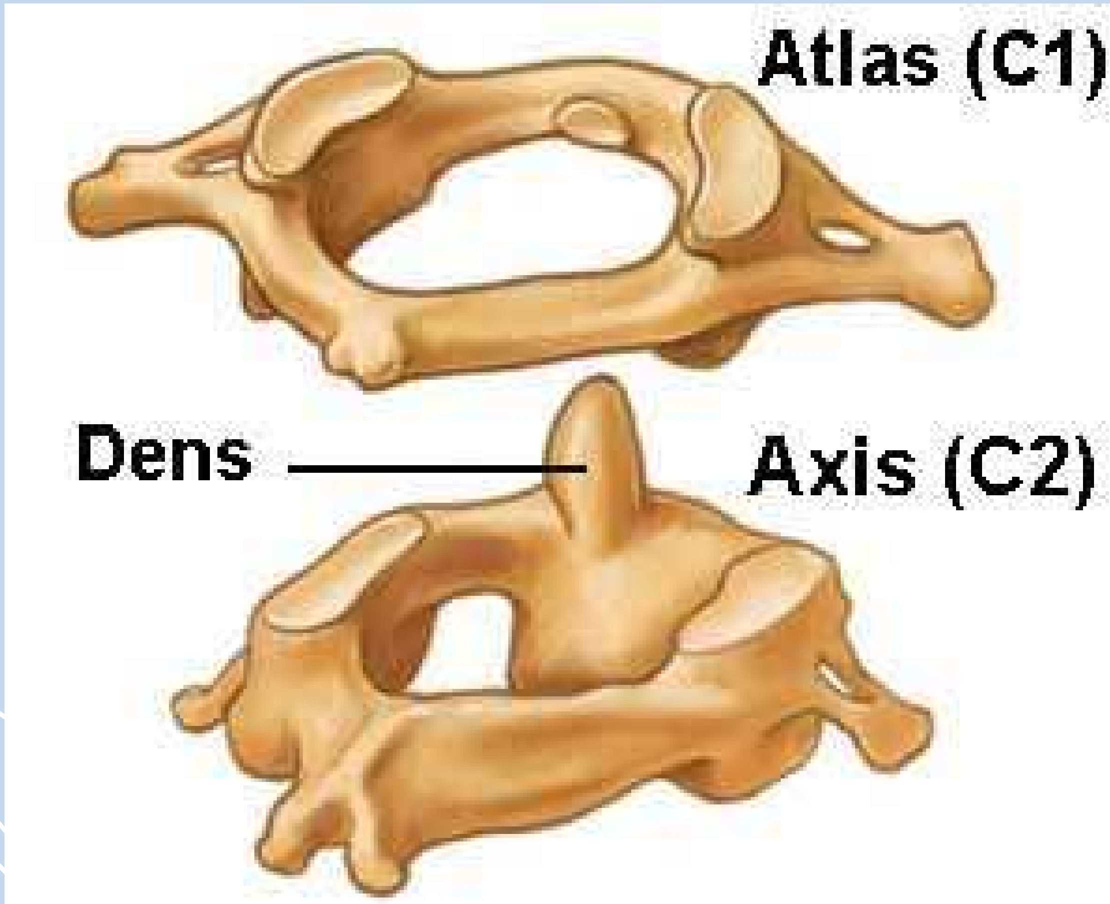
ATLAS:

- Ring shaped vertebrae. Sits like a washer betwn skull and lower Cx spine.
- Cradles occiput to transmit forces from the head to Cx spine.
- Adapted for attachments of ligaments and muscles.
- Lateral masses joined by slender arches ant and post
- Sup aspect of each mass has deep socket that is concave anteropost and medlat so that occiput sits securely.
- Size and shape of socket of each sides vary directed upward and medially
- **Clinical relevance:** Atlanto occipital ROM varies and doesn’t always implies impairment. Relationship betwn other signs and symptoms to be established.

- Transverse process of atlas prim site for attachment of muscle. TP accomodates the loading associated with suspension of scapula thru the attachment of lev scapulae.So any movt of U/L exerts compressive forces on the entire Cx spine.

AXIS:

- It accepts the load of the head and atlast and transmitts to remainder Cx spine.
- Odontoid process acts as a pivot around which ant arch of atlas spins and glides.
- Foramen transversarium gives way to vertebral artery.


Atlas (C1)
Dens
Axis (C2)

RANGE OF MOTION

- Both jt.s of complex participate equally during flex/ext in sagittal plane.

Unit of complex	Type of Motion	Representative Angle
Occipital – atlanta joint (C0-C1)	Combined flex/ext (±θx) One side lateral bending(θz) One side axial rotn.(θy)	25 5 5
Atlanto – axial joint (C1-C2)	Combined flex/ext (±θx) One side lateral bending(θz) One side axial rotn.(θy)	20 5 40

ROM

- Previously it was thought that very little or no axial rotn. betwn. C0-C1. However several investigator have shown axial rotations in range 3° - 8°
- Anatomic structure of C0-C1 is cuplike in its design in both frontal and sagittal plane. Thus relatively less axial rotn.even though little ligamentous restraint imposed by post. Atlantooccipital membrane.

- Approx. 60% of axial rotn. of entire Cx-spine and occipital found in upper region (co-c1-c2) and 40% in lower region.
- The large rotn.occuring at C1-C2 can cause clinical problem.
- *Selecki* studied the effect of this rotation on vertebral arteries that ascend in foramina transversarium and then pass through C1-C2. and atlantoccipital region before entering skull.
- He found that after 30° rotn. ,*there is kinking of the contralateral vert.artery.*
- At 45° rotn. → *Ipsilaterial artery also kinks*.

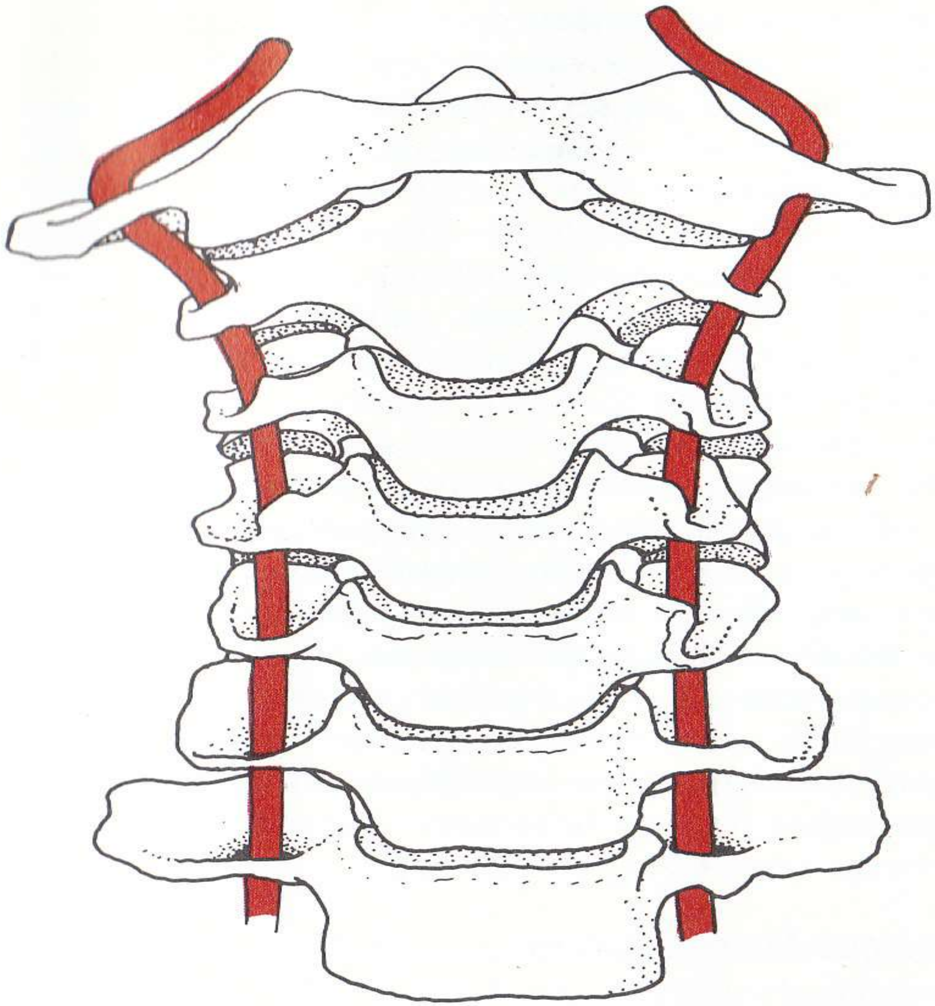


Figure 4–6. Cervical vertebrae with the vertebral artery in place. Lateral translation has the potential to compromise the vertebral artery.

- Situation in which this may occur → Yoga Calisthenics , overhead cervical traction.

  Cx traction → stretching + kinking of already compromised arteries.
- If both arteries compromised → Symptoms related to flow in post fossa elicited.

  Ex – case of stroke following chiropractic manpn.of head and neck.

Premonitory symptoms → Nausea ,Visual disturbance , vomiting , vertigo during prelim. Rx if present during chiropractic Rx should be stopped.

Craniovertebral joints

- The two atlanto occipital jts are typical synovial jts with intra articular inclusions.
- The atlanto axial jts consist of 3 synovial jts: Lt and Rt lateral atlantoaxial jts and median atlanto axial jt
- Rotn movt takes place at this jt. Large intra articular meniscoids present in the joint betwn articular spaces
- **CLINICAL RELEVANCE**: Meniscoid as a source of pain in bruishing following Cx trauma.These structures being innervated can cause pain.

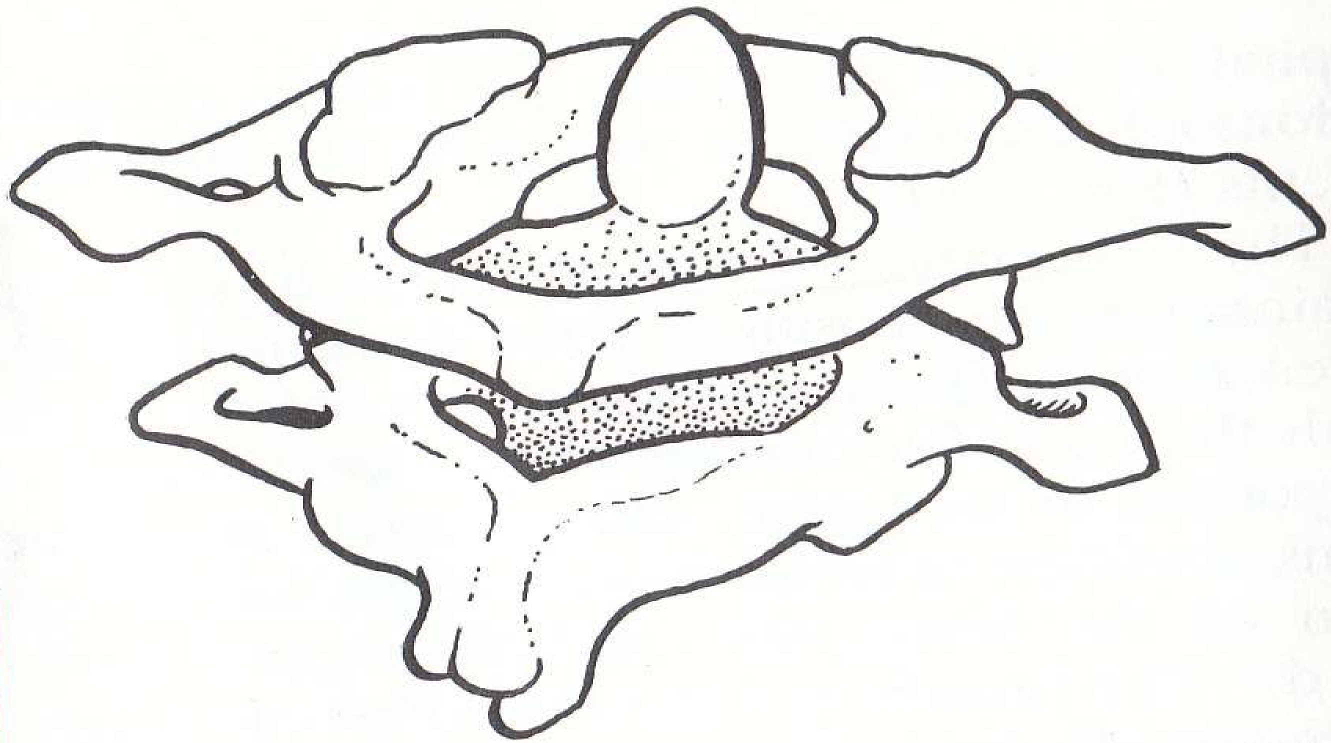


Figure 4–22. Atlanto-axial articulations. These articulations include those between the facets of the atlas and axis, the transverse ligament and dens, and the dens and anterior arch of the atlas.

Ligaments of Craniovertebral joints

- **Transverse Ligament**: Strong structure consisting of exclusively collagen fibers.attaches on inner porrtion of each lateral massof atlas .
- Resists forward translation of atlas relative to axis and integral in stability of atlanto axial jt

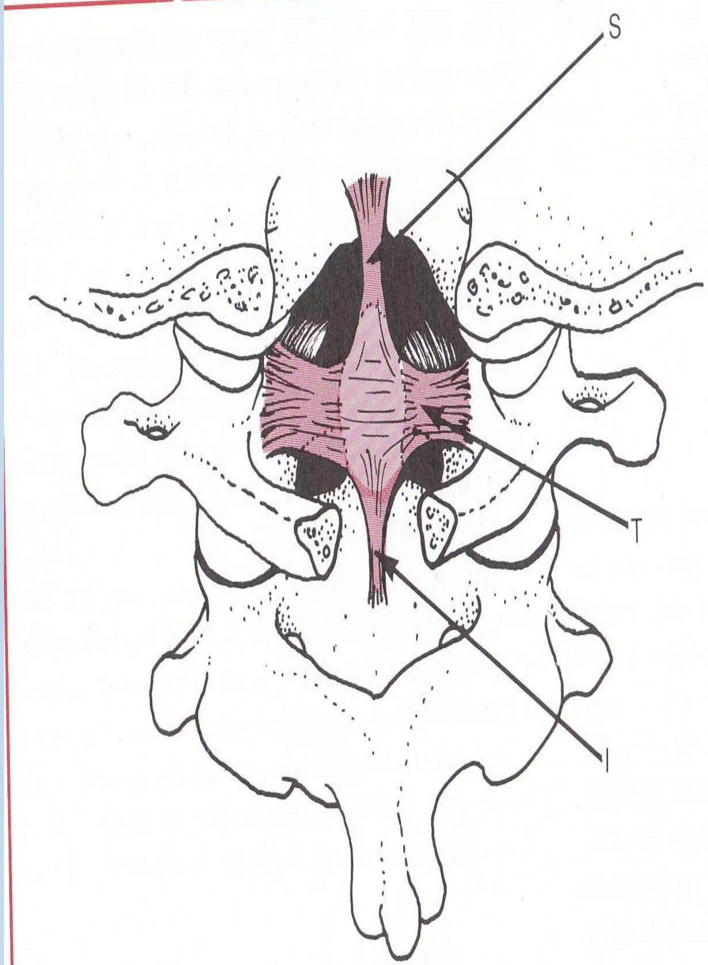
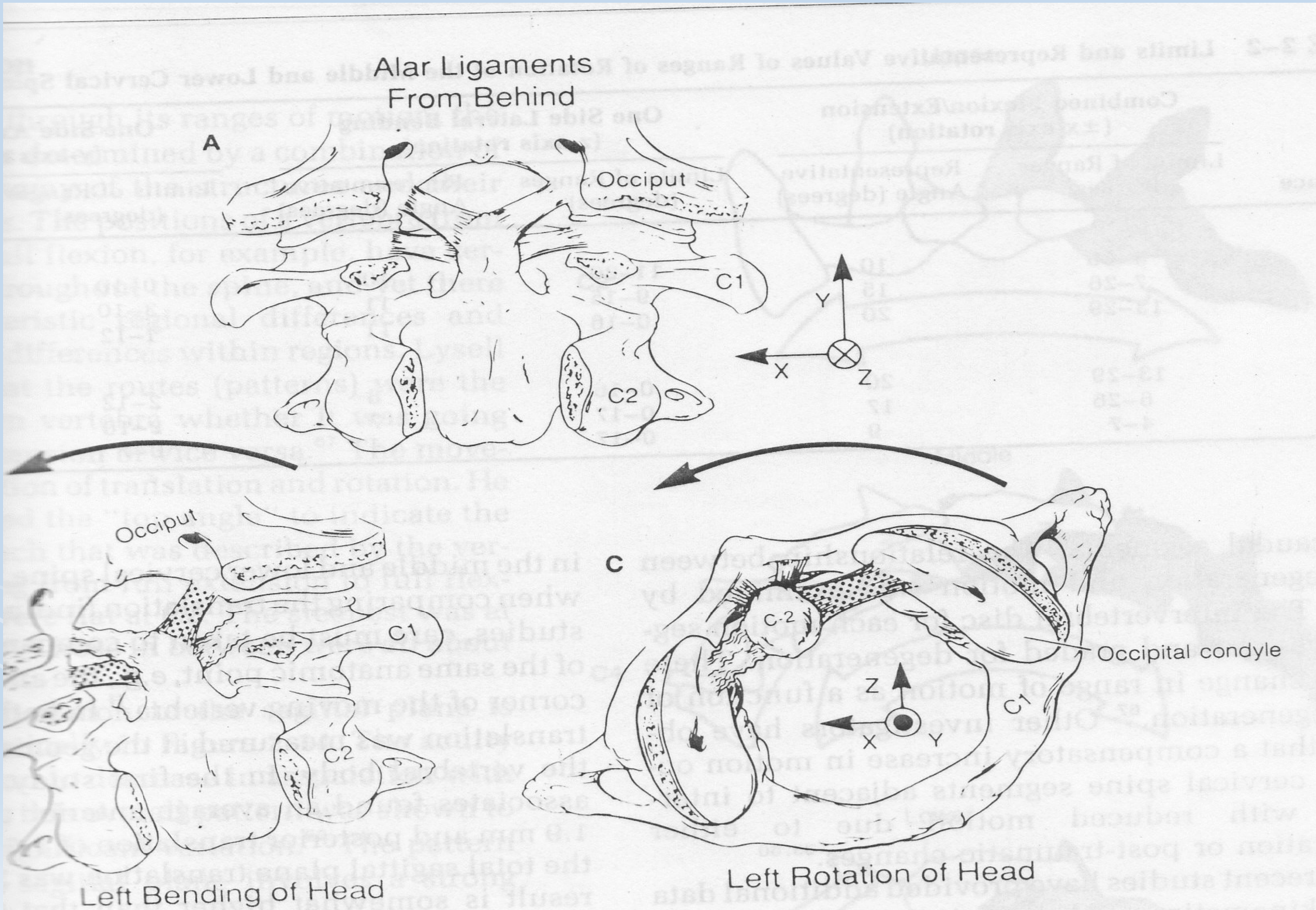


Figure 4-24. Components of the cruciate ligament. I, inferior band of the cruciate ligament; S, superior longitudinal band of the cruciate ligament; T, transverse band of the cruciate ligament.

- Transection of transverse lig results in about 4mm of forward translationof median atlantoaxial jt after which jt stabilised by alar lig

ALAR LIGAMENTS:

- It passes laterally and upward from the odontoid process to the margins of foramen magnum.
- They are critically imp in limiting rotn of head and atlas on axis
- Rotn restricted by the opp side lig
- Dvorak et al have shown that axial rotn increases by about 11º(30%) following transection of contralateral alar lig


Alar Ligaments
From Behind
A
Occiput
C1
C2
Y
X
Z
Occiput
C1
C2
C
C-2
Occipital condyle
Z
X
Y
C1
Left Bending of Head
Left Rotation of Head

Tectorial membrane

- It is a wide sheet of collagen fibers that covers atlanto axial ligament complex.
- Extends from post surface of vert body of axis upto margins of foramen magnum and is direct prox continuation of PLL.

Atlanto – occipital and atlanto axial membranes:

- Ant and post atlanto occipital membranes found spanning the space betwn the upper border of ant arch of atlas and basiocciput and post arch and post margin of foramen magnum.

Apical ligament:

Missing in 20% individuals

No known biomechanical importance

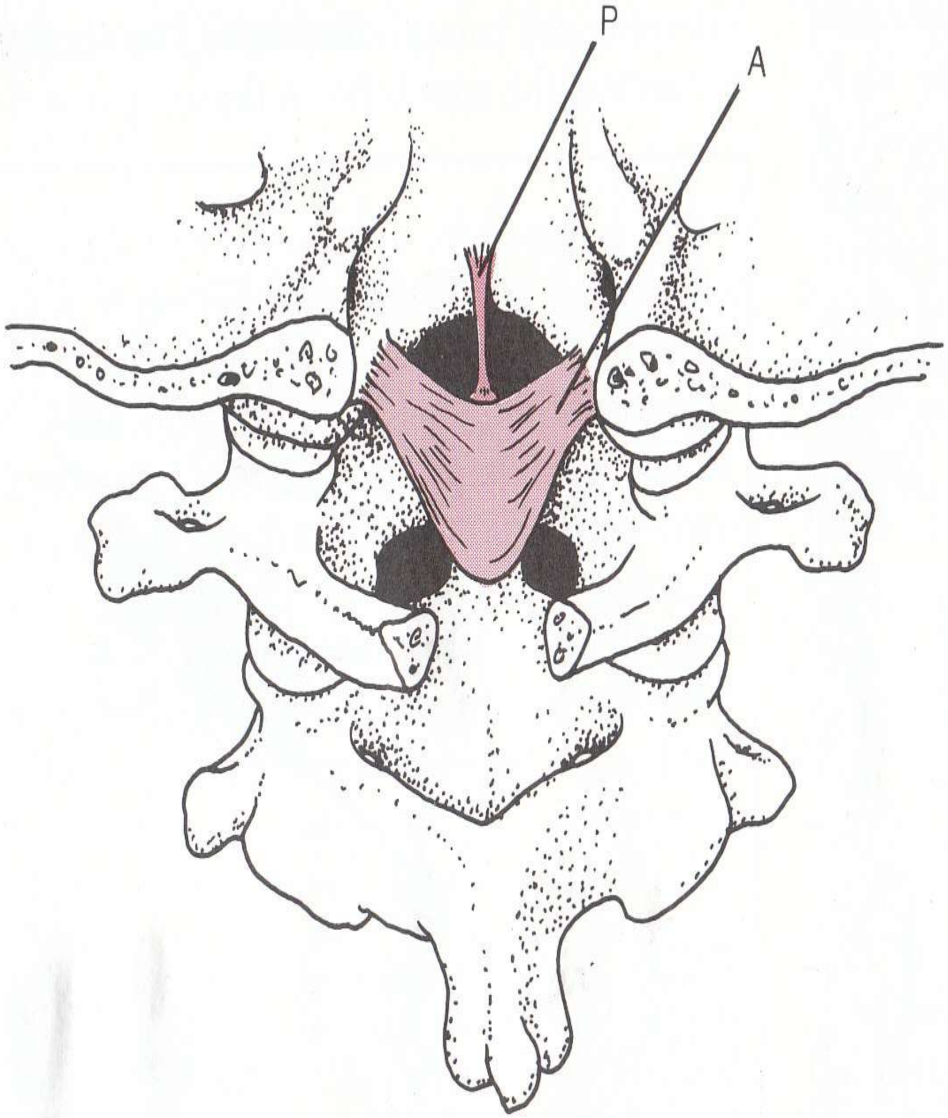


Figure 4–19. Attachments of the alar and apical ligaments. A, alar ligament; P, apical ligament.

JOINTS OF LOWER CX SPINE
Interbody joints:

- Vertebral bodies below C2 are joined via IVD
- IVD should be strong enough to accommodate motion , transfer load and not be injured during movt.The form and function of Cx IVD is however distinctly different from that of Lumbar IVD.
- In adults, the AF in Cx region is a discontinuous structure surrounding a fibrocartilaginous core, instead of being a fibrous ring enclosing the gelatinous NP like in lumbar region.
- Anteriorly the Af in Cx region is a thick crescent of oblique fibers joining the vert bodies to constitute a strong interosseous ligament located at the pivot point of axial rotn.

- Posteriorly the AF is a thin narrow vertically oriented band of fibers joining the vert bodies.laterally there is no distinct annulus, only flimsy fascial tissue that is continuos with the periosteum.
- Cx disc are different from the thoracic and lumbar disc in that they donot extend to the lateral rims of the vert. bodies as uncinate process located laterally.
- Cx disc ht in comparision to its surface area is higher. So large amount of motion in Cx spine
- Cx lordosis → due to wedge shape of the disc
- Few studies if intradiscal pressure of Cx IVD
- *Hattori* and colleague studied intradiscal pressure in Cx with pt in supine,needle type semiconductor pressure transducer placed into C4-C5, C5-C6,C6-C7 IVD under fluoroscopic control and pt brought to sit

- In normal discs the highest pressure occurred when the neck was taken into extension
- Extension > Flexion >Rotn and lateral bending
- But they didn't mention whether it was active or passive

*IVD pressure in sitting was 1.4 times greater than those in supine.

Cx traction applied with a head halter resulted in a decrease in Intradiscal press proportional to the traction force.

With a 10 kg wt the press decreased by 57% with traction forces applied in supine and 44% with traction forces applied in sitting

** They concluded that it might be reasonable to assume about a 50% decrease in intradiscal press with a 10 kg traction force.

- Hattori et al also noted that degenerated discs present a slightly different and highly unpredictable picture
- With increasing disc deg , there is less intradiscal pressure.
- Some IVD exhibited higher press in extension, whereas others show higher press in flex.
- The press decreased with Cx traction and with a 10 kg traction force, press often went to zero

DISC DEGENERATION:

Mostly seen after 4th decade.

Most frequently at C5-C6 level and C6-C7 level.

Cervical protrusions usually occur laterally (intraforaminal herniation) because of the width of the PLL.

Apart from causing radiculopathies, cervical disc protrusions may result in myelopathy because the

- Spinal cord occupies most of the Cx spinal canal. As a result UMN signd may be present with Cx lesion
- Pt.s with developmental cervical stenosis are predisposed to Cx myelopathy and therefore less ability to accommodate Cx disc protrusions.
- Reduced spinal canal might be due to IVD buldges, hypertrophic lig flavum, foraminal osteophytes,hypertrophy of facets.

The **uncinate process** which begin to develop at 6 to 9 yrs of age fully developed at 18 years.

- Thought to prevent post. translation and also limit lat.bending
- In addition serves as a guiding mechanism to patters of flex/ext
- As long as either all ant.elements or all post elements are intact, there is no gross abnormal motion.

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CLINICAL RELEVANCE:

- **Discogenic pain**: This pain cant arise from posterolat fissure in the AF as in lumbar disc as there is no posterolat AF.
- Possible sources of disc related pain inCX are strain or tear of ant AF, especially following hyperext trauma , and strain of the lateral(alar) portions of PLLby a buldging disc.

- The NP of Cx IVD is also distinctly different from Lx nucleus
- At birth, the nucleus comprises less than 25% of the discs, whereas in the Lx disc it comprises atlaest 50%
- The adult Cx nucleus is characterised by fibrocartilage with no gelatinous component

ZYGAPOPHYSIAL JOINTS

- They are typical synovial jts, articular surface line by cartilage and enclosed by a joint capsule.
- Variety of intra articular inclusions found within the joint like meniscoids.

