MODELING OF THE CERVICAL SPINE – RELATIONSHIP BETWEEN MUSCLE TONE AND SHAPE OF THE CERVICAL SPINE

Čemusová Jitka, Kaczmarská Agniezska, Otáhal Stanislav

Charles University, Faculty of physical education and sport/Dep. of anatomy and biomechanics, Prague, Czech Republic

cemusova@mbox.catr.cz

Abstract: Modelling of the human body is the modern view on the physiologic and pathologic situations in the human body. In the cervical region there is a lot of number of muscles which are able to change shape of all cervical region. For illustration of function of these muscles we use centre of rotation (COR) or instantenous centre of rotation (ICR). There is possiblity to use X-ray or CT, NMR scans for illustration of bone and muscle sturctures and palpation of muscles for investigation of muscle tension. Changed muscle tone influate motion of cervical spine, therefore we can use some kinematic techniques for documentation these motion. This article is orientated to the COR and the ICR as a approach for illustration of muscle function or centred position of vertebrea.

Introduction

During movement of spine in the sagittal plane there is some centre of rotation or point around a vertebra is moved. This point is usually cold as a centre of rotation (COR) and instantaneuous centre of rotation (ICR). This point is usually placed approximately in the middle of the lower vertebra and it`s localisation isn`t so hard [according next text]. The ICR or COR are used as a reliable parameter for vertebral movement of the cervical spine and for classification of spine abnormalities. Position of this COR is dependent on the muscle tone of cervical muscles.

Materials and methods

Identification of COR - ICR is useful for finding or locating normal - physiologic position and kinematics of all cervical spine and also for location of abnormalities of this region. For locating ICR and for evaluation of kinematics of cervical spine is