CLINICAL RELEVANCE:

- In rear impact collision produce hyperext movt of head and neck.
- It is postulated that this movt causes impingement of meniscoids which could become inflammed and be a source of undiagnosed neck pain following whiplash inj

The middle and Lower Cervical spine

- The lower 5 vertebrae exhibit features that reflect mobility, stability and load bearing fn.
- Together lower 5 may be considered as triangular column consisting of anterior pillar composed of vertebral bodies and 2 post columns consisting of Rt an Lt articulating sup and inf articular process

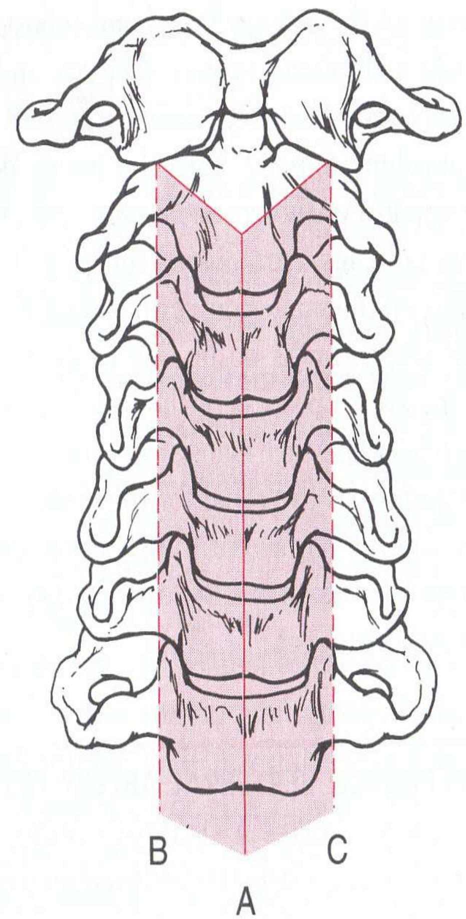


Figure 26.4: Anterior view of the cervical vertebral column. The cervical vertebral column consists of a central anterior pillar *(A)* and the right *(B)* and left *(C)* articular pillars, forming a triangular column.

- The sup facets directed superiorly and post and inf facets directed ant and inf
- In addnt to above orientation, C3 sup facet faces medially at about 40º
- The sup articular facets change from posteromedial orientation at C2/C3 level to posterolat orientation at C7/T1, transition typically occurs at C5-C6

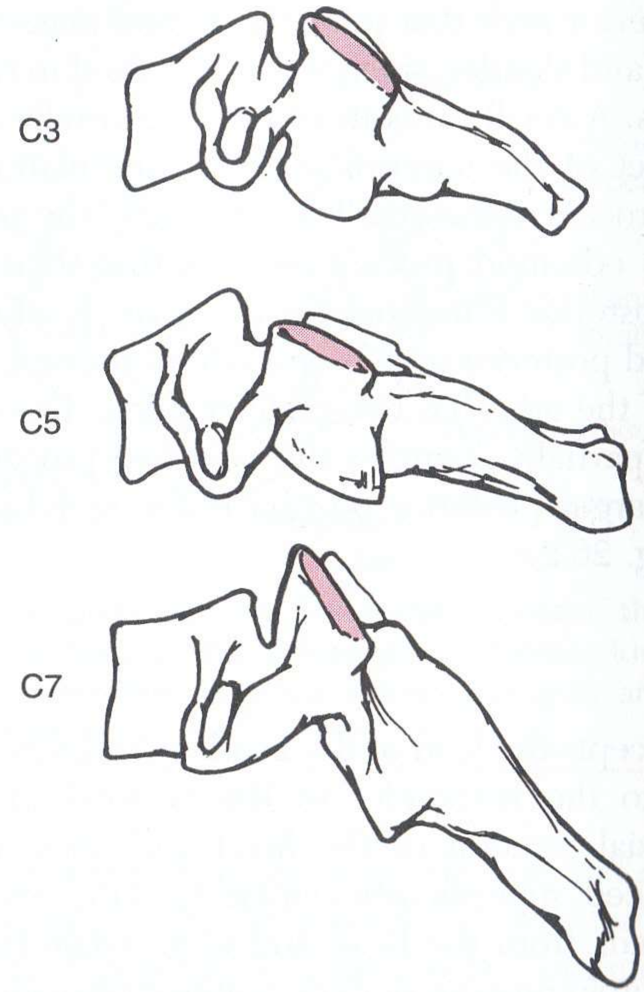


Figure 26.6: The superior facets of C3 face slightly medially as well as superiorly and posteriorly. The superior facets of C3 and C7 are more steeply oriented than those of C5.

- C7 is the point where neck is contilevered off the more rigid thoracic spine. So due to attachment of various muscles, spinous process and post tubercle are strong and robust.

LIGAMENTS OF LOWER CX SPINE

- **ALL**: Multilayered lig firmly adherant to the IVD and to adjacent vertebral margins.
- **PLL**: broad thick lig that blends with the post surface of the IVD and attaches to the vert bodies near their upper and lower margin and post surfaces. Cranially forms tectorial membrane
- PLL and ant AF are imp stabilizers of each interbody segment.
- **LIG FLAVUM**: thinner than in LX region. This elastic lig passes from the border of the lamina of one vertebra to the at surface of the lower edge of the vertebra above.

LIGAMENTUM NUCHAE:

- Lig nuchae is a median fibrous septum, triangular in shape which divides the muscles of post neck into Rt and Lt compartments and provides attachment for the upper fibers of trapezius, Rhm minor, splenius capitis and serratus post sup.
- It is composed of a free post border that extends betwn the ext occipital protuberance and the spinous process of the C7, an ant border that is firmly attached to the Cx spinous process and a short sup border that extends along the ext occipital crest.
- It is a substantial midline structure that is imp in the control of head posture.

MOVEMENTS

Atlanto occipital joint

- The nodding movt that occurs during flexion of the head is a result of rolling and sliding of the occipital condyles in their sockets.
- As the head nods forward,the occipital condyles roll forward in the atlantal sockets, tending to roll up the ant wall of the socket. Because of compression loading exerted by the mass of the head, the flexor musculature, or the tension in the jt capsules, the occipital condyles concomitantly translate downward and backward. As a result ant rotn is coupled with downward and post sliding, and the condyles effectively stay nestled in the floor of the atlantal sockets, ensuring max stability of the head on neck.

EXTENSION

Cranio cervical junction (Co-C2)

At CoC1, the IAR of extension appears to lie in the post inf.border of the basocciput central level with the sup.lat. edge of the occipital condyles.

- Constraints to motion are primarily the AL, AOAM and the facet capsules.Muscular control is most by release of ant. tension rather than post.muscle contraction.

At C1-C2 , the IAR of extension appears to lie in the upper third of the dens. The strong CL especially the TL maintain dens atlas ant. approxm. The C1 ant. arch. glides superiorly on the odontoid within its facet.

COUPLING CHARACTERISTICS

- There is a strong coupling pattern at the atlanto axial jt.
- The axial rotn. of C1 is associated i,e vertical translation.However there is some disagreement.
- *Henke* described it as a double threaded screw jt. Due to biconvexity of the articulation between C1 and C2.
- This analysis was criticized by Hultkrantz, who studied sagittal sections of the C1-C2 articulation and found some of the surfaces were slightly biconvex and some were slightly biconcave. It has been observed that although the bony configuration may be concave,the configuration of the cartilage is such that the complete articulation has biconvex design.which is thought to account for screw motion .Screw motion occurs at extremes of ROM.

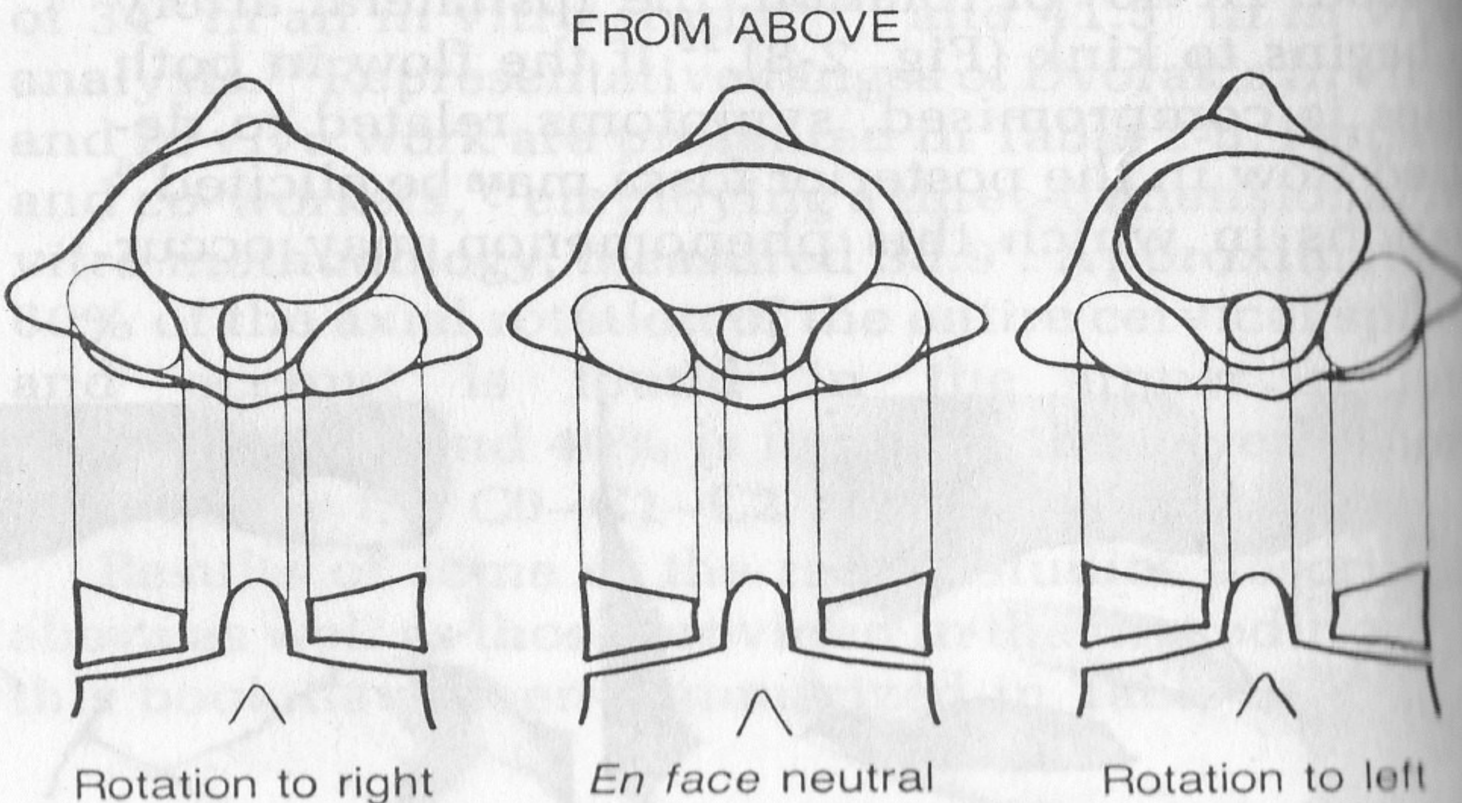


FIGURE 2-9 When C1 rotates to the right ($-\theta y$), the apparent distance between the dens and the right articular mass (lateral mass) of C1 increases. When C1 rotates to the left ($+\theta y$), the concomitant movement of the left lateral

Upper Cervical Spine

- Co-C1 rotn. Demonstrated as a small axial rotn.btwn the occipital condyles and the C1 facets. It is accompanied by translation of the condyles. The condyle ipsilateral to rotn. will translate posteriorly and contralaterally.

- The contralateral condyle will translate anteriorly and also contralaterally.The contralateral AL and the ApL will restrain excessive motion. At Co-C1 the IAR of rotation appears to lie in the ant arch of atlas.
- The atlas screws down on axis as it rotates.Any assymetry in the articular cartilages results in coupling of ipsilateral or contralateral sidebending with the axial rotn, the side of coupling depending upon the direction of asymmetry
- The suboccipital muscles act directly to rotate the head on the neck. Again coupling is key in this motion.

- C_1-C_2 rotn.is the segmentally greatest in the spine accounting for 50% of head and there is no rotn. of Co-C1 during pure side bending. It is generally agreed in vivo that the sidebending of the head forces couples sidebending of the lower Cx spine with spine its associated ipsilateral rotation

Rotn.of C1 occur as a helical motion frequently referred to as

(w) screw like motion that reduces the vertical height of the upper cervical spine.There is also lateral displacement of C1 betwn. Co and C2. Since the facets are concave ,this will be accompanied by Contralateral tilt of the occiput.

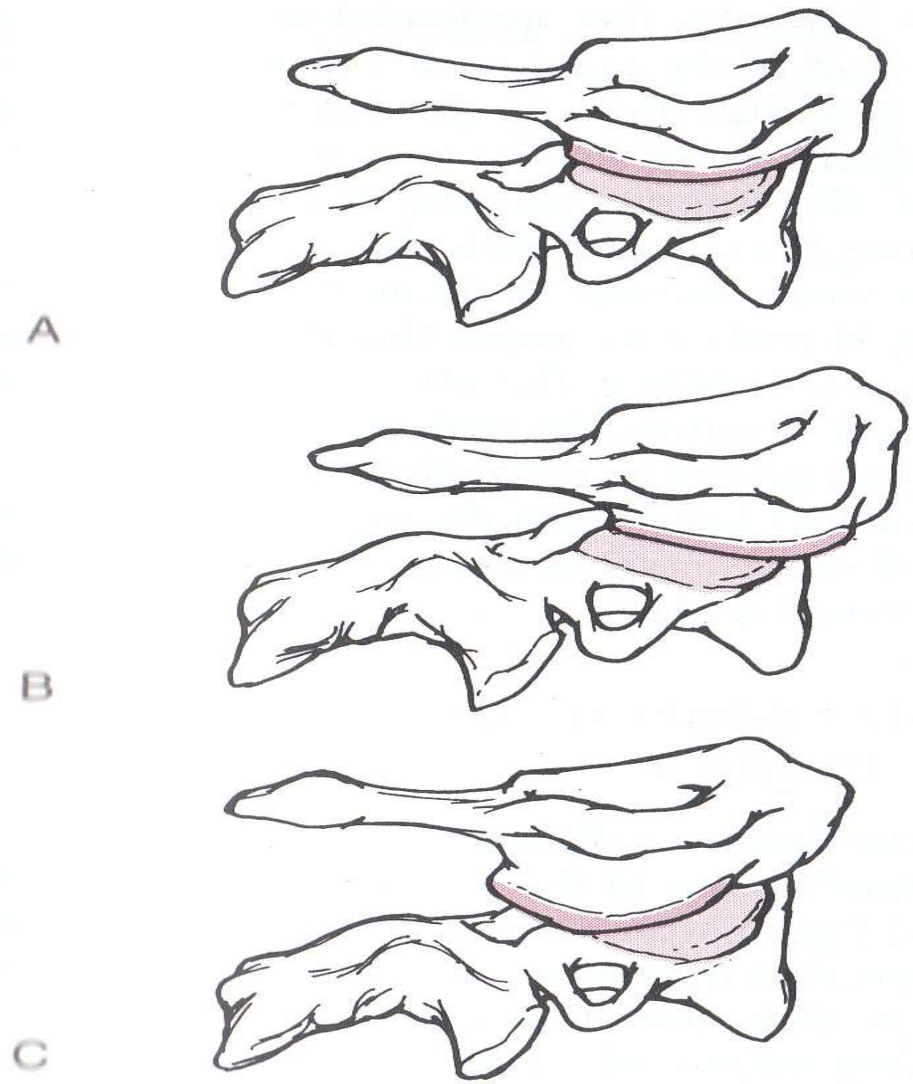


Figure 26.15: In axial rotation of the atlantoaxial joint from the neutral position **(A)**, the inferior articular facet of the atlas slides down the anterior slope of the convex superior facet of the axis during contralateral rotation **(B)** or down the posterior slope of the convex superior facet of the axis during ipsilateral rotation **(C)**.

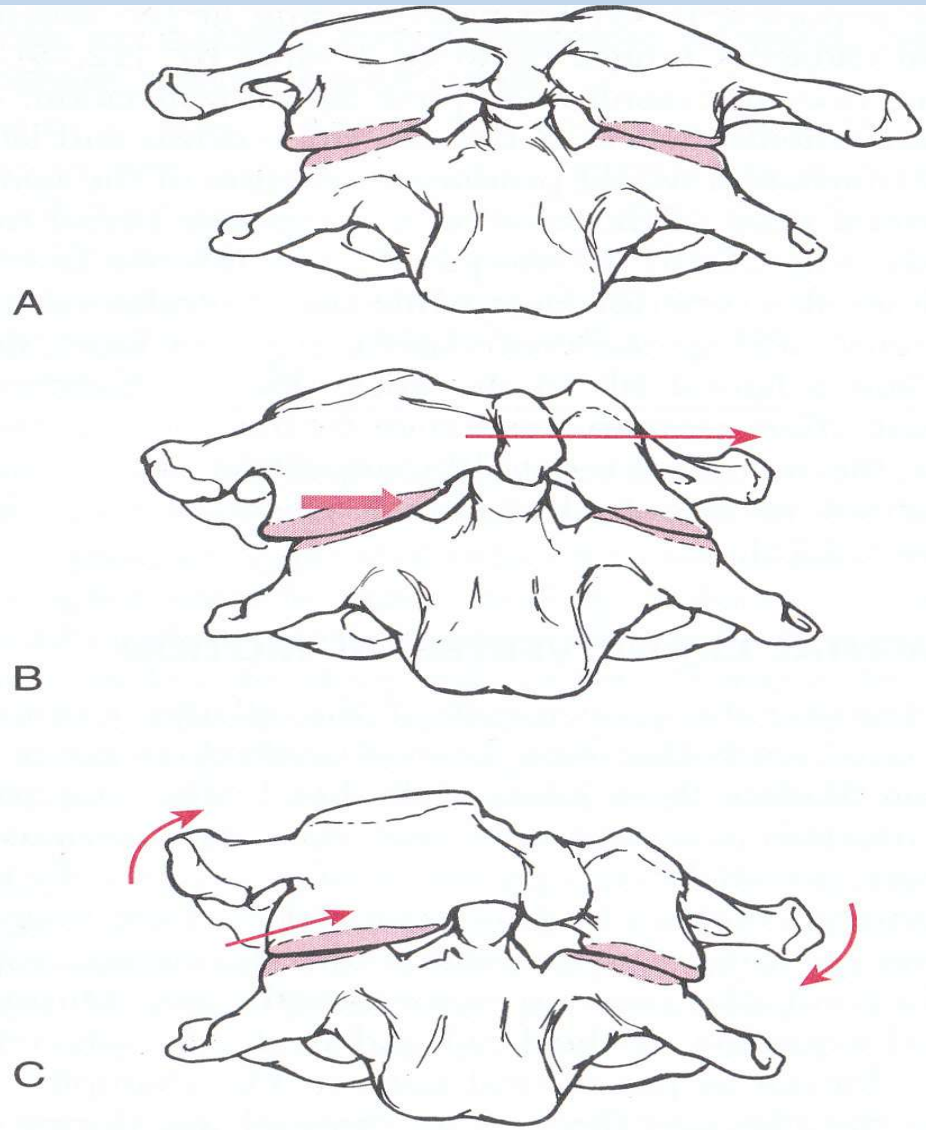


Figure 26.16: Lateral translation and side-bending at the lateral atlantoaxial joints. **A.** The superior articulating facets of the axis slope laterally and inferiorly. **B.** As the atlas translates laterally, its inferior facet impacts on the superior facet on the axis. **C.** As the atlas translates, one inferior facet slides up on the underlying superior facet as the other rides down, imparting a lateral tilt to the atlas.

FUNCTION OF ANATOMIC ELEMENTS

- At C0 – C1 articulation → Flex checked by skeletal contact between ant. Margin of foramen magnum. and tip of dens.
  - Ext. Limited by tectorial membrane (cephalad continuation of PLL) with flex at C0-C1 beyond neutral , tectorial membrane becomes taut and limits forward flex at C1-C2 jt.s

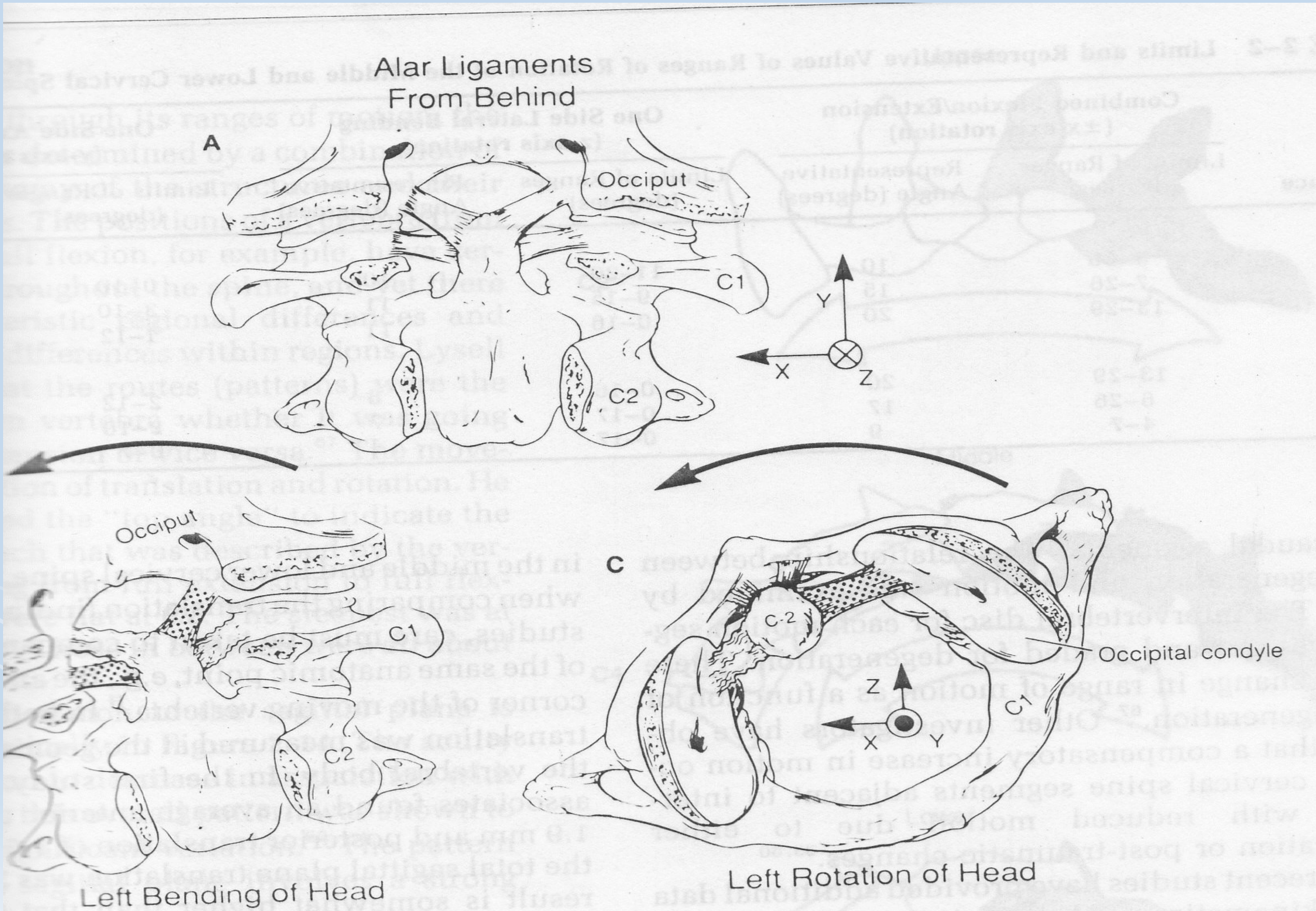
  Similiarly with extension → tectorial membrane again becomes taut and limits extension betwn. C1and C2.

Axial rotn. betwn. C0 and C1 limited by the ligaments and osseous anatomy of C0-C1-C2 articulations.

- Alar lig. Symmetrically placed in both sides of dens , with one portion connecting dens to occiput and remaining dens to atlas.

MECHANISM OF LAT. BENDING is more complex.

- This motion involves 5° to one side at C0-C1 and also at C1-C2.
- The C0-C1 motion is controlled by both components of the alar Ligaments.


Alar Ligaments
From Behind
A
Occiput
C1
C2
Y
X
Z
Occiput
C1
C2
Left Bending of Head
C
C-2
Occipital condyle
Z
X
Y
C-1
Left Rotation of Head

- During left lat. bending the upper portion of the alar lig. connected to the occiput and the left lower component connected to the ring of C1 , check the motion.
- Left axial rotn.is checked by right alar.lig.

Craniocervical Junction (Co-C2)

Co – C1 and C1-C2 are most usually discussed as a unit based on their unique features and close movt.coupling.

Co-C1subserves head on neck posturing and stability in sagittal and coronal plane.

C1-C2 subserves head motion in the transverse plane and can't function properly without the stability from above.

- The lower cervical spine may be seen to act as the dynamic arm compensating for balance disturbance from below.

These fn. are supported by the dense mechanoreceptor population of the Cx spine and proportionately large muscular system supporting the upper and lower sections both independently and jointly.

ROM OF LOWER CX SPINE

- Flexion in the lower Cx is a combination of ant translation and ant rotn in the sagittal plane
- Extension→ post translation and post sagittal rotn

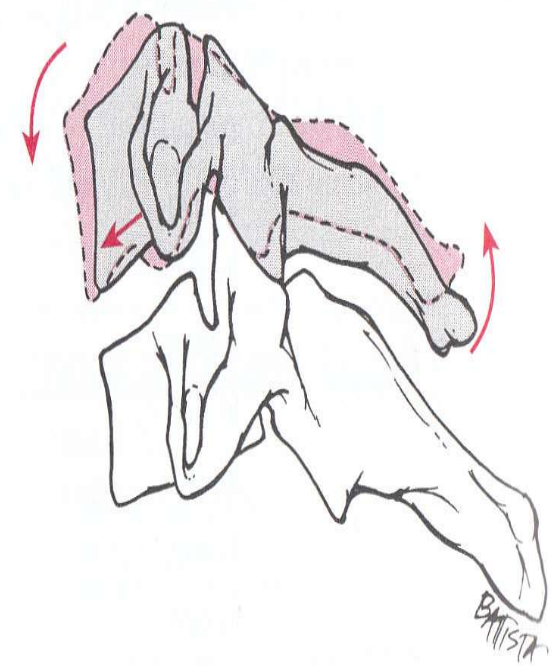


Figure 26.17: Flexion in the lower cervical spine combines anterior translation and sagittal plane rotation of the superior vertebra.

LOWER CX ROM FLEX AND EXT

	Dvorak et al	White and Panjabi	Penning
C2-C3	10	8	12
C3-C4	15	13	12
C4-C5	19	12	20
C5-C6	20	17	20
C6-C7	19	16	15
C7-T1		6	

LOWER CX ROM- LAT BENDING IN ONE DIRECTION

	White and panjabi	Penning	Moroney et al
C2-C3	10	6	4.7
C3-C4	11	6	4.7
C4-C5	11	6	4.7
C5-C6	8	6	4.7
C6-C7	7	6	4.7
C7-T1	4	6	4.7

LOWER CX ROM – ROTN IN ONE DIRECTION

	WHITE AND PANJABI	Penning	dvorak
C2-C3	9	3	3
C3-C4	11	6.5	6.5
C4-C5	12	6.8	6.7
C5-C6	10	6.9	7
C6-C7	9	5.4	5.4
C7-T1	8	2.1	2.1

Does Head Posture affects Cx ROM?

- Posture of the head and neck influences whether flex/ext of the atlas occurs during Cx motion.
- During flex and ext of the neck, atlas exhibits paradoxical motion.for example during flex atlas may flex or extend and vice versa.
- This incongruity occurs because the convexities of inferior facets of atlas rest on convexities of superior facets of axis.
- The equilibrium of the resting position is thus susceptible to small variation in the position of compression forces passing through the lateral masses. If the compression load exerted anterior to the fulcrum of articular surfaces

- Of lateral atlantoaxial jt, the atlas tilts into flexion. If the compression load exerted post to the fulcrum,atlas tilts into extension.
- If the chin is protruded as the neck flexes,the atlas flexes in accord with the other cervical vertebrae as the compression force is displaced anteriorly. If the chin is tucked, the atlas extends when the other cervical vertebrae flex as the compression load moves posteriorly within the lateral atlantoaxial jt. Initial head posture therefore may influence craniovertebral movt patterns.

THE MIDDLE AND LOWER CERVICAL SPINE (C2-T1)

- The C5-C6 interspace is considered to have the largest range.
- For lat.bending and axial rotn.there is a tendency for a smallerROM in the more caudal segments.
- Some investigator have observed that a compensatory increase in motion occurs in Cx spine segment adjacent to interspaces with reduced motion.

COUPLING CHARACTERISTICS

- The coupling patterns in lower Cx spine are dramatic and clinically important.
- Coupling is such that , with lateral bending the spinous process go to the convexity of the curve.
- In lat.bending to the left , spinous process go to right and in lat.bending to the right , the spinous process go to left.

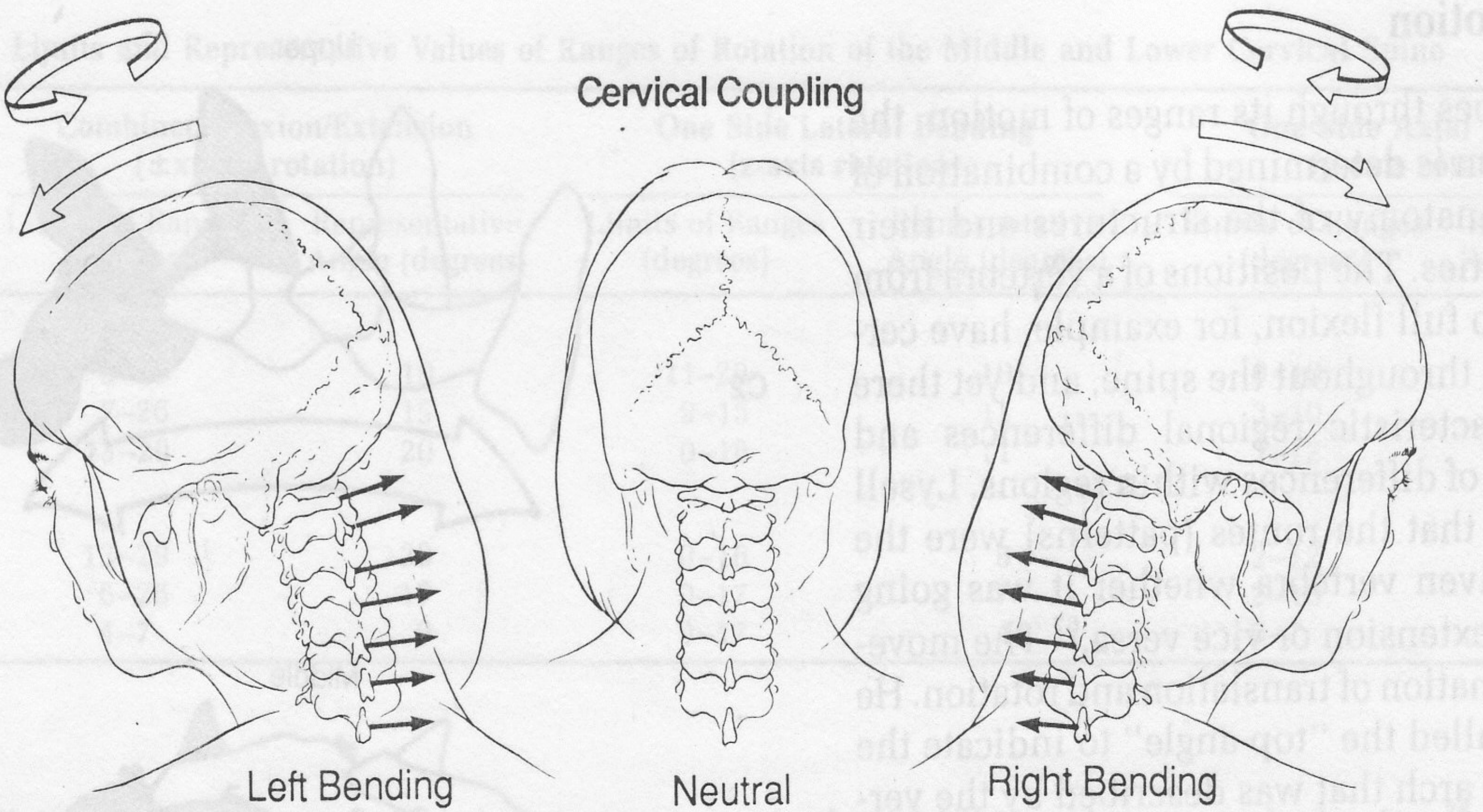


FIGURE 2-15 An important cervical spine coupling pattern. When the head and neck are bent to the right, the spinous processes go to the left. The converse is also shown. (Expressed in the coordinate system, + z-axis rotation is coupled with − y-axis rotation, and − z-axis rotation is coupled with + y-axis rotation.) This is a good frame of reference for describing and remembering the axial and lateral-bending coupling relationships in other regions of the spine. See also Figure 2-20.

- **CLINICAL SIGNIFICANCE**

In trauma with axial rotn. and lat. bending may result in unilateral facet dislocation.

At C2 → there are 2° coupled axial rotn. for every 3° of lat.bending , a ratio of 2:3.

At C7 → There is 1° of coupled axial ratio for every 7.5° of lat.bending (Ratio of 1:7.5)

Betwn C2-C7 → Gradually cephalocaudal decrease in the amount of axial rotn i,e associated with lat.bending (Gradual change in coupling ratio may be related to a change in the incline of the facet Joint. Angle of the incline of facet joints in sagittal plane increases cephalocaudally.

Coupling during side bending

The mid and lower Cx demonstrate ipsilateral coupled rotn. During sidebend.This varies decreasing caudally.

At C2-C3 , 2° of rotn. Accompany 3° of sidebending.

C6 C7 has been demonstrated as 1° rotn. →7.5° sidebending.

- Sidebend with the head forward c lower Cx motion will couple C_o – C_1 sidebend with C_1-C_2 contralateral rotn.
- C1 will glide ipsilaterally btwn. Co and C2.
- Most authors agree that there is no rotn.of C0-C1 during pure sidebending.

It is generally agreed that sidebending of the head forces couples sidebending of the lower Cx spine with its associated ipsilateral rotn.

Coupling of motion in the craniovertebral segment is more than articular kinematics.

The AL and CL contribute to the occurrence of craniovertebral coupled motion. Their absence and radiologically absent coupled motion is *evidence of instability*. Their role in side bending is to limit axial rotn. of Co and C1.

The contralateral AL and TL fibers tighten. With the ant.attachment of the AL to the dens, C2 ipsilateral rotn. is forced.

Rotation

Mid /Lower cervical (C2-T1): passive constraint against rotn in the cervical spine occurs though the contralateral capsular ligaments, supraspinous ligament(SSL) and the weak interspinous ligaments (ISL).

In the cervical spine, the vertical direction of annular fibers doesn’t particularly lend support to the IVD but is a primary passive restraint to axial rotn. or torsion.

The uncovertebral jts. are the prim.barriers to excessive rotn. with surgical transection altering experimental ROM by as much as 50%.

- The facet capsules afford modest resistance to axial rotation.
- The IAR for rotation is also poor researched , but thought to be slightly superior of the centrum of vertebral body.
- Studies show that the role of multifidus is as a derotator or stabilizer, against rotn. in the mid and lower spine, much as it is in the lower spine.
- It appears that the *suboccipital musculature initiates rotn*. *with local segment control*.
- The Lig flavum afford elastic resistance to rotation. The longitudinal lig structures afford little restraint.

Flex / Extn.(Sagittal or X-axis Rotn.)

Mid/Lower cervical(C2T1): during flex, all lig. except ALL
Under tension.

At each cervical level → Flex occurs as ant.and sup.
translation of one vertebra on the one below.

Biomechanically the motion is described as sagittal rotn.

The IAR is along the ant.border of the lower vertebra of the motion segment. It is close to centre pt.in neutral and descends with increasing flex.

- During flexion there is superior and ant.translation of the upper segments on the lower with the reverse occuring during extension.

- True neutral is biomechanically best defined as the pt.at which IAR is midway betwn its two extremes and the articular facets in greatest contact.

- It is complicated by the fact that with all lig. Structures intact, the IAR is different depending on the position of C_0-$C_{2.}$

- The mid cervical zygapophysial jts.do not offer bony stability .The available resources to control or stabilize the cervical spine are lig, muscles, uncovertebral jts and IVD.

The uncovertebral jts.in sagittal motion serves as guiderail for zygapophysial jts.motion. They restrict lateral translations throughout motion. They limit the extreme of the motion assisting the post lig. structure in protecting the zygopophysial jts.facets from ant.dislocation and the IVD from excessive post.tensile stress. They conversely assist the ant.ligamentous structure in protecting against post. Facet dislocn. and undue ant. IVD tensile stress .

- The spine would sustain normal physiologic loads so long as all of either the ant or post elements, plus any of the opposing element were intact.This was universal for all directions of movt.

- The mid cervical spine possess the largest uncinate processes , the narrowest discs and the largest angulations betwn.disc and facets as compared to the lower Cx spine .These all contribute to somewhat less motion in the middle then the lower cervical spine. This is consistent with the greatest degenerative and stability problems occuring at C5-C6.

  The discs are probably more protected in the sagittal plane. Patterns of Cx disc deg. indicate that purely sagittal motion are the least culpable.

EXTENSION

Mid / Lower Cx (C2-T1)

Extension is considered in biomechanical literature to be part of total sagittal (x-axis) rotn.

Limits to motion are the ant.elements.

Ext excludes the PLL from tension.

COUPLING DURING SAGITTAL(X-AXIS)MOTION

Coupling is the rule ,not the exception in cervical movt.

It occurs at all levels and in all motions.

** Approaching end range in vivo, full cervical flexion paradoxical motion is described. It doesn't occurs during isolated Co-C2 flexion.(nodding) . Backward translation of one or more segment occurs , most often at Co-C1 but also at other levels. C5-C6 and C6-C7 are the next most common and occationally C1-C2 . These are described as physiologic occurrences i,e variations within normal parameters. During movt. from full flex towrds ext. or post, rotation on the x-axis, paradoxical movt. is not demonstrated

.

During flexion of the full cervical spine (Co-T1) maximal head flex doesn't occurs.

Studies observe that either full mid and lower cervical flexion with reduced Co-C2 flexion or extension occurs or full Co-C2 flexion occurs(nod) with reduced mid and lower flexion.

**In order to determine maximal available excursion in the cervical spine , chin to chest must be examined with head in extension and nod examined with neck towards extension(chin tuck)

Forward motion betwn.these Co-C1 and C1-C2 is coupled by the ApL , AL , PLL,TM vertical fibres of CL and POAM

Apl→ lies on the ant.aspect of the dens, which results in counterbalancing tipping of C1 on C2.

AL→ Reach forward to the occiput from the post dens.

Both ligaments encourage post. translation of the occiput thereby reducing force through the dens, protecting it from bending forces which could result in # or instability.

The AOAM and POAM stabilize the C1 ant. arch, allowing the dens to rock in its atlantal articulation.

Musculature of the cervical Spine

Importance of coordinated pain free movement of the cervical spine

- Mobility of the neck is important because head and neck posture often are rapidly assumed to optimize the position of sense organs such as the eyes and ears.
- For example to track an object with eyes, it is essential that there is concurrent coordinated contraction of the cervical spine musculature to allow the eyes to follow the object.
- Rapid head and neck positioning required when people are subjected to a sound
- These movt of Cx occur smoothly and rapidly without conscious effort.

- These postural adjustments occur due to reflex connection between sensory and auditory apparatus and motor neuron pool in the cervical spinal cord and brainstem
- CLINICALLY it is the inability to rapidly position the head and neck in pain-free position that is a major complaint.
- A rapid reflexive movt of head can dramatically increase pain in injured tissues.
- Ex- looking over one's shoulder while backing a car or holding the head and neck in a particular position and making subtle movt while reading a book can be painful.

- So mobility and coordination deficits especially those that exacerbate the painful syndrome assume great imp in Cx pain syndrome and the clinician should know about the musculature of Cx

Role of muscles:

- Effective protection of the jt. largely depeds on appropriate functioning of the muscle system.
- Dysfn of muscle and jt so closely related that should be taken as one single inseparable fn unit and assessed, analysed and treated together.
- Practical clinical experience shows that almost all techniques used in modern manual therapy is on muscle.Ex- MET, Post isometric relaxn, Myofascial release etc.

- In acute pain→ increased muscle tone(spasm) plays decisive role in pain prodn. Without muscle spasm jt dysfn remains painless.
- So muscle assessment should be given special attention in both assessment and treatment of painful disorder of Cx.
- Muscle analysis very imp in chronic condn in order to treat them and prevent recurrences.
- Ex- Painful area on occiput→ considered to reflect periosteal pain or painful post arch of atlas.*can also occur at the insertion of muscle in spasm.

- The coordination betwn Cx muscles and the orofacial muscles should also be emphasized.
- For the muscles of mandible to actively and rhythmically open and close the mouth, the occiput must be stabilized, with subtle changes in position and fixation continuosly occuring.
- Muscles related to scapula should be viewed wrt endurance, strength and postural stability as scapulothoracic mechanics has influence on postural mechanics of both shoulder girdle and head and neck.

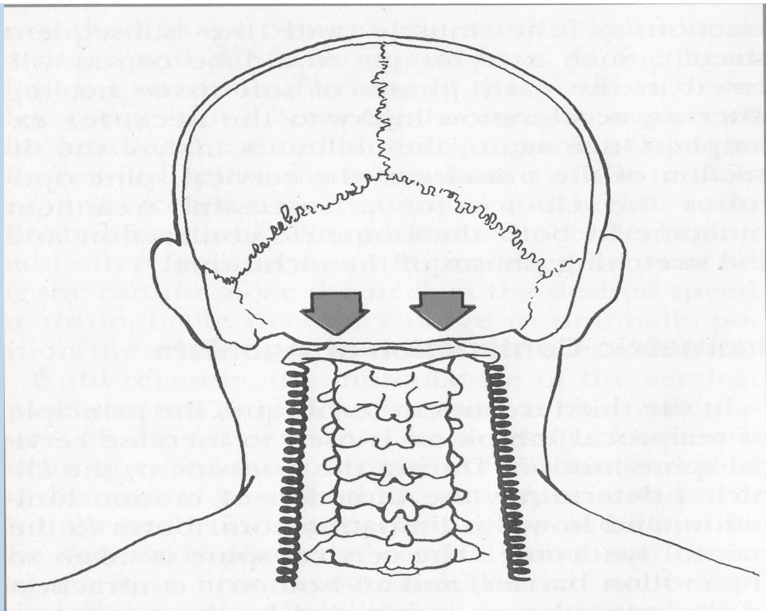


Figure 3–1. The action of the musculature results in compression to the vertebral segments as well as movement.

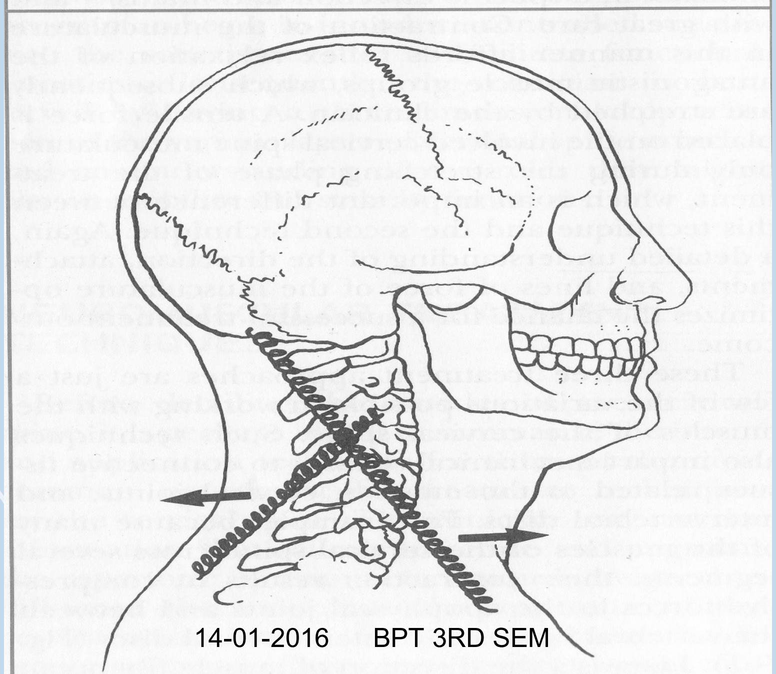


Figure 3–2. Contraction of the musculature results in anterior or posterior shear forces on the cervical

Fascia of the Cervical spine

- Fascia plays an imp role in directing the force of muscle contraction through the wt bearing tissues such as the articular cartilage of the apophyseal joint and vertebral body-IVD interface.
- Organises muscles into different planes
- Imp fascia is Prevertebral fascia having attachment to vertebral body and cover the cervical paraspinal muscles posteriorly.It is continuous with thoracolumbar fascia of low back.

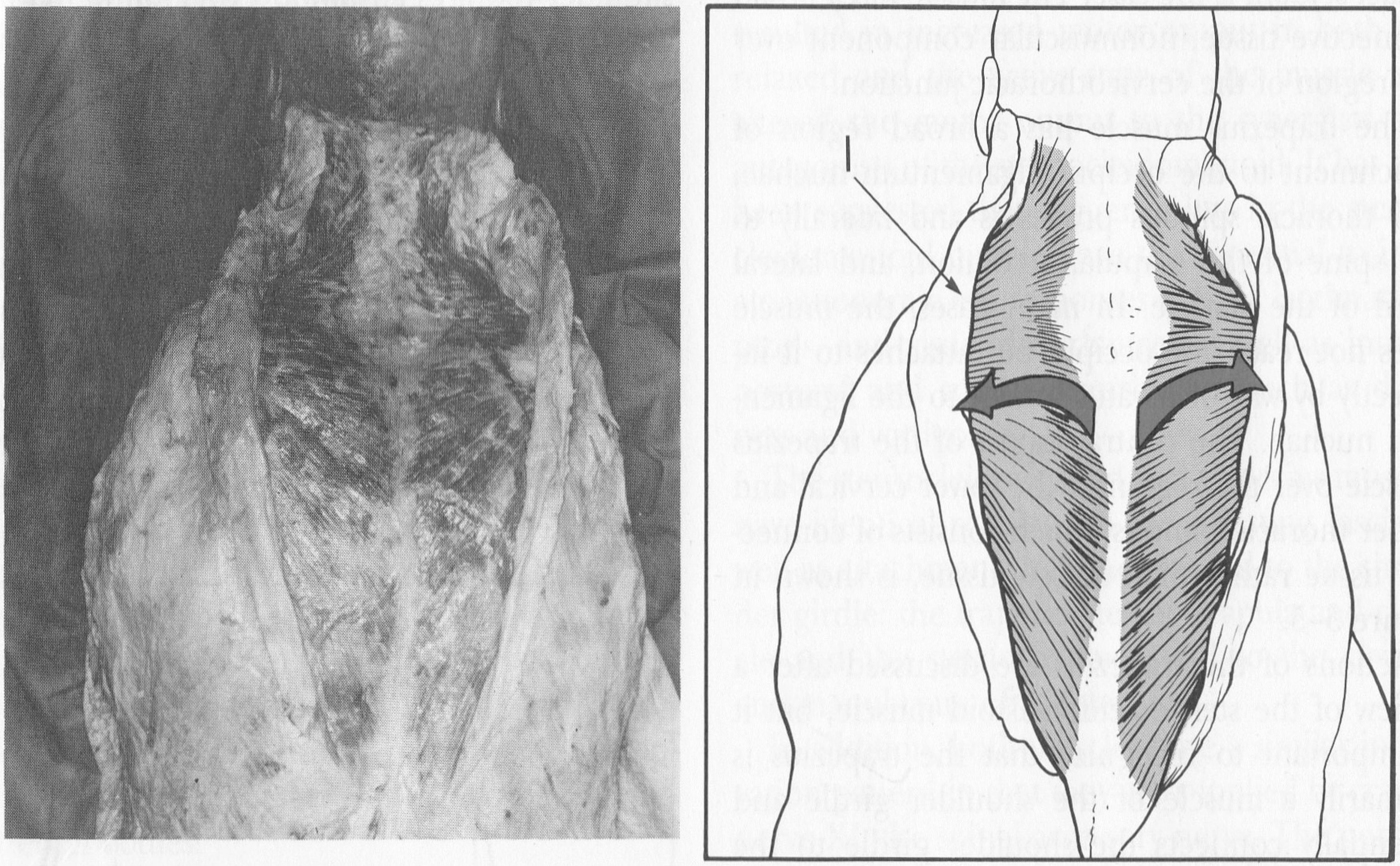


Figure 3–4. Investing layer of fascia (I). This fascial layer must be removed before the superficial muscles are seen.

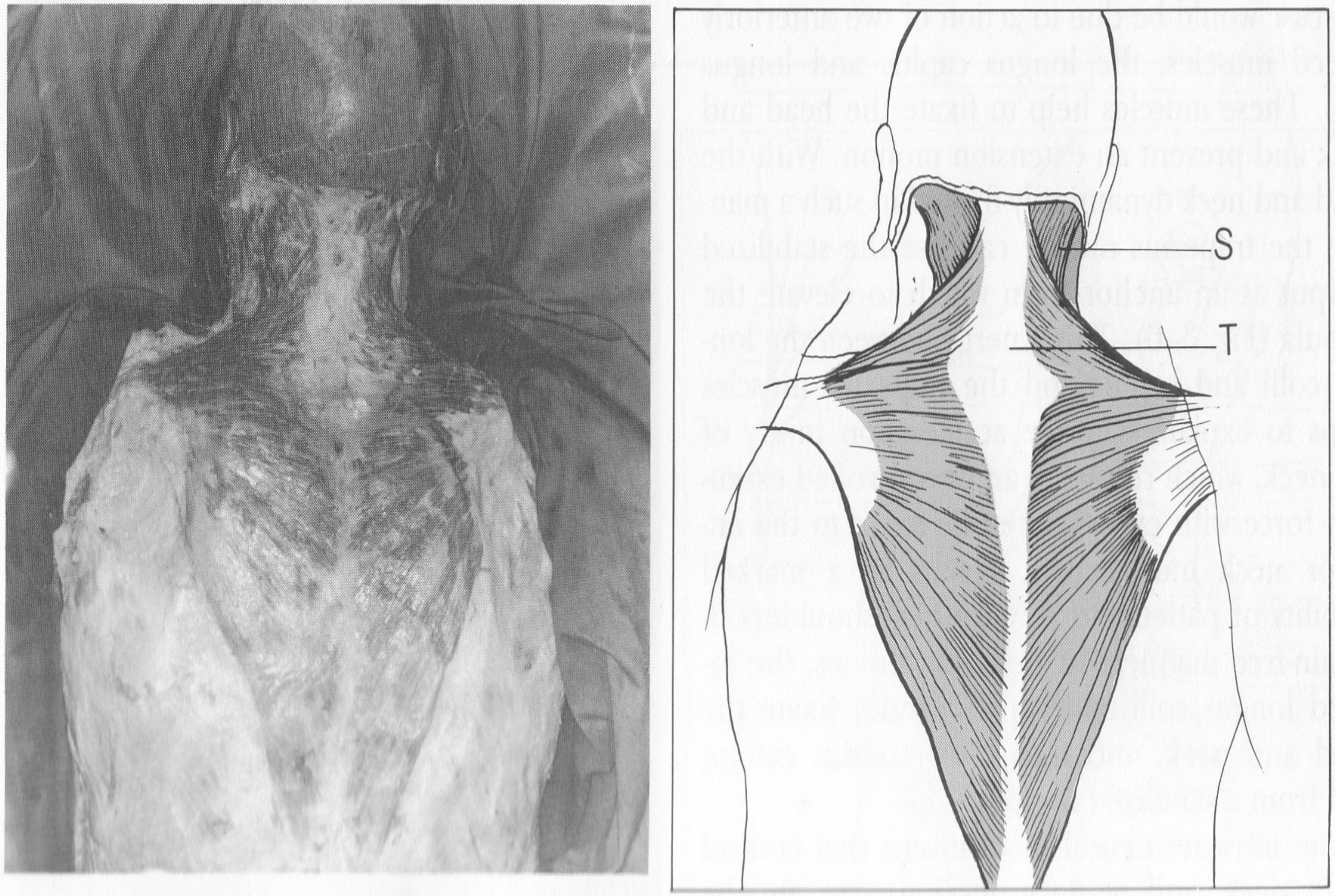


Figure 3–5. Tendinous attachment of the trapezius at the cervicothoracic junction. S, splenius capitis muscle; T, tendinous attachment of the trapezius muscle at the region of

Posterior Muscles of Cervical Spine

TRAPEZIUS MUSCLE

- Much of the fibres attach to the deep layer of investing fascia.
- Contraction of trapezius places tensile forces through this fascia
- There is the prominent tendinous region of trapezius over the lower cervical and upper thoracic spinous processes.
- Trapezius has a ***broad connective tissue nonmuscular component rather than muscle tissue over the region of cervicothoracic junction.***

- Trapezius is prim a muscle of shoulder girdle and essentially connects the shoulder girdle to the vertebral column.If UE is Strongly fixated, trapezius can extend head on cervical spine.
- Conversely for trapezius to elevate scapula, the occiput and Cx must be fixated .Fixation of occiput would be due to action of two ant placed muscles, longus colli and longus capitis which prevent ext motion.
- With the head and neck dynamically fixated,trapezius can use the stabilized occiput as an anchor to elevate scapula.

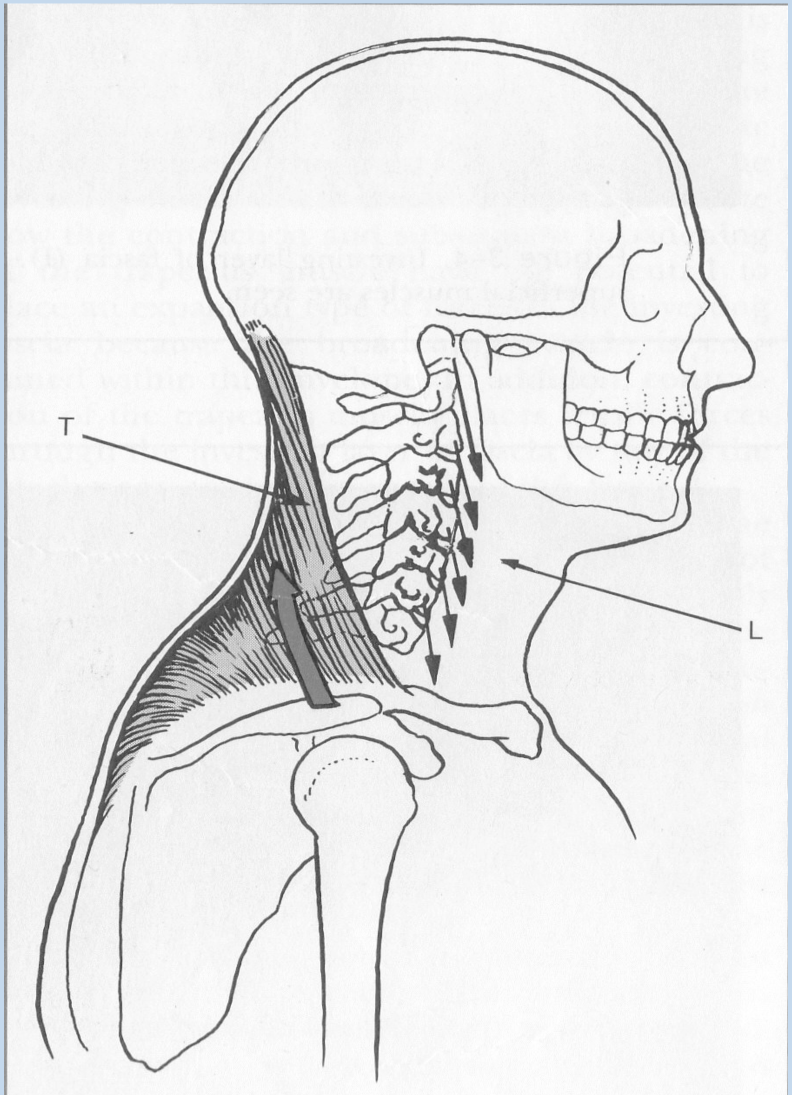


Figure 3–6. Sagittal view of the cervical spine showing the synergistic relation between the trapezius and the longus capitis and colli. The longus capitis must prevent the occiput from extending for the trapezius to use this fixed origin from which to ele-

Clinical relevance:

- In accln inj of the neck, there is marked inability to elevate the shoulders in a painfree manner due to excessive tensile force on ant musculature and thus inj.
- Because injured longus colli and capitis cannot fixate the occiput for trapezius to act as elevator.

- Levator scapulae and upper trapezius act as synergist for elevating the shoulder girdle.In contrast,a complete abduction of scapula requires an upward rotn movt of the scapula.When the scapula is rotated upward, the upper trapezius is actively shortened and a lengthening contraction occurs with the levator scapulae muscles.so with abduction of the shoulder both muscle act as antagonists.
- Trapezius mostly develops trigger point causing temporal headache.Pain on motion caused by such trigger pt.s occur when head and neck are fully rotated to the opp side as the muscle is in maximally shortened position

STERNOCLEIDOMASTOID:

- McNab identified tears in SCM as the most common lesion after accln injury when impact from behind followed by damage to longus colli and ALL& separation of IVD from vert bodies.
- Referred pain from SCM occurs in the muscle and gets diffused in the temporomandibular area.
- It has been suggested that trigger points in the SCM has the potential to initiate autonomic eye responses such as lacrimation,ptosis ans visual disturbances as well as induce postural and spatial disturbances such as dizziness and vertigo

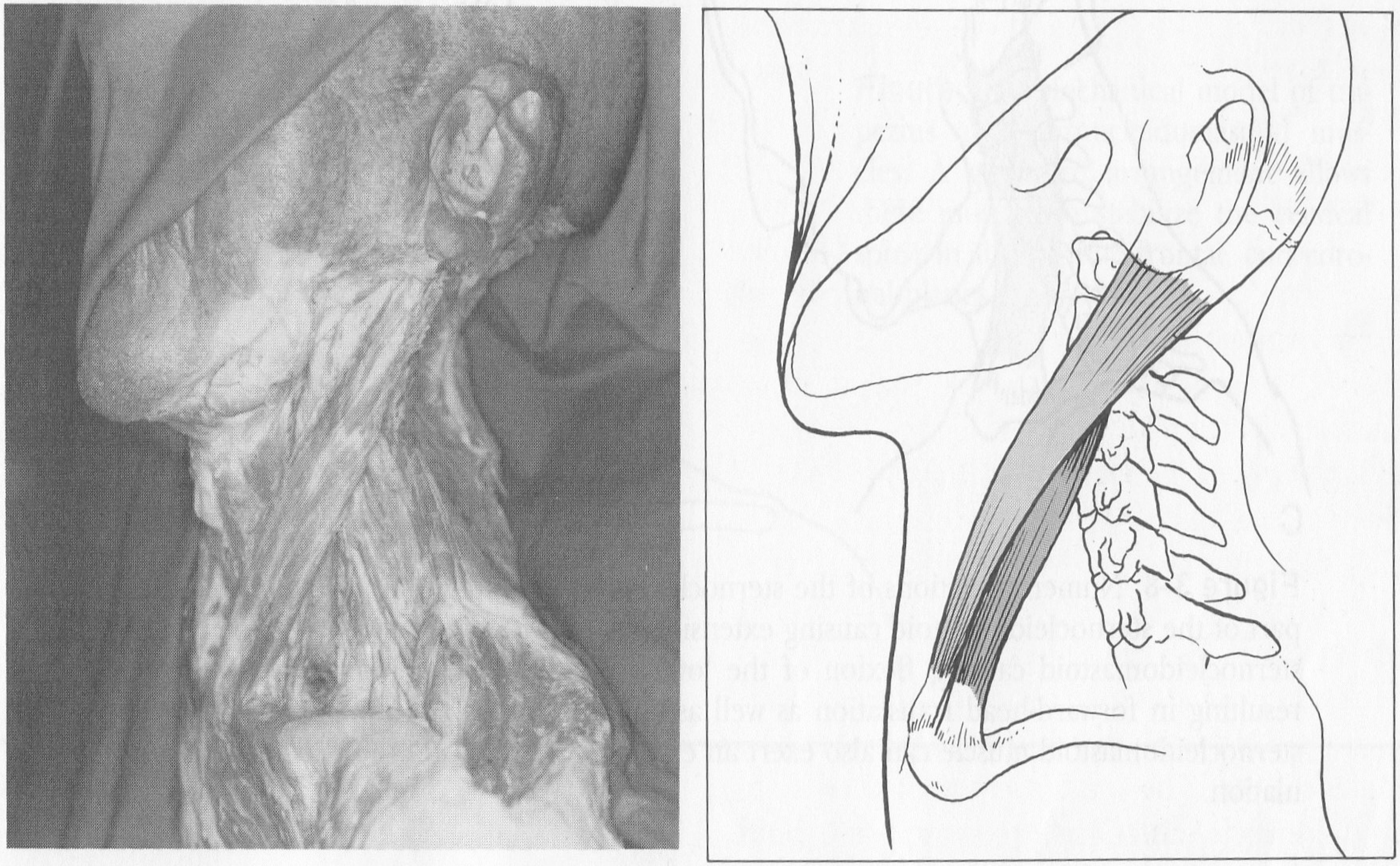


Figure 3–7. Muscle belly and attachments of the sternocleidomastoid muscle.

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The SCM and trapezius have similar relationship to the investing fascia as well as attachment to the bone related to the shoulder girdle i.e trapezius to the scapula and clavicle and SCM to the clavicle and manubrium of sternum.

Both supplied by XI cranial nerve i.e spinal accessory nerve.

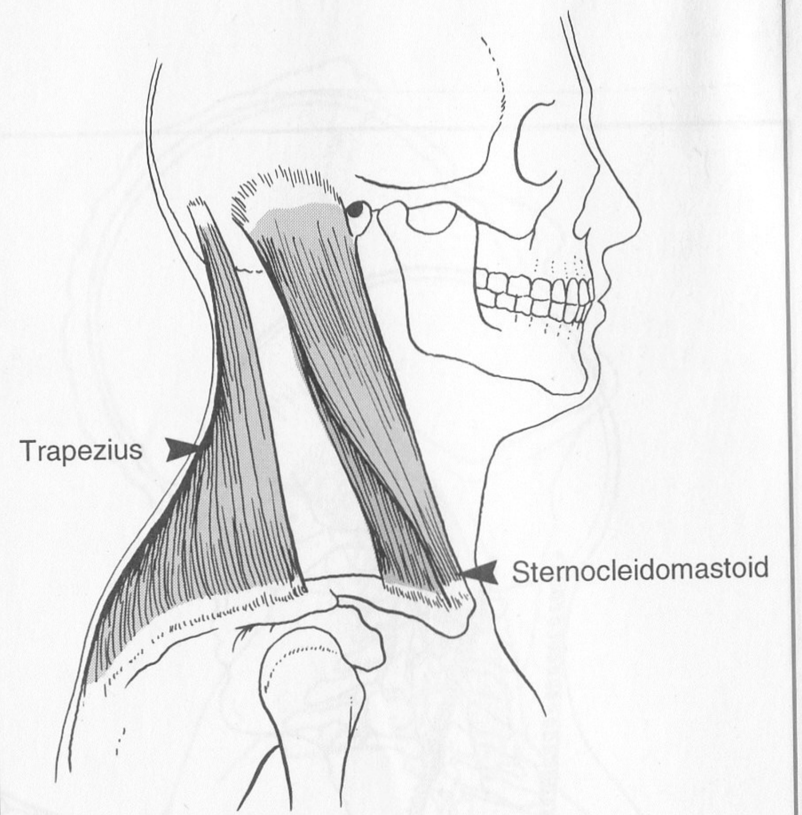


Figure 3–10. The sternocleidomastoid and trapezius muscles almost encircle the neck. A muscle-fascia collar is formed by the investing fascia, trapezius muscles, and sternocleidomastoid muscles.

- As SCM is superficial, serves as a guide to detect forward head posture.The greater the verticality of SCM when the neck is viewed in the sagittal plane, the greater the likelihood thet forward head posture is present.
- The SCM has many individualized functions.Its oblique course in passing from sternal origin to mastoid insertion allows it to cause rotn at most of the Cx segments. Because the upper portion of the muscle is posterior to the centre of rotn for flexion and extension of the Cx and the inferior portion of the muscle is ant to this centre of rotn, the SCM has the potential to extend the upper cervical segments , especially the occiput on the atlas and flex the lower Cx segments.

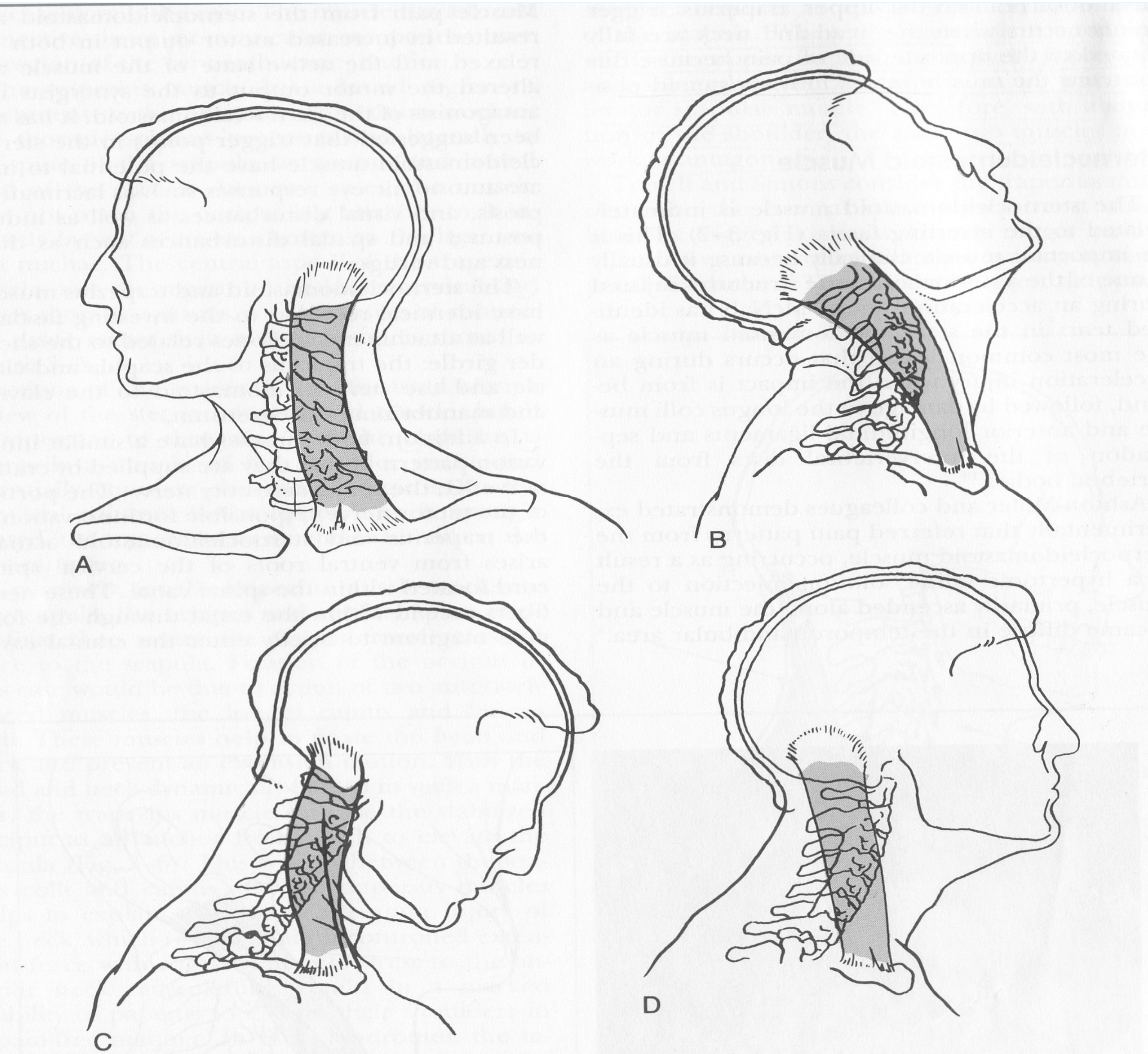
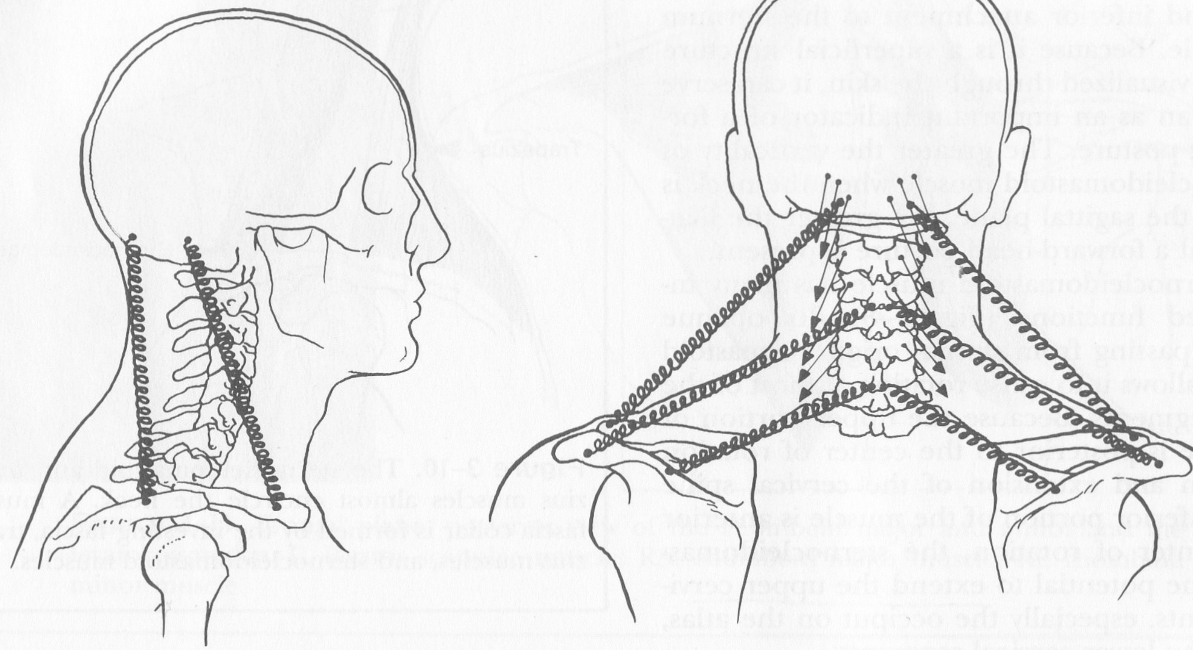


Figure 3–8. Numerous actions of the sternocleidomastoid muscle. *A,* Rotation. *B,* Upper part of the sternocleidomastoid causing extension of the upper spine. *C,* Lower part of the sternocleidomastoid causing flexion of the lower cervical spine. *D,* Bilateral contraction resulting in forward-head translation as well as anterior shear. The upper portion of the sternocleidomastoid muscle can also exert an extension moment on the occiput-atlas articulation.

- The lower aspects of the SCM muscle are oriented to resist forceful extension or backward movt of the Cx, which is one of the reason they get injured in the accln inj forcefully extending the Cx.
- When both SCM contracts, causes a relative forward translation of the Cx with ant shear betwn jt surfaces.
- SCM and trapezius serve as efficient guy wires in the sagittal, frontal and coronal planes as they have attachment located significantly far from the centre of rotn of the Cx,



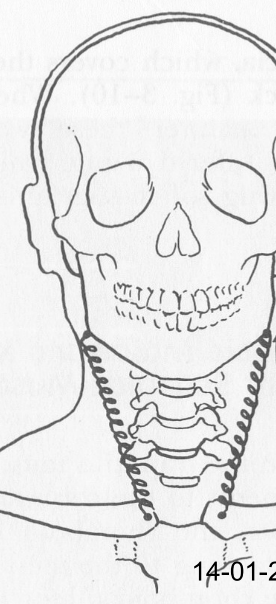


Figure 3–9. Mechanical model of trapezius and sternocleidomastoid muscles. A guy wire arrangement allows these muscles to stabilize the cervical spine in the sagittal, frontal, and coronal planes.

Rhomboid Major and Minor & Levator Scapulae muscle

- The attachment of rhomboids to the spinous process is tendinous.
- Levator scapulae has large cross section unlike the rhomboids.It is a scapula elevator and lateral flexor of the neck.it is optimally aligned to direct a post shear on Cx. So can be compared to lumbar portion of erector spinae.
- Levator scapulae takes origin from superomedial border of scapula and courses ant, med and sup to attach to Cx transverse processes.

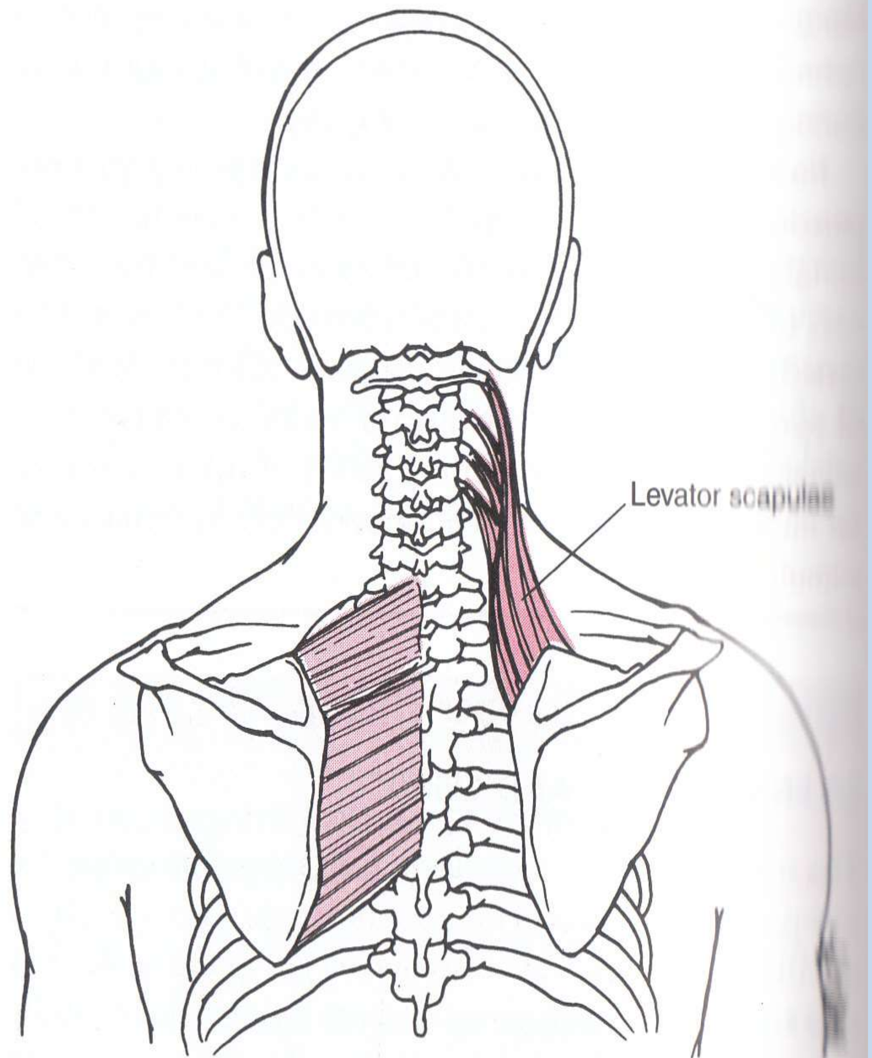


Figure 27.6: Levator scapulae runs superiorly and medially to attach to transverse processes of cervical vertebrae.

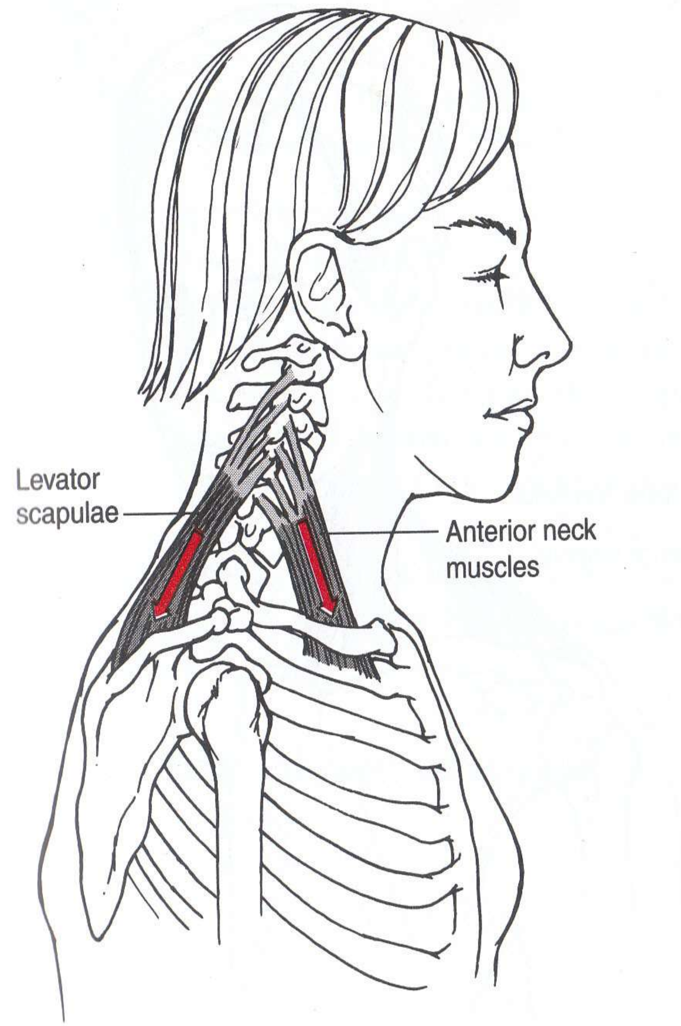


Figure 27.7: The "guy wire" arrangement of the levator scapulae and antagonistic anterior neck muscles. The levator scapulae and anterior cervical muscles provide opposing forces that help stabilize the cervical spine.

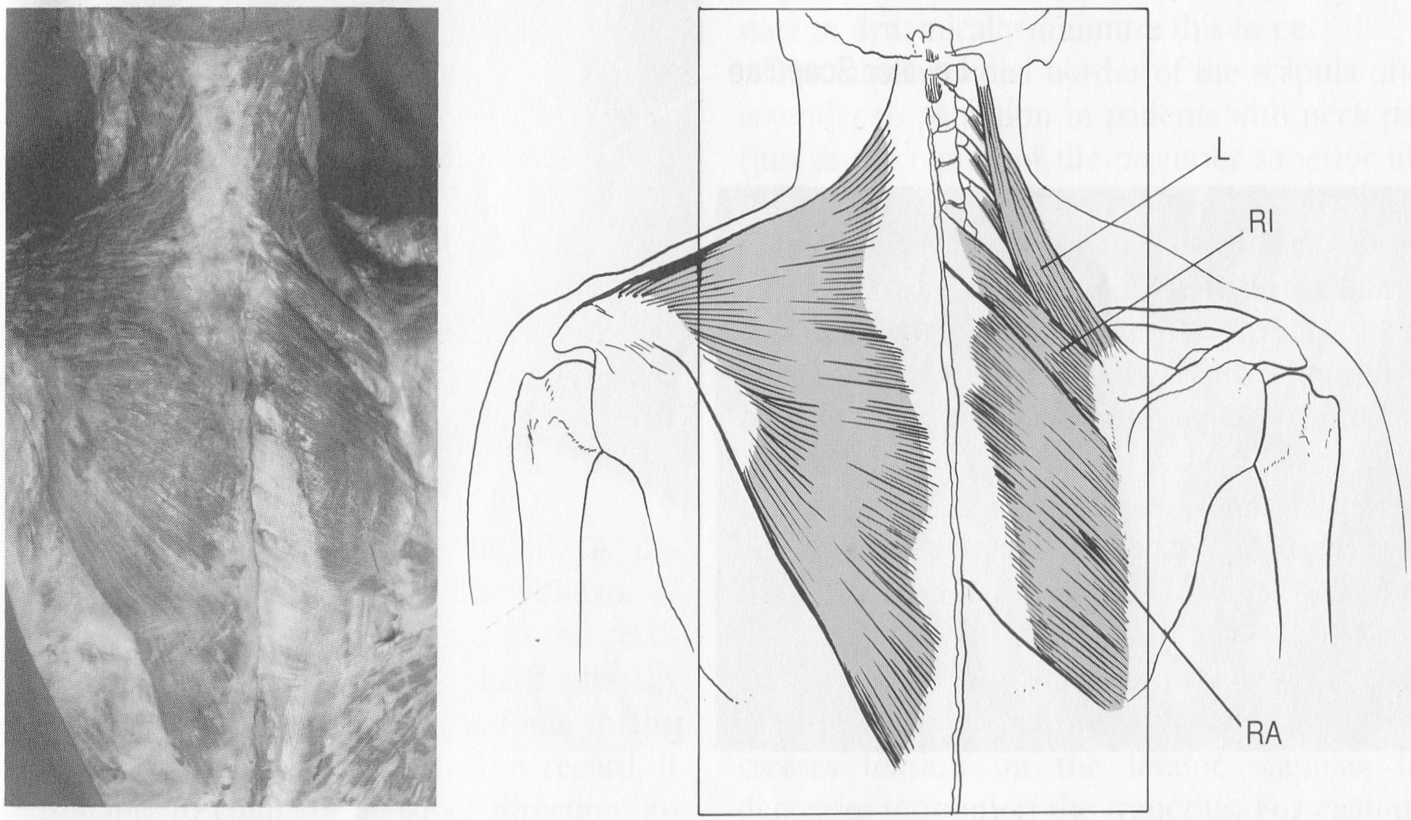


Figure 3–11. Frontal plane, posterior view of the rhomboid major and minor and the levator scapulae. L, levator scapulae muscle; RA, rhomboid major muscle; RI, rhomboid minor muscle.

Relevence of Cervical Lordosis

- In normal posture, the cervical vertebrae form a lordotic curve. This curve is supported and accentuated by the semispinalis capitis, splenius capitis and cervicis, trapezius and levator scapulae muscles.
- In a Cx lordotic position, ant and post stresses on the Cx vert bodies are nearly uniform and minimal compared with those in other postures.
- With a kyphotic Cx posture, compression forces on the ant margins of the vertebrae can be 6 to 10 times larger.
- The Cx lordosis improves the ability of the spineto absorb axial loads. When a Cx spine is straightened, and axially loaded, the time to failure and total displacement at failure are significantly lower than their lordotic counterparts.This implies that a non lordotic Cx spine has a decreased ability to absorb axial force. The presence of Cx lordosis provides shock absorption for the head from forces that are transferred from the body and lower extremities
- Loss of Cx lordosis can result in a decrease in shock absorpn capability of the spine.

FORWARD HEAD POSTURE:

- The Cx is subjected to ant shear force resulting from the pull of gravity caused by cervical lordosis and the levator scapulae is oriented to help provide a dynamic restraint to this force. A forward head posture *accentuates the ant shear force at the Cx and this posture obliges the levator* scapulae to maintain a continuous contractile state to dynamically minimize this force.
- Jull characterizes the levator scapulae as one of the muscles in the neck-shoulder girdle region that becomes overactive with poor posture such as forward head.Due to overuse it results in pain and discomfort.
- The superomedial border of scapula is often tender to palpation in pat.s with neck pain.
- Articular structure in this region may be experiencing altered loads as a result of suboptimal postural changes.
- Pain and spasm of this muscle may further compromise these articular structures as they will not receive adequate suppost usually provided by the guy wire.

- Palpation of lev scapulae can be facilated by rotn of the head and neck towards the opp. side.Because of attachment of lev scapulae(TP)and trapezius(SP), such a maneuver increases tension in the lev scapulae but decreases tension in the trapezius.

- ** When increased tension is palpated,caution should be used against immediately concluding that the muscle needs to be stretched. Depending on the mechanics of injury, the stage of healing and the ability of the injured tissue to attenuate various forces that reach the region, muscle guarding may be an appropriate neuromuscular response to injury.
- Rather than immediately stretching the muscle, one should consider ways to minimize the ant shear force occuring over the Cx, thus decreasing demand on lev scapulae

- Scapula is not fixed like pelvis. So the position of the scapula is maintained by trapezius, Rhomboids major and minor(scapular retractor), upper trapezius(elevator), lower trapezius(depressor). Scapular fixation also results from serratus ant muscle.

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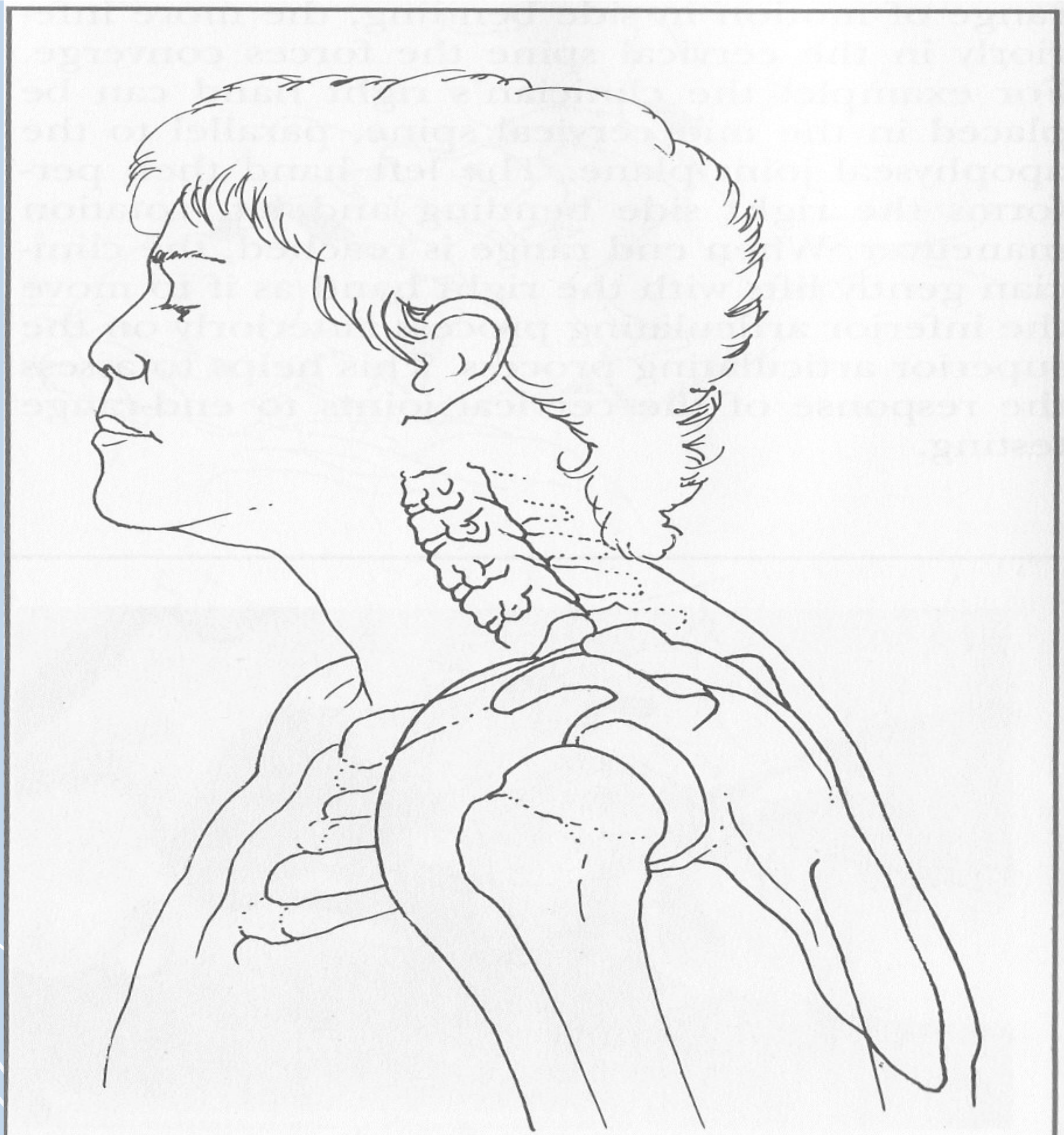


Figure 5–39. Forward-head posture, compression of the neurovascular bundle by the lateral aspect of the clavicle, and tipping of the scapula upward and forward.

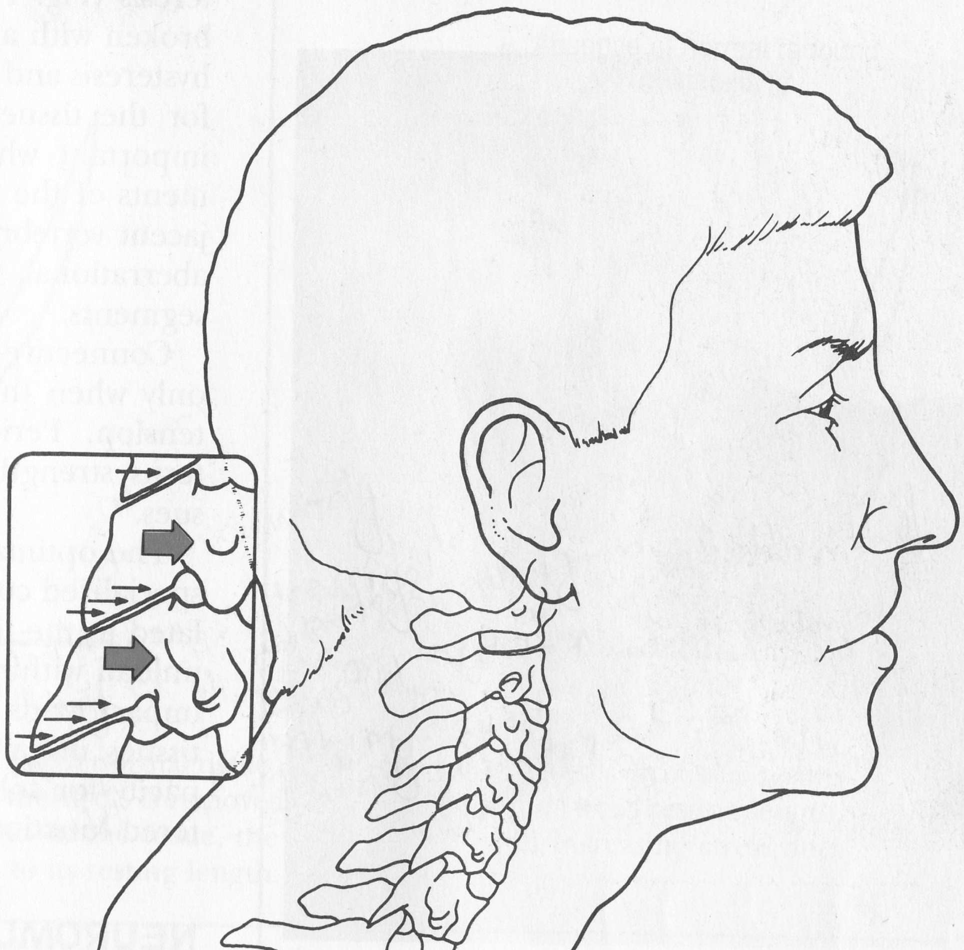


Figure 1–8. Sagittal view of the head and neck showing the compressive force on the articular cartilage of the facets that occurs with forward-head posture because of the plane of the facets and the resultant loss in the compression-decompression cycle necessary for maintaining articular cartilage health.

ROUNDED SHOULDER POSTURE:

- It is commonly attributed to the lengthening or weakness of scapular retractors.
- ** Attention should also be given to role of abdominal muscles as they work synergistically with the scapular retractors, diaphragm, and pelvic floor muscles to allign the abdomen and thorax as well as to the relation of the scapula to the thorax.
- Weakness of the abdominal muscles results in the sternum and the chest being carried more caudally, which accentuates the rounded shoulder posture.
- Scapular retractor strengthening , scapulothoracic postural positioning, and abdominal wall training provide a more complete treatment approach for the forward head rounded shoulder posture.

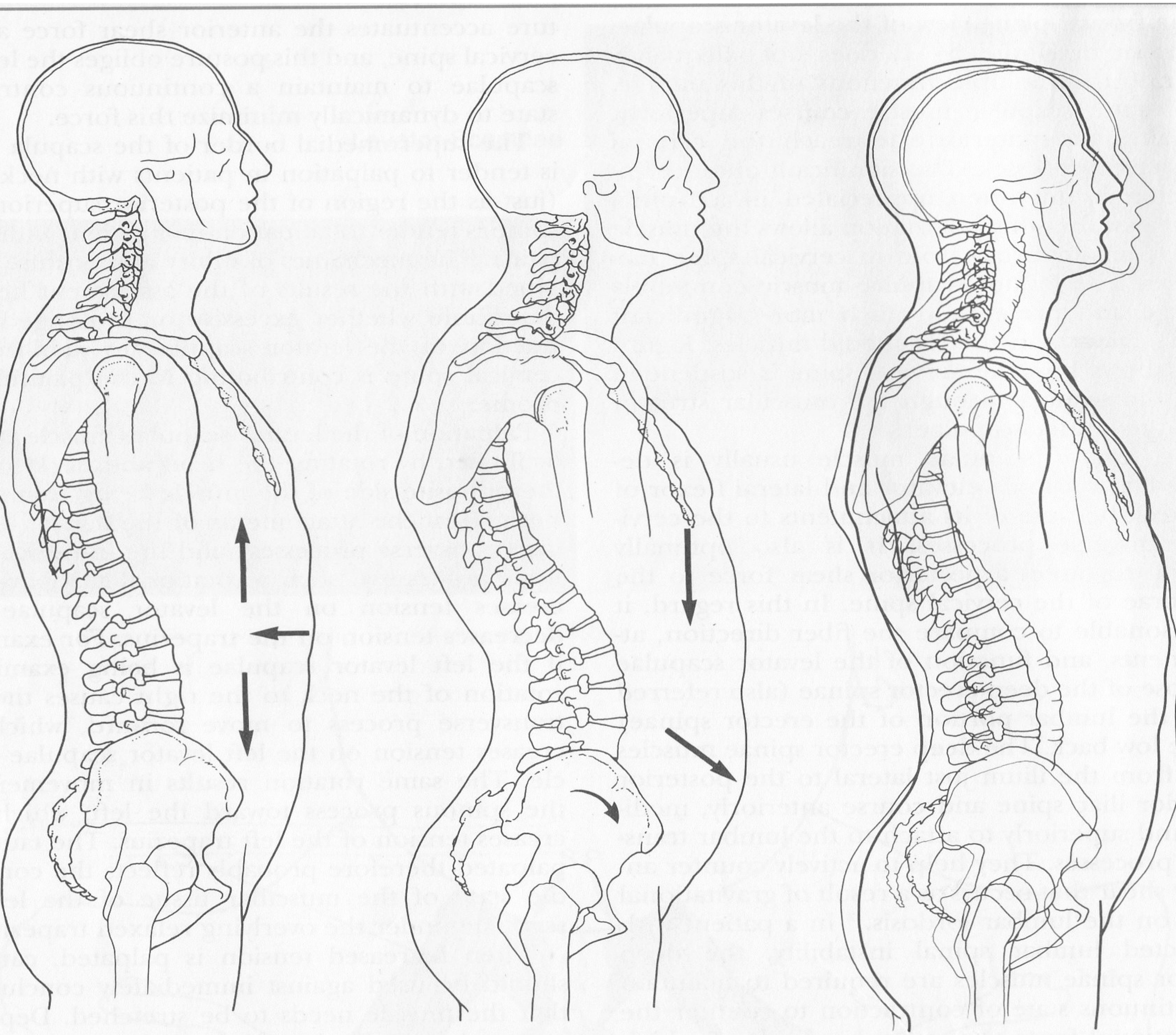


Figure 3–14. Synergistic relation between the abdominal wall and the scapula retractors. Weakness of the abdominal wall results in the inferior collapse of the chest. This change in abdomen-chest relationship places the scapulae in a more protracted position with a resultant lengthening of the scapular retractors.

EFFECTS OF POSTURE ON CERVICAL MUSCLES

- The posterior neck muscles appear to be most efficient when the head is in a neutral position.
- Muscle length, which is a function of head position is probably tha main influencing factor in this relationship, suggesting that maintaining a neutral head position is imp in reducing the load on the cervical extensors.
- Cx muscles with largest moment arm like SCM, semispinalis capitis,splenius capitis and trapezius are expected to be most efficient in moment prodn.
- Changes in posture alter the moment produced by the wt of the head by changing the location of the head's COG wrt the point of rotn in the CX spine

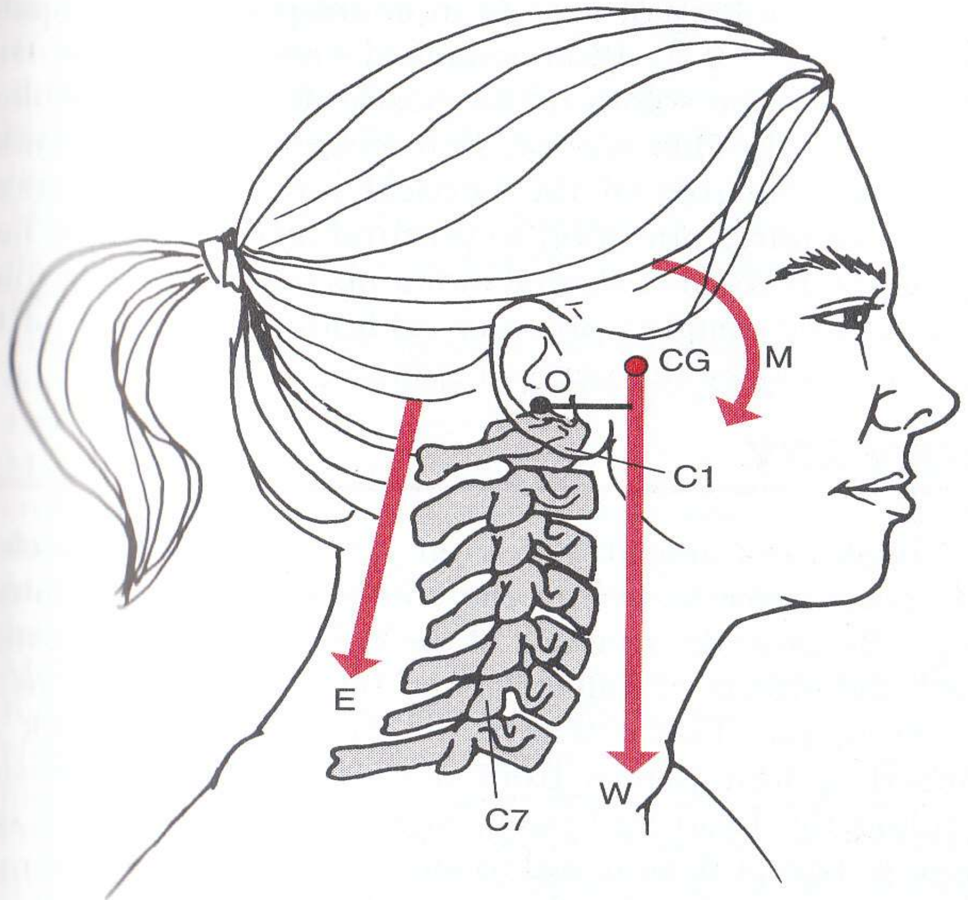


Figure 27.15: Sagittal plane view of the head and neck illustrates a flexion moment *(M)* around the point of rotation, or axis, *(O)* produced by the weight of the head *(W)*. The weight of the head is applied at the head's center of gravity (CG). The extensor musculature must produce an extension moment *(E)* to balance the head.

Clinical relevance:

- The posture assumed while working on a computer can affect the muscles used to perform that task.
- Data shows that increased Cx flex produces increased EMG activation of the trapezius muscle B/L in some subjects.
- Backward leaning(Reclining the trunk) decreases the activation of trapezius B/L in some subjects
- **Higher computer screen heights result in subjects assuming a more erect Cx spine posture and a more backward leaning position.

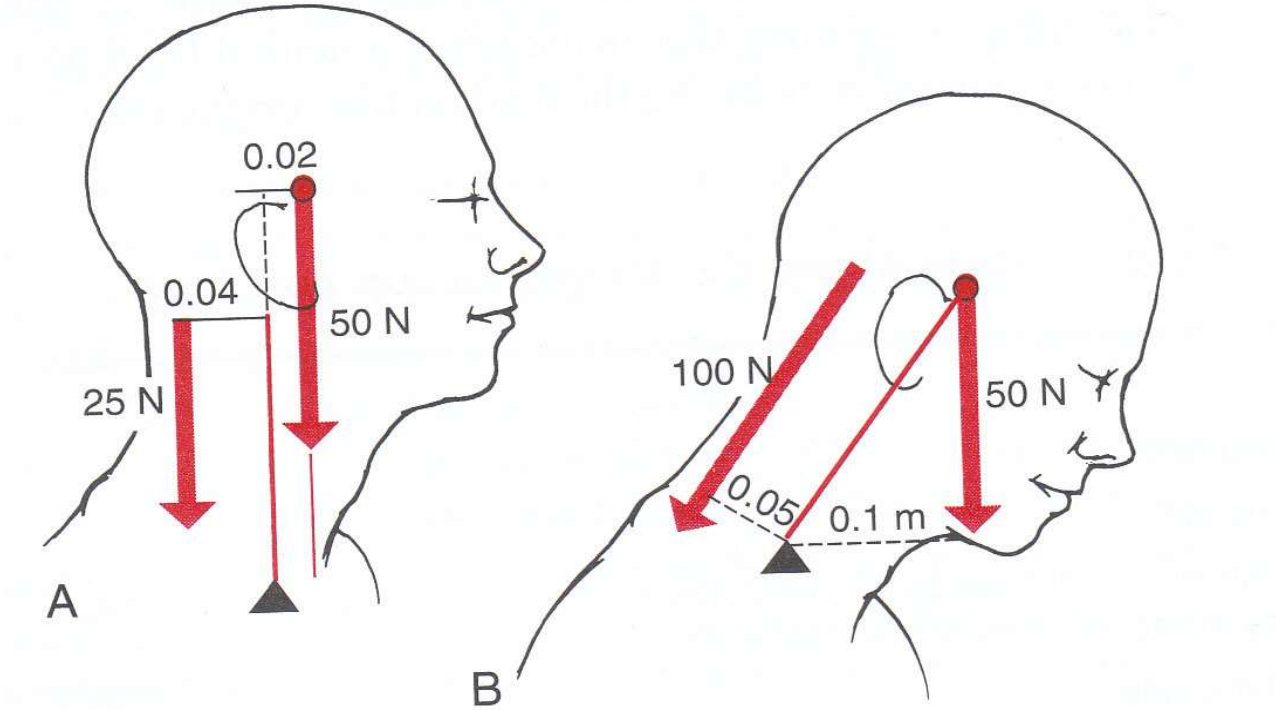


Figure 27.16: Biomechanical model of the force couples required to balance the head in two different head positions. **A.** Neutral head position requires 25 N of muscle force to balance the system. **B.** Forward head position requires 100 N of muscle force to balance the system.

PREVERTEBRAL FASCIA AND SPLENIUS MUSCLE

- Prevertebral fascia encircles neck and is related to deeper muscles. It is continuous with the thoracolumbar fascia of the low back.Covers the Splenius and semispinalis muscle groups and attaches to occiput.
- It covers the scalene laterally and longus colli and capitis anteriorly.

- Splenius capitis and splenius cervicis are large flat muscle that courses from CX and Tx and lig nuchae and extends upward and lateral to attach to the superior nuchal line and mastoid process and post portion of Cx transverse process.

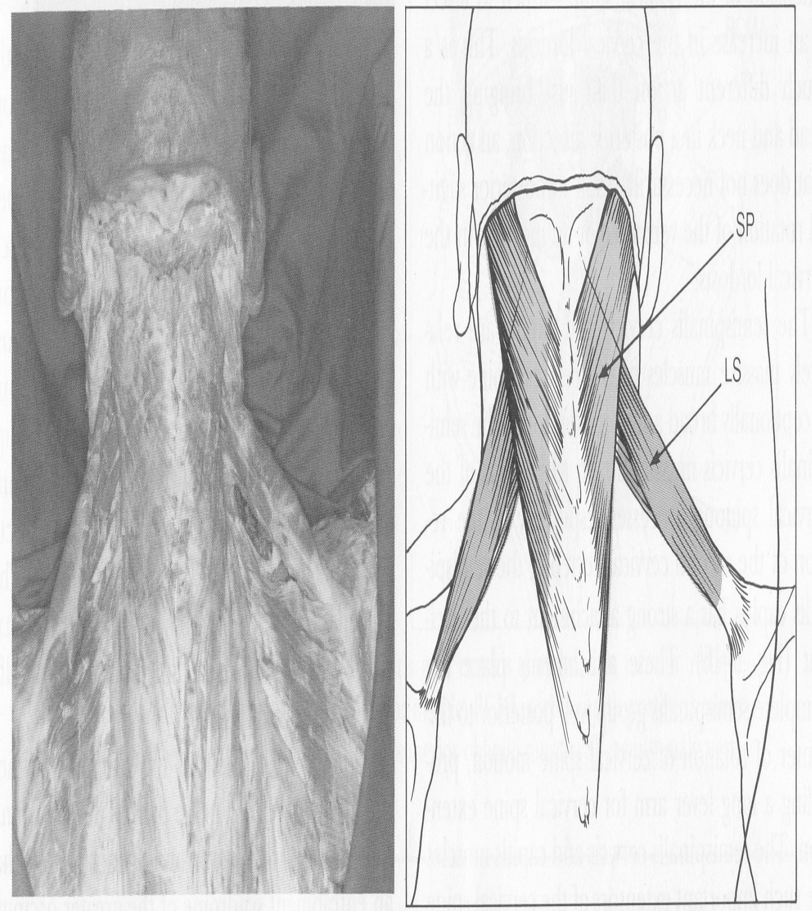


Figure 3-15. Splenius capitis muscle. LS, levator scapulae muscle; SP, splenius capitis muscle.

- The mastoid portion attachment of splenius capitis is imp as it serves as the attchment of several large muscles like SCM,Splenius capitis, longissimus capitis.
- Splenius capitis has excellent lever arm for Cx ext because of itz attachment to occiput.and the lateral course makes it well suited to rotn of Cx.This rotary fn is due to its attachment to post tubercle of CX transverse process and mastoid process.Rotn occurs to the same side.
- B/L activity causes extension and no activity in upright balanced antigravity position.

SEMISPINALIS MUSCLE GROUP

- Semispinalis cervicis and capitis are the most imp extensors of occiput and Cx.
- Surgical relevance: Recommended that any surgical procedures for post aspect Of Cx should minimally disrupt these muscles because removal of the muscles and incorrect realignment may result in loss of normal cervical alignment.They are considered the prime movers for increasing and dynamically maintaining the cervical lordosis.
- *Weakness of semispinalis muscles compromises maintainance of upright head posture.*
- Semispinalis cervicis arises from TP of upper Tx and courses superiorly to attch to the spinous process of C5-C2.

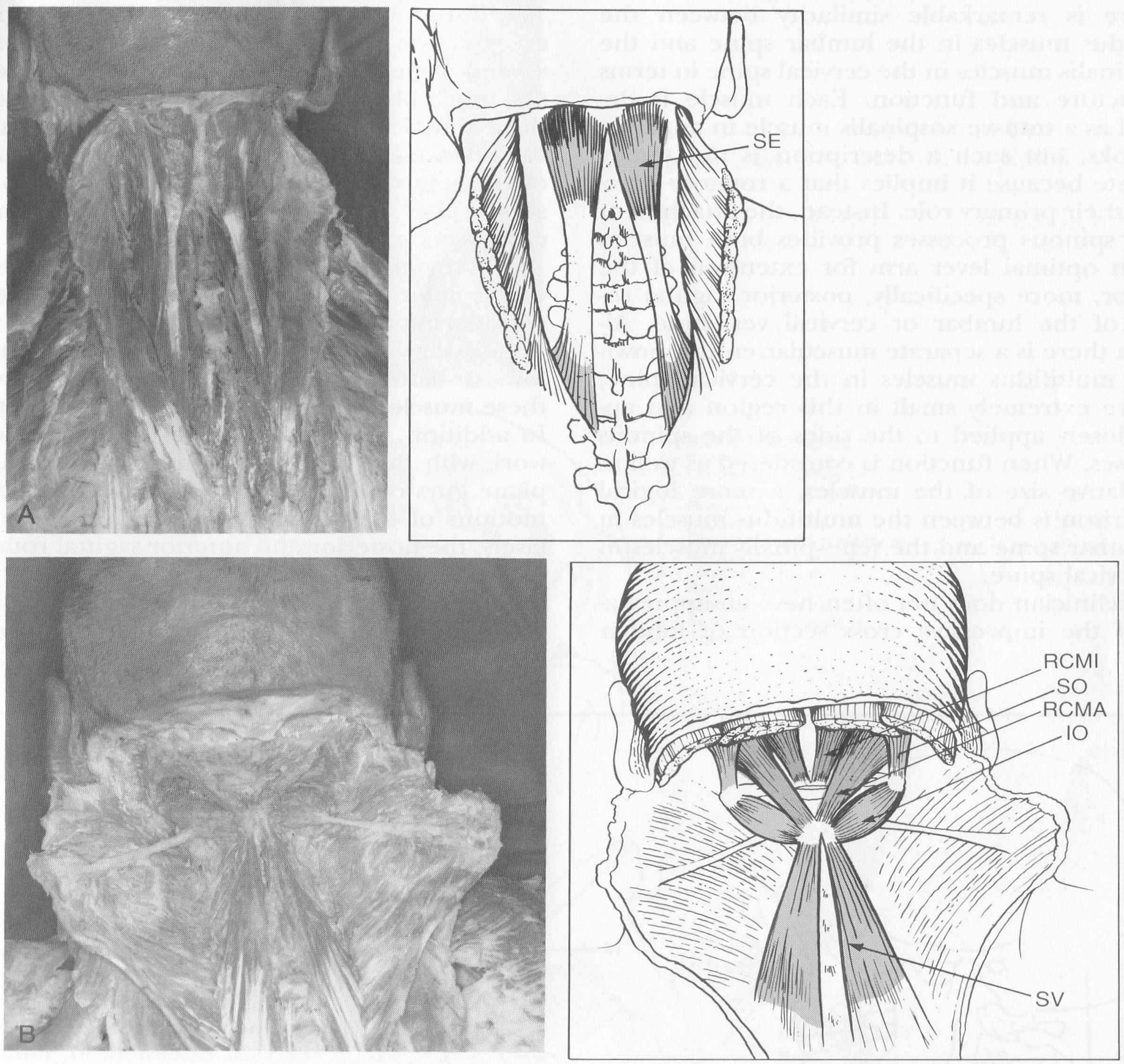


Figure 3–16. *A* and *B,* Semispinalis capitis and cervicis muscles. IO, inferior oblique muscle; RCMA, rectus capitis posterior major muscle; RCMI, rectus capitis posterior minor muscle; SE, semispinalis capitis muscle; SO, superior oblique muscle; SV, semispinalis cervicis muscle.

- Semispinalis capitis covers cervicis. Arises from upper Tx and lower Cx goes superiorly to attach to occiput between sup and inf nuchal line.These 2 muscles perceived by clinician as the rounded muscle bundle immediately lateral to the Cx spinous process
- **Clinical relevance**: Travell and Simons suggest that an entrapment syndrome of the greater occipital nerve is caused by hyperirritability of the semispinalis capitis muscles. Pain and numbness or the burning sensation over the scalp and occipital region are typical symptoms of greater occipital nerve entrapment. This is different from symptoms of PID or cervical jt problem.

- There is remarkable similarity between lumbar multifidus and semispinalis muscle in Cx in terms of structure and function.Both have an optimal lever arm for ext of spine.
- In Cx one should consider semipinalis and multifidus as one group.these muscles act with the longus colli and capitis as sagittal plane guys controlling the ext and flex motion of Cx that increase or decrease Cx lordosis.
- **Clinical relevance**: understanding the relation between these muscles allows a more specific neuromuscular Rx approach using muscle contraction into or away from the physiological barrier to be used.

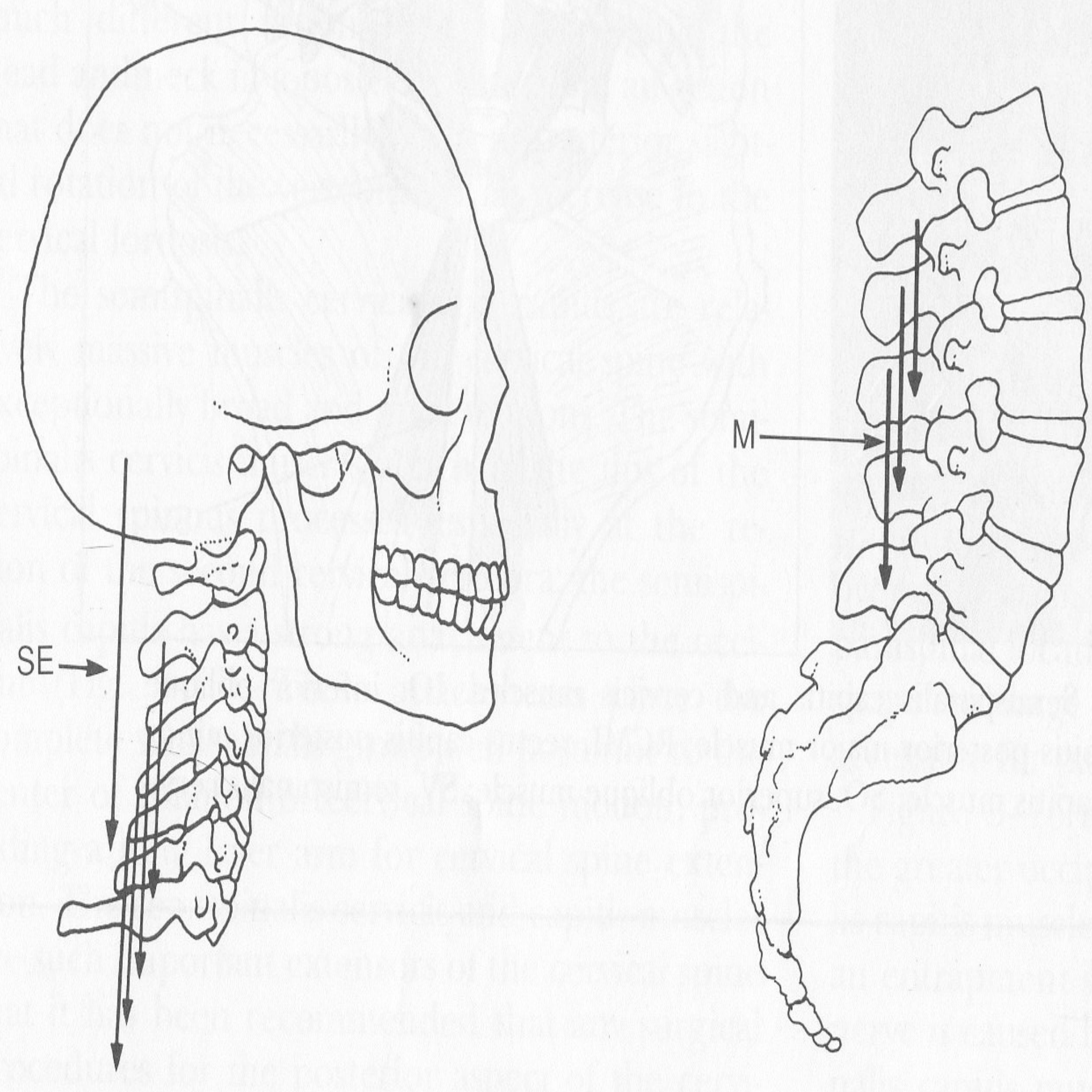


Figure 3–17. Function of the semispinalis capitis as compared with the multifidus muscle. The semispinalis capitis has an optimal lever arm for cervical extension. M, multifidus muscle; SE, semispinalis capitis muscle.

Longissimus Group

2 groups: longissimus cervicis and capitis.

Longissimus cervicis courses from upper thoracic TP to most of the post tubercle of Cx TP.

Longissimus capitis courses from upper Tx TP and post tubercle of lower Cx TP to mastoid process.

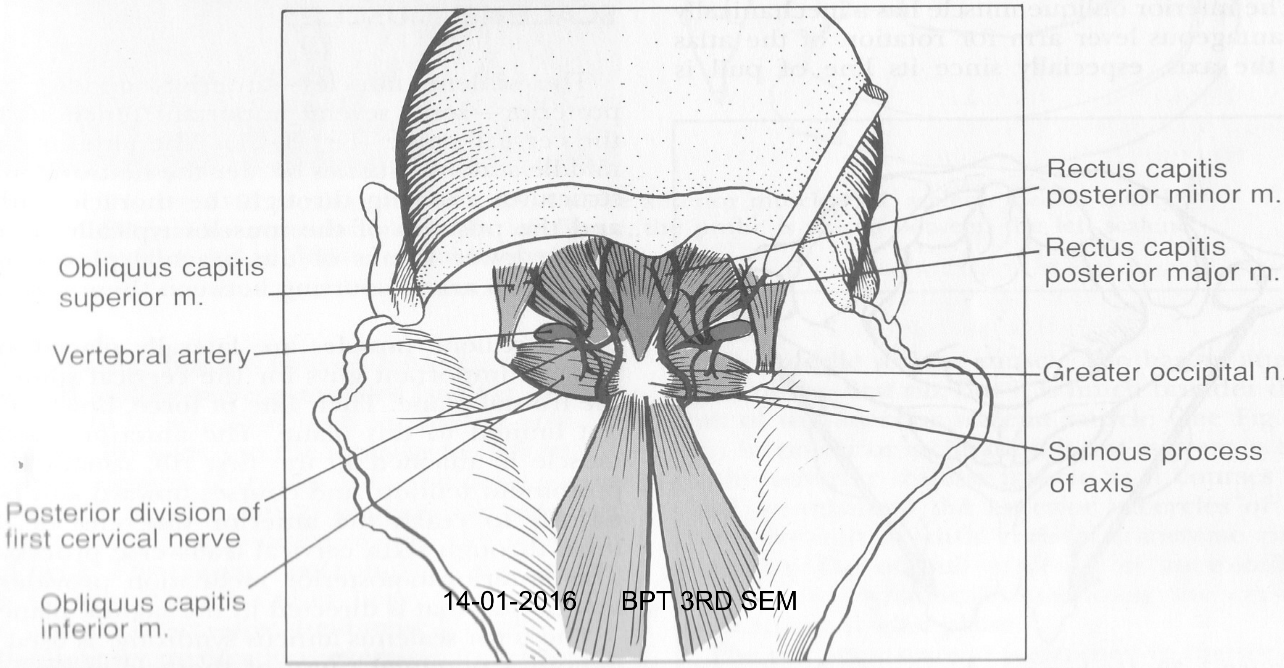
Longissimus capitis, semispinalis capitis and SCM are attached to the mastoid so that it is the focus of muscle forces..it is a potential site for accln inj and sometimes tender due to prolonged muscle guarding in painful syndromes of neck.

Longissimus muscle serves as lateral guys to help stabilize the head and neck in the frontal plane.

Suboccipital muscles

- The suboccipital triangle is formed by the arrangement of of the small muscles related to the occiput, atlas and axis.In the midline are the rectus muscles:rectus capitis posterior minor and rectus capitis post major. The inferior oblique muscle forms the inferior and lateral border of the suboccipital triangle.
- The superio oblique muscle forms the superior and lateral border of the suboccipital triangle.structures in the triangle are vertebral artery, dorsal ramus of 1st cervical nerve(suboccipital nerve)—supplying the motor innervation of the 4 suboccipital muscles.

Figure 3–19. Suboccipital triangle.



- The suboccipital muscles are positioned to move the occiput-atlas axis complex independently of the lower cervical spine.This fn allows the lower cervical spine to be positioned and fixated while the upper cervical spine moves into positions that optimize the placement of the various sense organs of the head.
- It is imp to realise the depth of the suboccipital muscles and the tissues that overlie them.
- Pain in the suboccipital region is attributed to involvement of the suboccipital muscles when in fact any of the overlying tissue may be involved.
- Suboccipital region palpated lateral to 2nd SP.Superficial to deep the tissue includes the skin, investing layer of fascia, the trapezius, splenius capitis, semispinalis capitis and suboccipital muscles.

CLINICAL RELEVANCE: CERVICAL HEADACHES

- All of these muscles supplied by dorsal ramus of C1(suboccipital nerve) which exits within suboccipital triangle superior to the arch of atlas. It is prim a motor nerve but can have cutaneous branch that can give rise to pain if stretched or trapped.
- But more often headache of Cx origin hav been attributed to greater occipital nerve(dorsal ramus of C2) which innervates post aspect of head upto vertex.
- It has been suggested that entrapment or stretching of the nerve as it passes betwn the lamina of the axis and the inf oblique muscle may result in headache or post neck pain.

CERVICAL HEADACHES

- Cervical headache refers to headaches arising from dysfn or inflmn of the musculoskeletal structures of the upper Cx spine (i.e atlanto-occipital jts,atlanto axial jts,C2-C3 facet jts and disc, and the capsules, lig and muscles crossing these jts)
- Aggravating factors include sustained postures(usually sitting), certain neck movt, and emotional stress.

- Suboccipital ms are deep and diff to palpate
- It is difficult to isolate pain resulting from muscular tightness or trigger points as coming from these muscles
- Kendall describes pain associated with ms tightness in this area as a result of postural problems. She observed that persons with marked forward head and marked kyphotic upper thoracic region have a compensatory hyperext of Upper Cx spine and head. This leads to shortening of the suboccipital muscle and stretch weakness of ant neck muscles.
- Mechanism of pain is abnormally large compressive forces on the facet jt due to sustained pull of shortened muscles

SCALENE MUSLES:

- The scalene muscles- ant, middle and post serve imp fn for the Cx.
- The anterior and middle scalene muscles border the neurovascular structures coursing through TO., particularly the lower trunk of brachial plexus and subclavian artery courses betwn them.
- Scalene muscles being laterally placed serve as imp guys for the CX in the frontal plane

CLINICAL RELEVANCE:

- Scalene anticus syndrome is used as a potential cause of TOS. Neurovascular symptoms may result from compression of the subclavian artery and brachial plexus at the region of ant scalene as the it passes betwn ant and middle scalene.

- This leads to sequelae such as oedema and cyanosis in the arms and inability to exercise or lift heavy wt. irritation of brachial plexus causes pain in ulnar or median nerve distribution or into shoulder and neck. Conservative mngmnt: anti inflammatory medication, exercises to condition muscles of shoulder girdle, postural instruction, ergonomics interventions, and steroidal injections in ant scalene
- The line of pull of middle scalene places it in an excellent position for dynamically stabilizing the Cx in frontal plane.
- The post scalene is placed immediately ant to lev scapulae.
- The scalene hav mechanically advantageous lever arm for lateral flex of Cx .ant scalene working bilaterally can flex the cervical spine but lever arm not as effective as SCM.as they are Cx flexors, have potential to sustain accln inj.

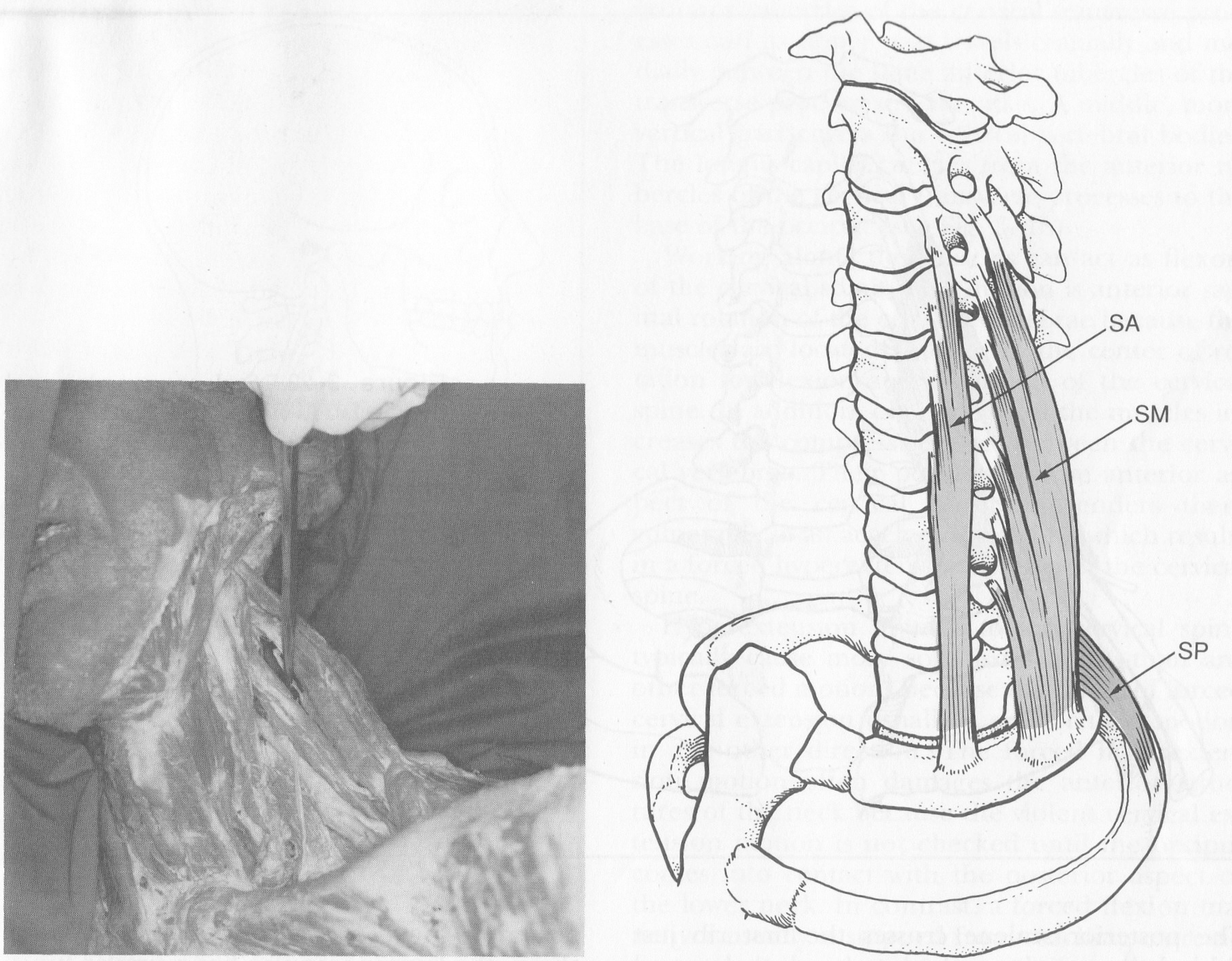


Figure 3–21. Scalene muscles. SA, scalene anterior muscle; SM, scalene medius muscle; SP, scalene posterior muscle. In left figure, the probe is placed between the left scalene medius and left levator scapulae muscles.

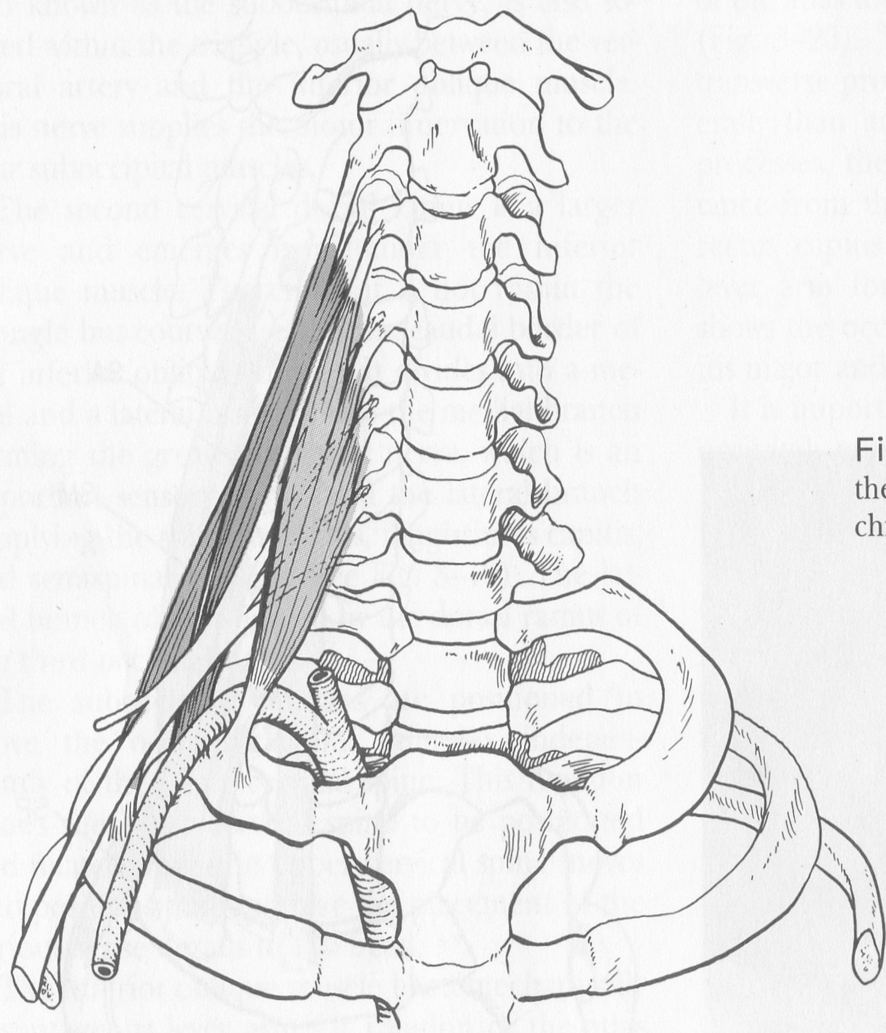


Figure 3–22. Scalene muscles and their relation to the trunks of the brachial plexus and the subclavian artery.

- The levator scapulae has the same fn as the deep erector spinae.(lumbar)
- The ant scalene muscle is similar to the psoas major muscle in the lumbar spine in that both attach to the ant aspect of vert TP and course inferiorly and ant. From that pt to reach their inf attachment-psoas maj to LT and ant scalene to 1st rib
- Deep erector spinae and psoas maj muscles are oriented to dynamically contribute to ant and post shear forces in Lx. Similarly lev scapulae and ant scalene are ideally positioned to have same effect on CX.
- Contraction of levator scapulae imparts a post shear force to Cx, contraction of ant scalene results in ant shear.

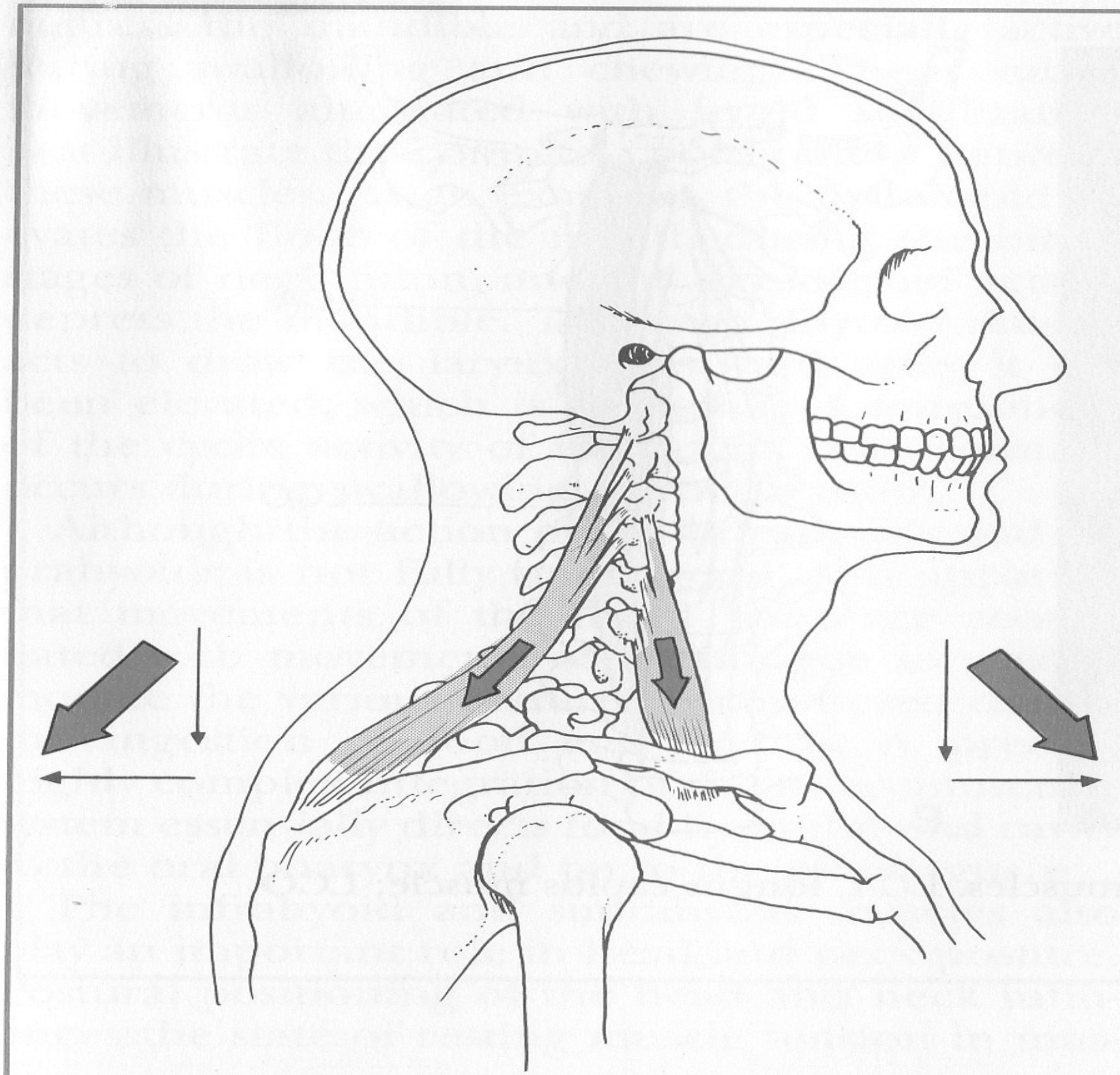


Figure 3–23. Stabilizing effect of the levator scapulae and anterior scalene muscles on the cervical spine. Such an arrangement offers stability of the cervical spine in the sagittal plane.

Anterior muscles

LONGUS COLLI AND CAPITIS

- Longus colli extends betwn upper thoracic vertebrae and atlas.It is triangular in shape.
- Longus capitis extends from the ant tubercle of the Cx transverse process to the base of occiput.
- Working alone, they can act as Cx flexors.contraction of the muscles increases the compressive force betwn the Cx vertebrae.As they are ant placed, prone to accln inj.
- **Clinical relevance**: when forced hyperext described by patient,, the longus colli and capitis should be suspected as possiblesources of pain.if injured, pain and pt unable to lift head from supine.

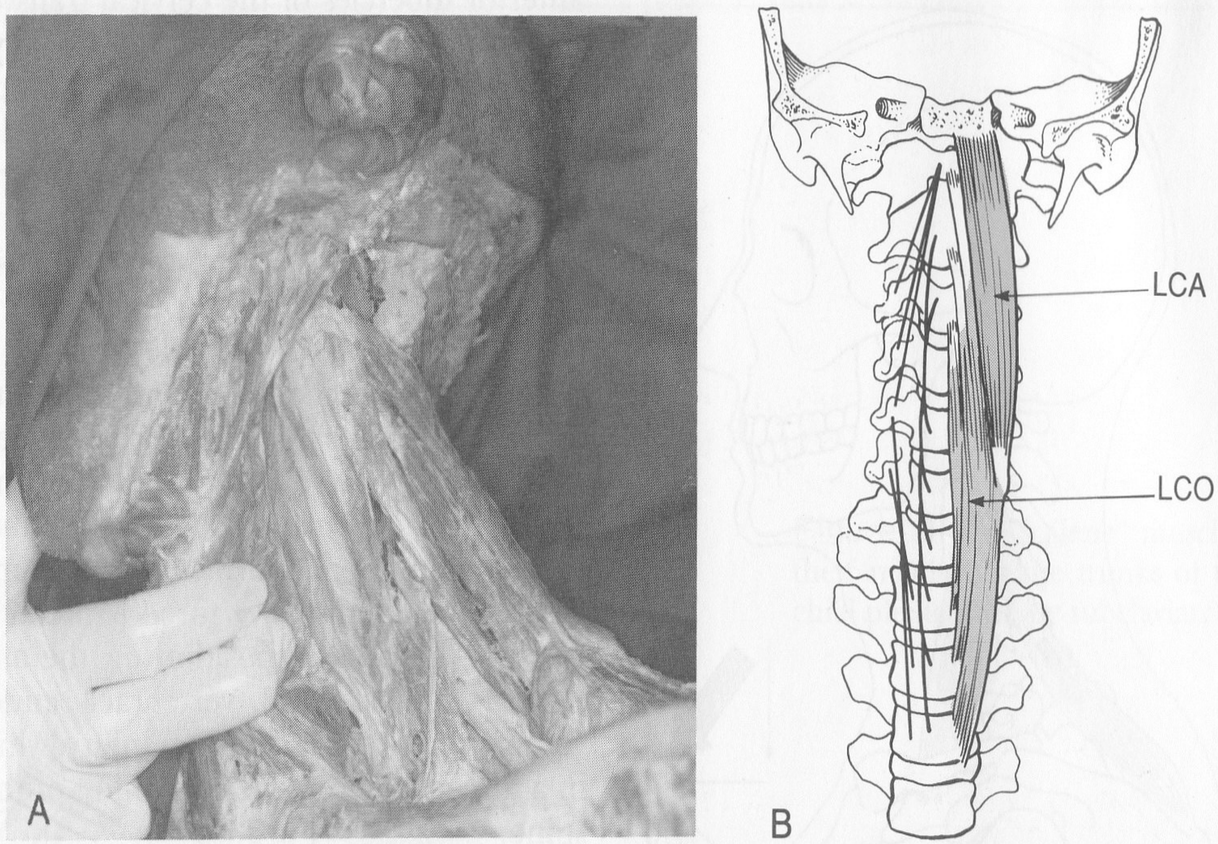


Figure 3–24. *A* and *B*, Longus colli and capitis muscles. LCA, longus capitis muscle; LCO, longus colli muscle.

Rectus Capitis anterior and lateralis:

- They have limited expanse from ant aspect of atlas to occiput.
- These muscles contribute to <u>proprioception for occipital motion rather than as prime movers</u> .This imp source of afferent input from the muscles provides the central nervous system with proprioceptive data that allows for continual adjustments of head and neck postural positioning.

Infrahyoid and Suprahyoid:

- The most superficial muscles of ant neck are infrahyoid(inf to hyoid), suprahyoid(sup to hyoid)
- Infrahyoid muscle consist of sternohyoid, sternothyroid,tyrohyoid and omohyoid.(ref to as strap muscles). These muscles act to fixate or depress the hyoid bone and thyroid cartilage.
- Suprahyoid muscles consist of digastric,stylohyoid, mylohyoid,geniohyoid.these muscles fixate or elevate the hyoid bone.
- Fixation and cyclic movt of the hyoid bone are essential during deglutition,and thus action of these muscles imp for coordination of that activity.

- With hyoid bone fixated, other muscles can have action on movable segment.
- Digastric and mylohyoid- depress mandible , active during swallowing and chewing.Myolohyoid elevates the floor of mouth during initial stage of deglutition and geniohyoid acts to depress the mandible.
- Sternothyroid acts to draw the lartnx downward after it has been elevated, which normally occurs during vocalization or swallowing.

- *the infrahyoid and suprahyoid muscle also play an imp role in head and neck posture. *ostural positioning of head and neck influences the state of resting muscle tensionin muscles related to the hyoid bone.With a head and neck posture that results in Cx being more forward in sagittal plane and the occiput subsequently being placed in excessive extension to keep the eyes looking more horizontally instead in a downward directionas a result of forward Cx, a passive tensile force is imparted to the hyoid muscles. The increased tension in these muscles results in the mandible being depressed and translated post.To counteract this passive pull into mandibular depression,the pt. must actively and continuosly contract the temporalis and masseter muscles to keep the mouth closed.

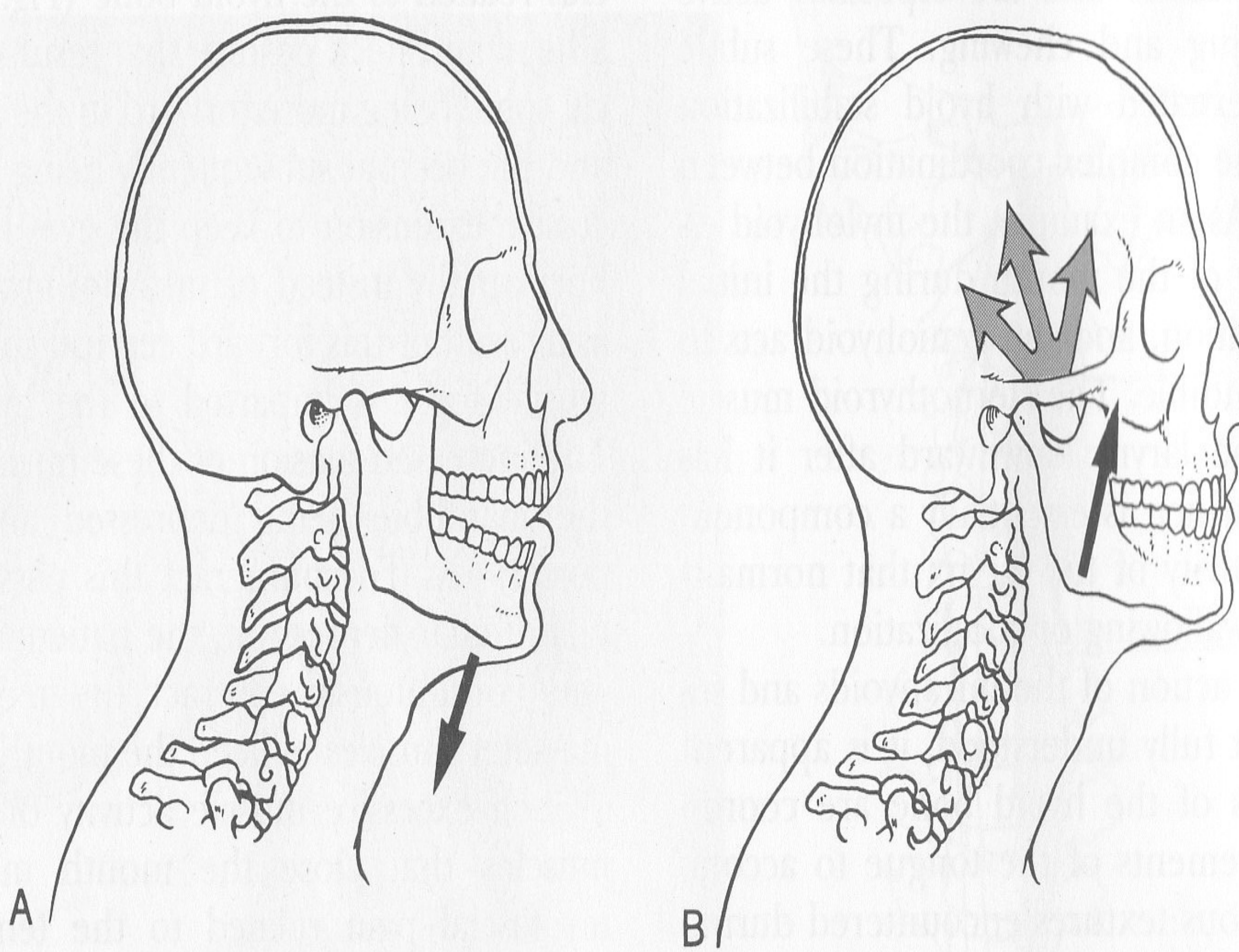


Figure 3–26. *A* and *B*, Relation between head and neck posture and the resultant contraction of the muscles of mastication (temporalis and masseter). Tightness of the anterior structures of the neck forces the mandible into an open position. Active and continuous contraction by the muscles of mastication is necessary to keep the mouth closed.

- Such excessive activity of the primary muscles that close the mouth may result in myofascial pain related to temporalis and masseter or discomfort in the TM jt.
- Referred pain from temporalis also may take the form of toothache in maxillary teeth.
- It is imp to recognise these biomechanical relationships betwn the face , jaw, and Cx especially whn complaints include excessive dry mouth(due to mouth breathng), difficulty swallowing,suboccipital headaches,teeth clenching, pain in the head and face over the temporal region, and tightness over the region of the throat.

ANALYSIS OF FORCES ON THE CX DURING ACTIVITY

- Normal upright posture characterised by a lordotic curve in the Cx so that atlanto-occipital junction lies ant to the cevicothoracic jn(C7-T1)
- As Centre of mass of head lies ant to AO jt , the head creates a flex moment both at AO jt and C7-T1 jn. Extension moment to keep the head upright is created by the extensor muscles.
- Moment arm of the wt of the head is approx one half of the moment arm of extensor muscle, putting the muscles in mechanical advantage so that extensor muscles have to generate a force of half of the wt of the head at AO jn.

- At C7-T1 the moment arm of the wt of the head is twice that of the extensor muscles, so mechanical disadvantage of the muscles.So muscles have to generate1.2 times force to keep head upright., so jt reaction force also increases at C7-T1.
- With head forward position, the moment to be generated by the extensor muscle further increases so also the load on the jt.s

CALCULATION OF THE MUSCLE AND JOINT REACTION FORCES AT THE ATLANTO-OCCIPITAL JOINT

The following dimensions are based on a 534 N (120 lb) female [32]:

Weight of the head (7% of body weight)	37.4 N
Moment arm of the head weight	0.02 m
Moment arm of the extensor muscle force (E)	0.04 m

Solve for the extensor muscle force (E):

$\Sigma M = 0$

$(E \times 0.04 \text{ m}) - (37.4 \text{ N} \times 0.02 \text{ m}) = 0$

$E = 0.75 \text{ Nm}/0.04 \text{ m}$

$E = 18.75$ N, or approximately one half the weight of the head

Calculate the joint reaction forces (J) on the occiput. Assume that the extensor muscle force is applied in the *y* direction

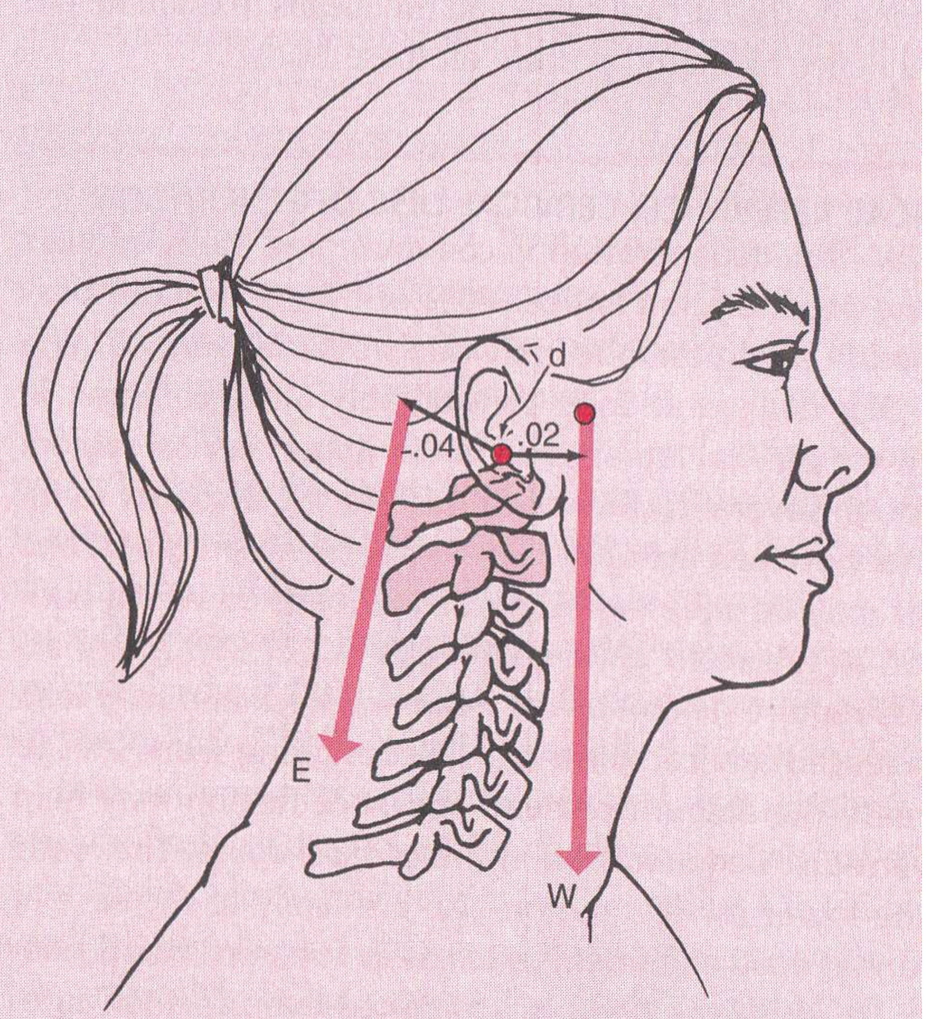
ΣF_x: no forces in the *x* direction

ΣF_y: $J - E - W = 0$

where E is the extensor muscle force and is equal to 18.75 N, and W is the head weight, equal to 37.4 N

$J = 37.4 \text{ N} + 18.75 \text{ N}$

$J = 46.15$ N, or approximately 1.2 times the weight of the head



Free-body diagram of atlanto-occipital (AO) joint. The weight of the head *(W)* produces a flexion moment at the AO joint that must be balanced by the extension moment from the force of the extensor muscles *(E)*.

CALCULATION OF THE MUSCLE AND JOINT REACTION FORCES AT THE C7–T1 JOINT

The following dimensions are based on a 534 N (120 lb) female [32]:

Weight of the head (7% of body weight)	37.4 N
Moment arm of the head weight	0.04 m
Moment arm of the extensor muscle force (E)	0.02 m

Solve for the extensor muscle force (E):

$\Sigma M = 0$

$(E \times 0.02\ m) - (37.4\ N \times 0.04\ m) = 0$

$E = 1.5\ N\ m / 0.02\ m$

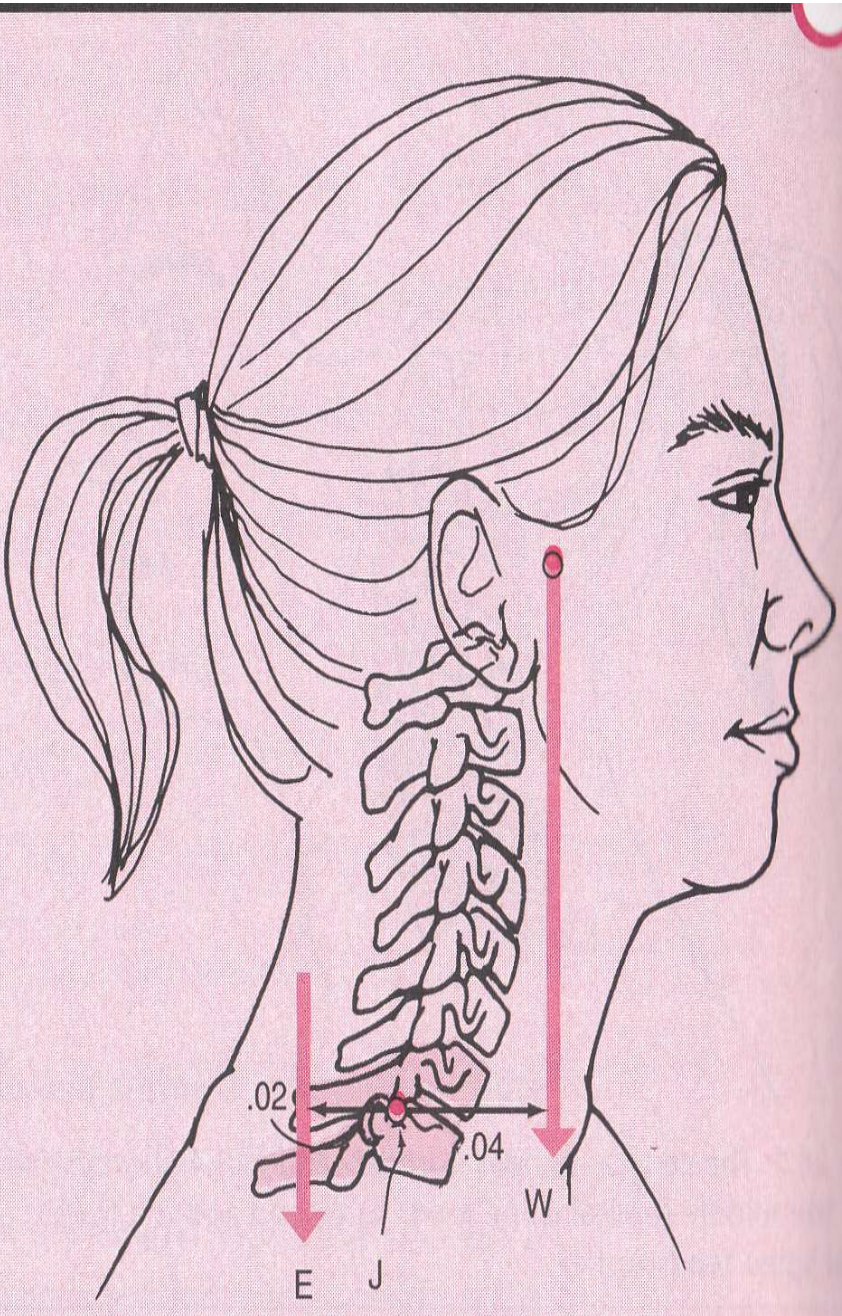
$\mathbf{E = 75\ N}$

Calculate the joint reaction forces (J) on the occiput. Assume that the extensor muscle force is applied in the y direction

ΣF_X: no forces in the x direction

ΣF_Y: $J - E - W = 0$

where E is the extensor muscle force and is equal to 75 N, and W is the head weight equal to 37.4 N



Free body diagram of the cervicothoracic (C7–T1) joint. The weight of the head (W) produces a flexion moment at the C7–T1 joint that must be balanced by the extension

Clinical Relevance: Cervical Disc Degeneration

- Study shows that deg present in over 80% of Cx disc above 60 yrs of age.
- Deg more common in lower cervical than upper Cx region. One factor contributing may be the loads to which each region subjected daily.
- Many activities require flex of the head and neck and may lead to increased Cx spine loads.
- Redesigning work sites to decrease the amount of head and neck flex may help to prevent disc deg in the cX spine
- *Loads on lower Cx increasing abnormal alignment like forward head posture, in which head positioned farther anterior to C7-T1 jn, increasing flex moment on lower Cx
- Intervention to decrease head forward may prevent disc deg as well as in treating symptoms of disc deg

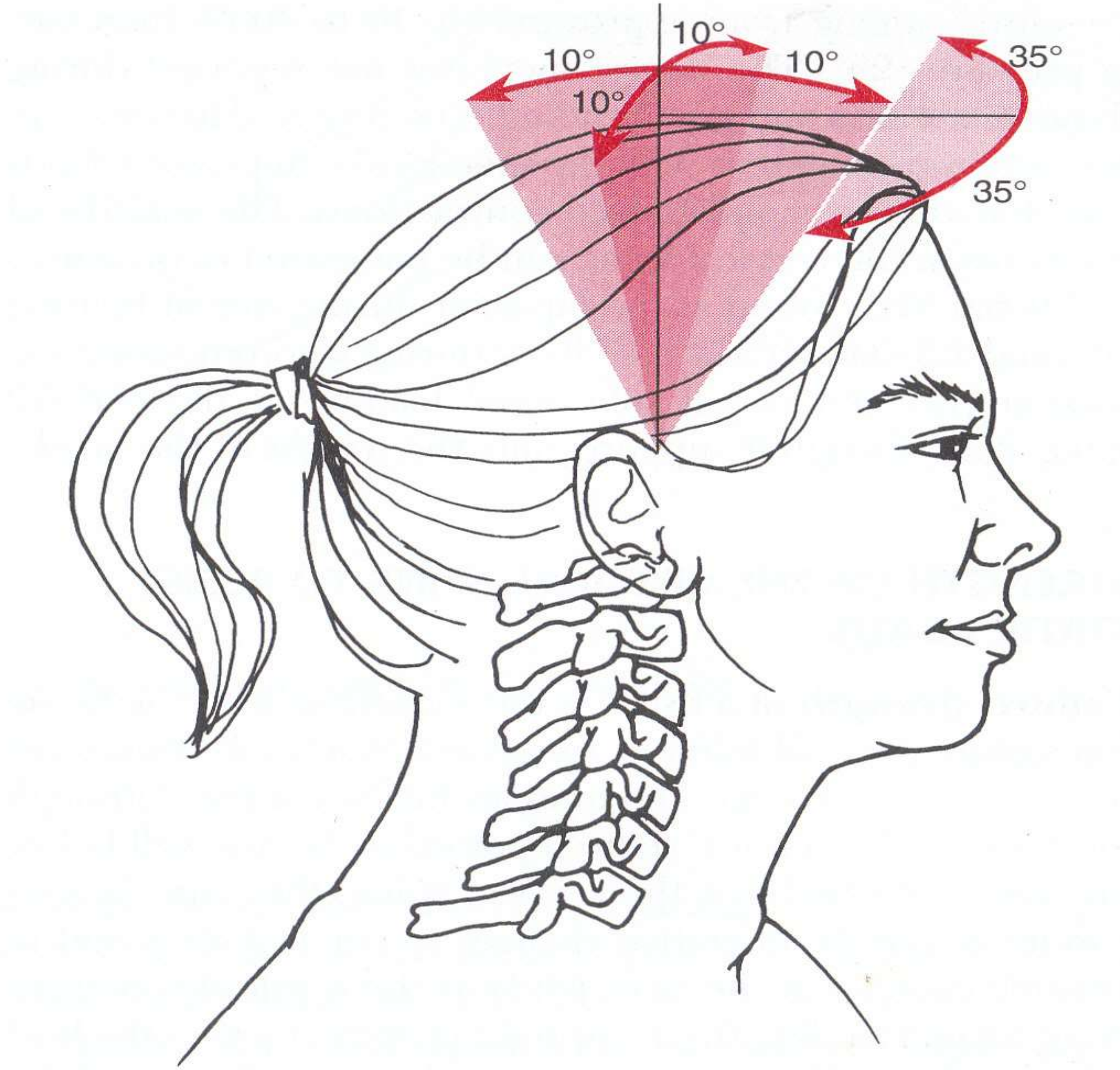


Figure 28.3: The neutral zone is the region through which the head and neck can move with little passive resistance from ligaments, joints, and muscles.

Muscle receptors:Clinical implication

- There is a continuos balance between mobility and stability demands of the spine due to combination of motor activity controlling and regulating accln, deccln and stabilizing fn.
- When the structure and fn of Cx musculature considered and viewed in relation to relation betwn Cx and CNS the focus which emerges is of **movt facilitation** in pts with Cx disorder and secondarily **strength training.**
- As the reflex activity primarily helps to determine motor behaviour of the muscles, a review about receptor system is imp

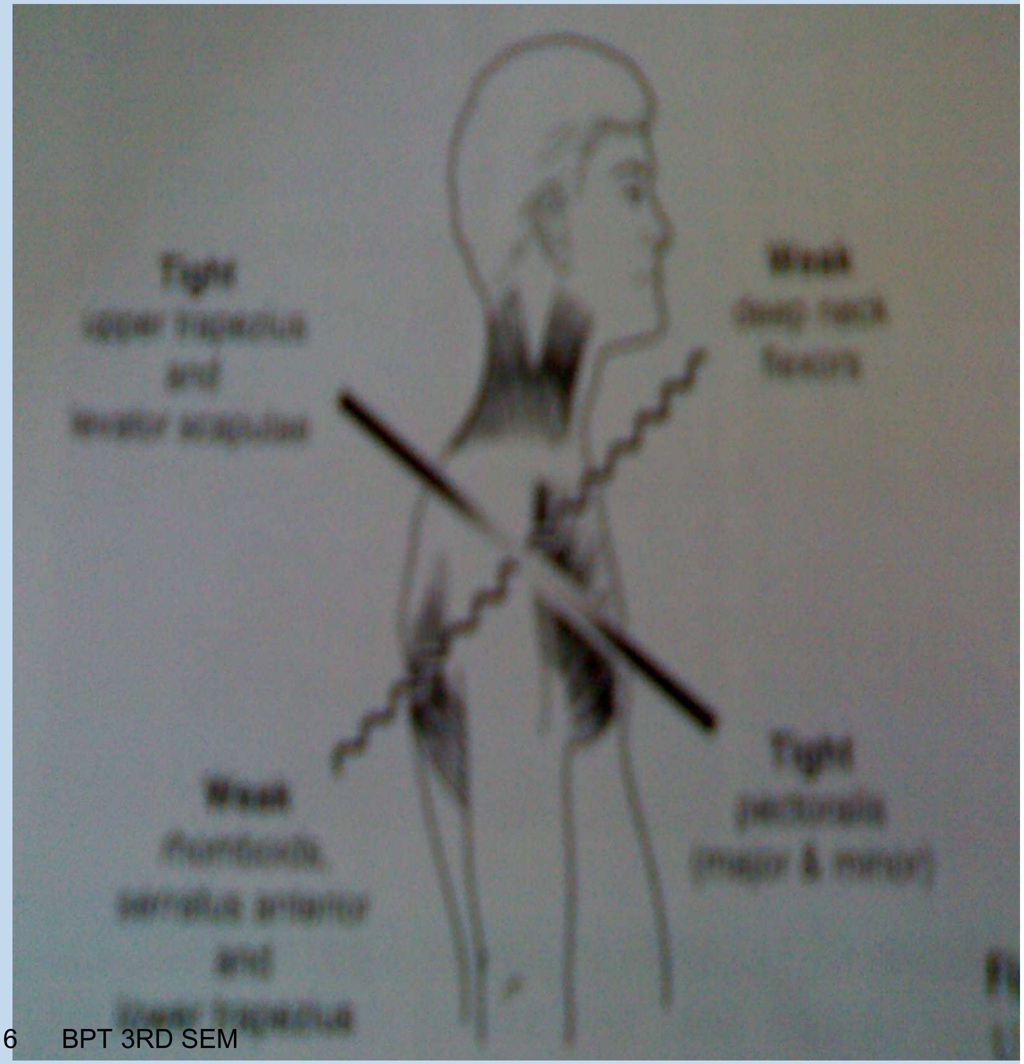
- 5 types of receptors in muscles: muscle spindles,tendon organs , pacinian corpuscles, undifferentiated receptors(free nerve endings), and capsulated mechanoreceptors
- Muscle Spindles: they are found in higher concentration in those muscles that control precise movts
- **Suboccipital muscles have about 150 to 200 muscle spinles per gram of muscle tissue**
- Some of the highest concentration of muscle spindles are per gram of muscle tissue are in the paraspinal muscles of the Cx region.Spindle density in the range of 2000 to 500 spindles per gram of muscle tissue can be found in the deeper muscle fibers of Cx spine, especially those that attach at each segment rather than spanning several several segments.they are usually dense aroudn the slow twich or oxidative muscle fibers i.e the postural muscles related to the spine.

With a prim goal of Rx in Cx problems is to *reactivate the neck*. It means that the Rx technique should be designed around the principle of *facilitating movt in a coordinated pattern of motion that minimizes stress to injured structures.*

- With a 3D appreciation of anatomy and an understanding of receptor system, the clinician is better able to optimize the healing environment of the injured tissueswhile promoting coordinated movt of the head and neck.

UPPER CROSSED SYNDROME

- Janda described a cervical upper crossed syndrome to show the effect of a poking chin posture on the muscles.
- With this syndrome the deep neck flexors are weak, as are the rhomboids,serratus ant and often the lower trapezius.
- Opposite this weak muscles are the tight pectoralis major and minor,along with upper trapezius and levator scapulae



SPINE FUSIONS

Procedure first introduce by Albee and Hibbs in 1911, arthrodesis is frequently use operations of the spine.

<u>Clinical Biomechanics of Spinal Fusions</u>

Reasons for spine arthrodesis

1. To support the spine when its structural integrity is compromised (To reestablish clinical stability)
2. To maintain correction, following correction of deformity like Scoliosis or Kyphosis , or following Osteotomy of spine.
3. To prevent progressions of deformity of spine in scoliosis , Kyphosis and Spondylisthesis.
4. To eleminate pain by stiffening of region of spine (Ex. Diminishing movt. Betwn various spine segment.

BIOMECHANICAL EFFECTS OF SPINE FUSION

- Some expt. Work shows increased motion below a fusion.(Quinnell R.C)
- The expt. Work of Lee and Langrana showed increase stress on adjacent unfused segments.
- Some obsevation of excessive motion , degenerative changes,spinal stenosis and even fracture dislocations have been observed in adjacent segment in ass. with spinal fusion.
- All this changes adjacent to fusion mass and most likely biologic and in some instances pathologic changes due to stress concentration at the interface of highly stiffened (fused) segment of the spine and the more flexible (unfused segment of the spine).

ELECTRICAL STIMULATION

- Kane has shown in randomised prospective controlled clinical study, that electrical stimulation improve the success rate in spinal fusion.

GRAFT MATERIAL

- The graft may serve as a structure to contribute to immediate post operative stability as a spacer or as a bridge to span a particular spinal column defect.
- The basic biologic use of graft material is to induce , establish or assist in osteogenesis.
- It has not been determine how this occur or even if it does occur. The main effect may be limited to the provision of a latticework or some structure for the in growth of new bone.

UPPER CERVICAL AND OCCIPITO CERVICAL ARTHRODESIS

- Stabn. and arthrodesis at craniocervical jn. → challenging problem → 80% of all head movt. occur at rostral 2 joints
- Stresses on the construct → Tendency to non fusions.
- Immob. Of those jt.→ Disability for the pt.
- Only solid spinal instrumentation are stable.

Cervical Spine Implants

Goals:

1) To obtain reduction
2) Restore alignmnt
3) Provide stability
4) Promote arthrodesis depending on particular pathologic process that has compromised spinal function.

Majority of the testing has been done in the middle and lower Cx spine

BIOMECHANICS OF FIXATION SYSTEM TO THE CERVICAL SPINE

- As long as bony fusion of the internal fixation has not been safely completed, the implant is subjected to both flexion and tortion according to the main movt of the cervical spine segments. Therefore biomechanical testing includes these direction of movt.
- It has been established experimentally and clinically that not only disc parts but also one of the main ligaments must be injured as a prerequisite for unilateral as well as complete luxation of the small intervertebral joints of the motion segment.
- An intact PLL due to its limited flexibility can safely prevent a luxation of the joints under pure flexion.
- Although PLL shows high rigidity against a tensile force, ex like under flexion, this offers little resistance to shear
- So it is assumed that tortional load is more likely to produce instability.

- In human cadaveric model, severance of the post ligamentous structures i.e, every lig except the ALL and PLL, reduced the torsional stability significantly while the flexural stability was preserved.
- Under pure flexural load, any post fixation method will achieve reliable stability under these condn , which always more stable than the intact specimen.
- Tortional stability can be only achieved by post hook plate.
- The low stabilization effect of post sublaminar wiring cannot significantly be improved by additional H-plating
- After post discolig severance,all post stabn method achieve a higher stability than the intact specimen with regard to the tilting angle. However , post sublaminar wiring alone is not able to avoid persistant translatory displacement in these cases.

- H-plate alone bends open under flexural loads. Exclusive anterior H-Plate requiresin complete discoligamentous instability requires additional external immobolization in the post operative phase to prevent flexion and torsion.
- Post hook –plate alone or in comn with ant H –Plate is able to guarantee the stability to mobilize the patient without any ext support in the post operative phase.

BIOMECHANICS OF CERVICAL SPINE INTERNAL FIXATION

ODONTOID SCREW FIXATION

- Used in Rx of odontoid #
- Achieves rigid fixation through the generation of high compressive forces across the #
- There is controversy regarding the use of odontoid screw fixation for non unions. The indication depends on whether there is sufficient bone density to allow screw purchase.
- The insertion of a single screw may cause rotn of the # fragment. In addition the alar ligaments may create rotatory forces that would be better resisted by two screws than by one. But there may not be adequate room for two screws in many pt.s. So preop CT imp
- Alternative Rx for odontoid # include Cx orthosis halo or post C1-C2 arthrodesis using a brooks or Gallie technique

ANTERIOR CERVICAL PLATES

- Used in deg and traumatic condn
- In traumatic cond hav been used to treat Cx burst #, dislocations and ext injuries
- In a study by Paul anderson et al, disraction flexion injury was created by division of all post lig including PLL and IVD to allow B/L facet dislocation. Both wiring and ant plate fixation were used and tested in flexion.
- It was found that anterior plate fixation should not be used alone in flexion type injuries but should be supplemented with posterior instrumentation or rigid external immobn

C1-C2 POSTERIOR SCREW ARTHRODESIS

- Post wiring of atlas to axis has proven to be a succesful technique.
- In cases where there is an absent or insufficient post arch of C1, standard wiring is not possible
- Studies were done to compare modified Gallie wiring vs Magerl's technique of C1-C2 post screw arthrodesis
- The Magerl technique was found to be stiffer in rotn than the Gallie technique
- No translation In AP plane was observed in screwed specimen whereas marked Ap translation was noted in wired specimen.
- Because of extensive dissection involved in MAgerl's technique for screw placement in C1-C2 arthrodesis, it is not preferred but is an alternative when standard techniques have failed

POSTERIOR CERVICAL PLATES

- It can be used when the lamina or spinous process is missing or incompetent. Alternatively it can be used when ant column can be load bearing e.g burst #
- 2 methods of screw placement are in use.
- Technique 1→the screw is placed in a more or less straight sagittal direction or angling outward 10-20º
- Technique 2→screw is placed llr to the facet jt and angled outward 30-40º
- The 2nd technique is found to be biomechanically superior(higher load to failure and is stiffer, also screws directed away from neurovascular structures)

A Kinematic Study of the Cervical Spine Before and After Segmental Arthrodesis

Spine. 23(15):1649-1656, August 1, 1998.

Fuller, David A. MD ; Kirkpatrick, John S. MD ; Emery, Sanford E. MD ; Wilber, R. Geoffrey MD

- Study Design. The acute kinematic consequence of segmental arthrodesis in the cervical spine on the remaining open motion segments was studied in a cadaveric model.
- Objectives. To evaluate the distribution of motion across unfused cervical motion segments after a segmental arthrodesis. The applied load was determined as a function of arthrodesis length and level by using a fixed range of motion for the cervical spine (C2-T1).
- Summary of Background Data. An increased incidence of degenerative disease may exist at the levels immediately adjacent to a cervical arthrodesis as a result of alteration in biomechanical behavior at these levels.

- Methods. One-, two-, and three-level fusions were simulated in multilevel ligamentous human cervical spines. Specimens were tested nondestructively through a 30[degrees] range of sagittal plane rotation. Motion was recorded using three-dimensional stereophotogrammetry. Sagittal plane rotation of each motion segment in the fusion models was compared with the corresponding rotation in the unfused specimen.
- Results. In the C2-C4 fusion, the increase in motion at C5-C6 was statistically less than the increase at C7-T1. In the C2-C5 fusion, the increase in motion at C5-C6 was statistically less than the increases at C6-C7 and C7-T1. For each of the five other fusion types tested, no statistical differences existed between the increases in sagittal rotation at any of the open motion segments. The bending moment necessary to produce 30[degrees] of sagittal rotation increased nonlinearly as the number of motion segments fused increased.

- Conclusions. Under what was considered a realistic loading paradigm, sagittal plane rotation was not increased disproportionately at the motion segments immediately adjacent to a segmental arthrodesis in the cervical spine. The nonlinear rise in applied bending moment to achieve constant displacement was characteristic of the behavior of the ligaments and intervertebral discs throughout the spine as they underwent increasing deformation.

Motion Compensation Associated With Single-Level Cervical Fusion: Where Does the Lost Motion Go?

Spine. 31(21):2439-2448, October 1, 2006.

Schwab, John S. MSc ; DiAngelo, Denis J. PhD ; Foley, Kevin T. MD

- Study Design. Seven adult human cadaveric cervical spines (C2-T1) were biomechanically tested in a programmable testing device.
- Objective. Compare the effects of incremental single-level fusion at different levels of the cervical spine.
- Summary of Background Data. Clinical studies have reported degenerative symptomatic disc disease at disc levels adjacent to fusion. No known study has attempted to delineate the effects of single-level fusion at different levels of the cervical spine.

- Methods. The spines were tested in flexion, extension, right and left lateral bending, and right and left axial rotation for 7 different conditions: harvested and 6 independent single-level fused conditions (i.e., C2-C3, C3-C4, C4-C5, C5-C6, C6-C7, and C7-T1).
- Results. Motion compensation was distributed among the unfused segments with significant compensation at the segments adjacent to fusion. Significant increases occurred at the level above C3-C4 and C4-C5 fusions, and below for C5-C6 and C6-C7 fusions in both flexion and extension.

- Conclusions. Increase motion compensation occurred at segments immediately adjacent to a single-level fusion. Significant differences occurred at the level above the fusion site for the C3-C4 and C4-C5 fusion in both flexion and extension. When the lower levels (C5-C6, C6-C7) were fused, a significant amount of increased motion was observed at the levels immediately above and below the fusion. However, greater compensation occurred at the inferior segments than the superior segments for the lower level fusions (C5-C6, C6-C7).

Does Anterior Plating of the Cervical Spine Predispose to Adjacent Segment Changes?

Spine. 30(24):2788-2792, December 15, 2005.

Rao, Raj D. MD ; Wang, Mei PhD ; McGrady, Linda M. BS ; Perlewitz,

ThomasJ. MD ; David, Kenny S. MD

- Study Design. In a human cadaveric model, the effects of plate supplementation on the mechanical behaviors of adjacent segments were investigated.
- Objectives. The objective was to determine the effects of anterior cervical fusion and plating on the adjacent segments.
- Summary of Background Data. Increases in intradiscal pressure and intervertebral motion at adjacent segments have been reported in the lumbar spine following an instrumented fusion. It is unclear if the same phenomenon presents in the cervical spine.

- Methods. Seven human cadaveric cervical spines (C2-T1) were used, and fusion of the C5-C6 segment was chosen for the purpose of this study. Two miniature pressure transducers were implanted within each adjacent disc. Flexion, extension, lateral bending, and torsion loads up to 2.5 Nm were applied to the intact spine, and following each of the two procedures, anterior discectomy and grafted fusion, and anterior plating of the C5-C6 motion segment.
- Results. At the surgical level, a significant increase in segmental stiffness was observed after plating in all directions. Following the grafted fusion, there were no statistically significant changes at the superior adjacent segment, and there was a 13.7% increase in axial rotation in the inferior adjacent segment. Once anterior plating was applied, slight increase (<12%) over the intact spines was noted in lateral bending in both adjacent segments. However, there was no significant difference between the grafted fusion and anterior plated fusion at either adjacent segment. At both adjacent disc levels, the differences in intradiscal pressures between grafted fusion and plated fusion were less than 30% in all directions, and none of these differences was statistically significant.

- Conclusions. Intradiscal pressures and intervertebral motion at the adjacent levels are not significantly affected by the instrumented anterior fusion. The clinically observed degenerative change at adjacent segments in the cervical spine is more likely to be attributed to natural progression of the spondylotic process as opposed to biomechanical effect of the instrumentation or fusion.

Effect of lower two-level anterior cervical fusion on the superior adjacent level

Park DH,Ramakrishnan P, Lim TH,J of Neurosurg Spine 2007 Sep;7(3):336-40

- OBJECT: Symptomatic multisegment disease is most common at the C5-6 and C6-7 levels, and two-level anterior cervical discectomy and fusion (ACDF) is performed most often at these levels. Therefore, it may be clinically important to know whether a C5-7 fusion affects the superior C4-5 segment. A biomechanical study was carried out using cadaveric cervical spine specimens to determine the effect of lower two-level anterior cervical fusion on intradiscal pressure and segmental motion at the superior adjacent vertebral level.

- METHODS: Five cadaveric cervical spine specimens were used in this study. The specimens were stabilized at T-1 and loaded at C-3 to 15 degrees flexion, 10 degrees extension, and 10 degrees lateral bending before and after simulated two-level ACDF with plate placement at C5-7. Intradiscal pressure was recorded at the C4-5 level, and segmental motion was recorded from C-4 through C-7. Differences in mean intradiscal pressures were calculated and analyzed using a paired Student t-test. When the maximum calibrated intradiscal pressures were exceeded ("overshot") during measurements, data from the specimens involved were analyzed using the motion data with a Student t-test. Values for pressure and motion obtained before and after simulated ACDF were compared.

- RESULTS: During flexion, the mean intradiscal pressure changes in the pre- and post-ACDF measurements were 1275 mm Hg and 2475 mm Hg, respectively . When the results of pre-ACDF testing were compared with post-ACDF results, no significant difference was found in the mean changes in the intradiscal pressure during extension and lateral bending. The maximum calibrated intradiscal pressures were exceeded during the post-ACDF testing in four specimens in extension, three in flexion, and two in lateral bending. Comparison of pre- and post-ACDF data for all five specimens revealed significant differences in motion and intradiscal pressure during flexion, significant differences in motion but not in intradiscal pressure during extension, and significant differences in intradiscal pressure changes but not in motion during lateral bending

- CONCLUSIONS: Simulated C5-7 ACDF caused a significant increase in intradiscal pressure and segmental motion in the superior adjacent C4-5 level during physiological motion. The increased pressure and hypermobility might accelerate normal degenerative changes in the vertebral levels adjacent to the anterior cervical fusion.

WHIPLASH INJURY

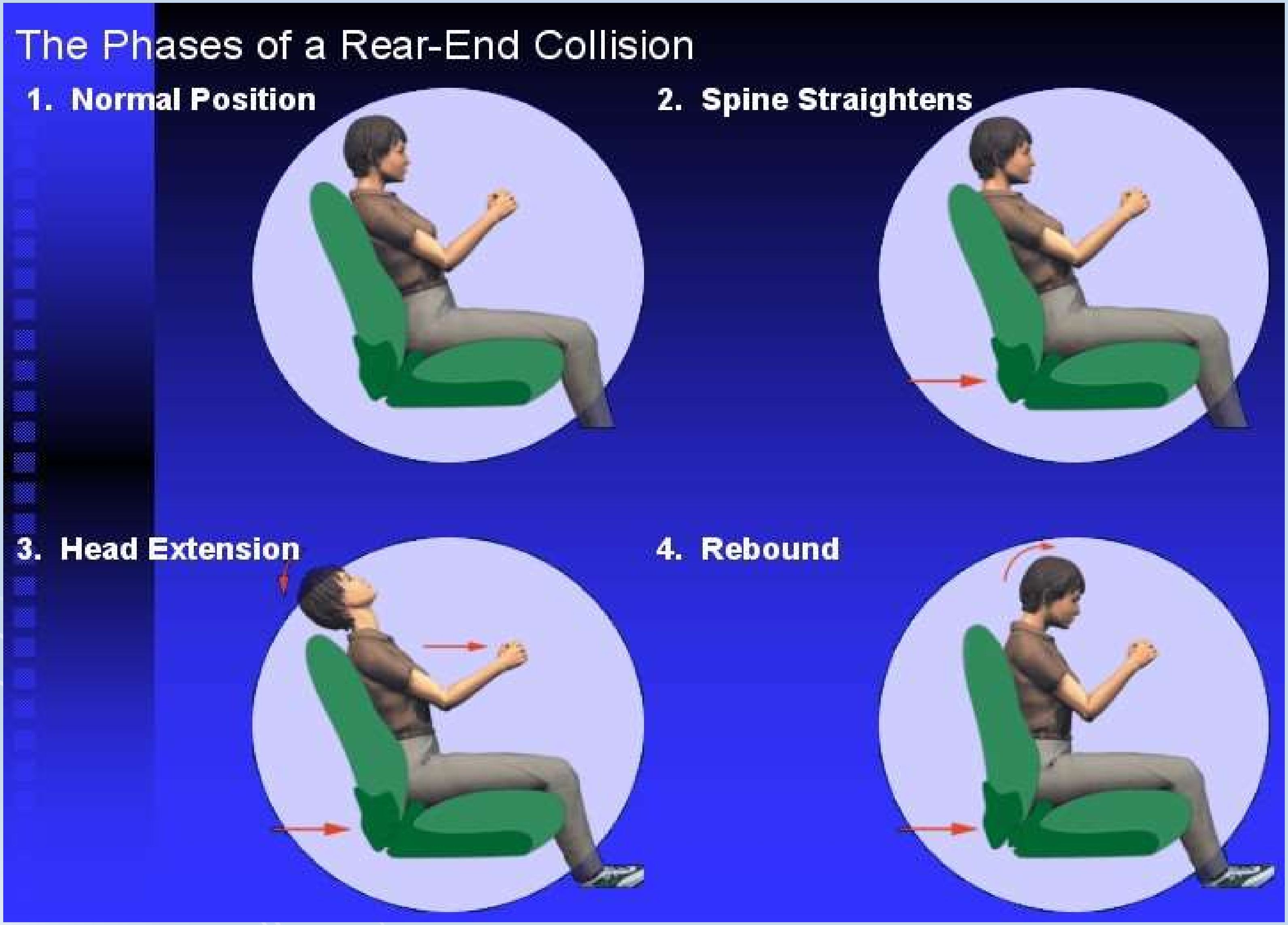
- There is usually H/o of minor or moderate rear end collision.
- Pt. presents with large variety of symptoms, neck pain being common
- Radiographs normal,possible loss of physiologic cervical lordosis

MECHANISM:

Exact mechanism not known. Believed to be hyperext.

The inertia of the head tends to hold it in a resting position following the sudden accln of the remainder of the body.The forward pull applied by the trunk to the lower portion of the head produces a moment and rotn of the head in the negative direction around x- axis causing

Extension of the Cx


The Phases of a Rear-End Collision
1. Normal Position
2. Spine Straightens
3. Head Extension
4. Rebound

Expt. Study:

- Macnab experimented with monkeys.Found that inj ranges from minor tear in SCM to partial avulsion in the longus colli muscle.
- The most frequent lesion were rupture of ALL and separation of annulus fibrosus from the associated vertebrae
- Above study supported by human occipito cervical spine specimen loaded in hyperextension
- There is associated brain inj due to contre coup phenomenon(movt of the skull causing trauma to cortex and cerebellum)
- Occational inj at the base of the brain due to sudden angular accln of the skull.

- External blow to the skull from part of automobile may occur whn pt.s body thrown forward
- Pruce, Torres et al reported significant EEG abnormalities in pt.s following whiplash inj.
- Ommaya et al in a study found that head rotn accln of 1800 rad/sec^{2} would result in a 50% probability of cerebral concussion
- An angular accln of 100,000deg/sec^{2} reached when a car is hit from behind producing 5 g horizontal accln of the car.
- This accln of 5g is equal to attaining a speed of approx 18 km/h from standstill within 0.1 second
- In other words, if a car is hit from behind, causing it to move at a speed of 18 km/hr within 0.1sec,there is 50% probability of cerebral contusion for the occupants.

- Study by Clemens et al on cadaver betwn 50 -90 yrs age,19 km/hr impact produced
- IVD failure → 90% cadavers
- Torn ALL →80%
- Tears of facet jt capsules → 40%
- Some bone # →30%
- Tear of yellow lig → 10%
- PLL tear →10%
- Injuries mainly at C5-C6 or C6-C7
- Severy et al simulated whiplash inj by using well instrumented anthropometric dummies and human volunteer(at slow speed) during controlled expt collision. Typically 13 km/hr rear end collision produced a 2g accln of vehicle and 5g accln of head.

- The head first goes into flex and then into ext in 0.2 sec
- The max injuring forces occurs in ext and are found mainly in the region of C6-C7.
- It is debatable whether head directly goes into ext or flex followed by ext
- So should be kept in mind about the flex component of inj
- **Motion of the head and the loads causing inj to the spine are dependent upon the seatback stiffness .
- The effect is horizontalaccln of the head is responsible for shear load in the neck after collision.The stiffer seatback produces less accln and therefore less shear stresses.
- Results of study shows that for angular accln of the head,less bending stresses occur in the neck when the occupant is sitting in a stiffer seat.
- SO HARDER SEAT IS SAFER

- Yoganandan et al demonstrated that externally the head and the neck do not exceed normal physiological limits.However Cx spine undergoes sigmoid deformation very early after impact.During this deformation,lower cervical segments undergo post rotn around an abnormally high axis of rotn, resulting in abnormal separation of the ant elemets of the CX and impaction of zygapophysial jts.
- Yoganandan et al using an intact, cadaveric head neck prepn including muscles and ligaments determined overall(head to T1), segmental(head-C2, C2-C5,and C5-T1) and local component (facet jt)motions to explain the plausible mechanisms of headache and neck pain.
- A pinching mechanism in the zygapophysial jt was attributed to neck pain and a post stretch in upper head neck complex in the early stages of whiplash acclnpulse was attributed to headaches.

- Post rotn of the head commences betn 60 and 100ms after impact, and has a peak magnitude of 45º betwn 100 and 130 ms. In particular the head doesn't rotate beyond itz physiological limit . The duration of positive accln of the head is betwn 100 and 110 ms qnd reaches 13 g
- Betwn 0 and 50 ms after impact→ no response by the body
- At 60 ms → hips and low back are thrust upwards and forwards
- By 100ms→ Upper trunk moves upwards and forwards. The upward movt of the trunk compresse the Cx form below and the forward movt displaces the neck and the trunk forward of the line of gravity of the head.
- By120ms the c.o.g of thehead starts to drop and causes the head to rotate backward

- At about this time, the seatback collapses backwards under the mass of the trunk.
- By 160 ms→ torso pulls the base of the neck forwards and tension through the Cx draws the head forward.
- At 200 ms→ Upward excursion of the torso peaks and the head reaches its peak post rotn of 45º
- By250 ms→ The trunk , neck and head descending
- 300ms→ descent is complete
- 400ms→ head achieves its max forward excursion and begins to rebound.
- Betwn 400 and 600 ms→ restitution of position occurs.

- Betwn 50 and 75 ms the Cx undergoes a sigmoid deformation as it is compressed by the risisng trunk, so that the lower Cx segments undergo ext while upper segment flex.By 120 ms the spine extends into a C shape.
- Although the Cx as a whole doesn't exeeds physilogical ranges of movt at any stage during its excursion, lower Cx segments consistently exceeds physiological limits of post rotn.
- This rotn occurs around an abnormal axis of rotn. The axis is located within the moving vertebra considerably rostral to its normal location.
- This abnormally hight location of the axis indicates that te vertebra undergoes no translation but purely post rotn and arises because of the forece producing movt is an upward thrust. No shear force is exerted on the vertebra at this point of time.

- As the vertebra extends about this abnormally located axis, its ant alements rotate upwards and itz post elemnts rotate downward.
- The upward rotn causes the ant ends of adjacent vertebral bodies to separate in an abnormal fashion. So articular processes of the zygapophysial jts instead of gliding over one another, the inf process of the moving vertebra chisel into the sup articular process of itz supporting vertebra.This post compression occurs about 100ms after impact.
- Muscles are recruited relatively less during the whiplash event. They start to be recruited by 100-125 ms but may tale further 60 ms to develop tension.
- By the time muscles are activated,compression of the Cx spine and the abnormal intersegmental movt have already occurred.

- Within less than 150 ms after impact,the Cx is compressed. During this period, the Cx buckles; upper Cx segments are flexed while lower segments extend aroung an abnormally located axes of rotn.It is during this period of compression that the Cx is vulnerable ti injury.
- The cause of compression is the upward thrust of the trunk. This has been attributed to seatback extending the thoracic kyphosis, for compression occurs only in stooped posture. It doesn’t occurs if subject is declined with the head applied to the head rest. Under this condn, the torso and the head collapse backward together as the seatback collapse, and no upward thrust is exerted on the neck.

3 BASIC SAFETY FACTORS RELATED TO WHIPLASH INJURIES

- Headrest limits the amount of extension allowed in rear end collision. Headrest should be atleast as high as the level of the ears, which approximates the c.o.g of the skull.If they are lower than the c.o.g, they serve as a fulcrum and accentuates the injury.
- Second, there is the restraining capacity of the shoulder strap. By restraing the motion of the chest, there is a decrease in the amount of inertial forces exerted on the Cx spine.So USE OF SEAT BELT IS IMPORTANT.
- Third, the spring which represents the stiffness of the seatback. The stiffer the spring, the safer the seat.

In a rear end automobile accident, pt develops immediate symptoms or after several symptom free days.

- Frontal or occipital headaches
- Numbness or wekness in one or both U/L
- Vertigo or tinnitus
- Dysphagia
- Blurring of vision or nystagmus
- Neck pain with muscle spasm, limited motion, loss or reversal of normal Cx lordosis.

- Dvorak and associates speculated about the possibility that C0-C1 instability secondary to failureor elongation of alar lig may be involved.
- Worth studied pt.s with neck pain after automobile accident and reported decreased motion in C0-C1 region.
- The idea of ligamentous inj followed by excessive motion and irritation of the high spinal cord or brainstem elements seems to be the more appealing hypothesis.

CLINICAL ,PSYCHIATRIC AND MEDICOLEGAL CONSIDERATION:

- Symptoms associated are much broader and less specific than in other neck injuries.

Macnab purports that these pt.s are not hysterical , neurotic or dishonest.He reports that pt with hyperext inj have much more symptoms than flex or lat neck inj.

RADIOLOGICAL CONSIDERATION:

- Wagner and Abel carried out clinical and expt studiesthat led them to the conclusion that whiplash phenomenon may include occult injuries.With specialized radiographic techniques, they identified various lesions:
- Interarticular isthmus # with or without lamin #
- # TP of C1
- Rotary subluxn of C1 wrt occiput and axis
- Luschka jt #

Clinical factors associated with poor prognosis following soft tissue injuries of Neck

- Numbness and/or pain in an U/E
- Radiographic visualization of sharp reversal of Cx lordosis
- Restricted motion at one interspace(flex/Ext)
- Need of Cx collar for>12 weeks
- Need of home traction
- Need to resume physical therapy more than once because of symptom exacerbation
- OBJECTIVE NEUROLOGIC SIGNS
- Neck stiffness
- Muscle Spasm
- Pre- existing Cx spondylosis

Treatment

- Support of the neck during severe muscle spasm and stiffness by Cervical orthosis
- Analgesics, Muscle relaxants
- Traction has been suggested
- If symptoms for > 3 mnths, may go for ant Cx fusion.

THANK YOU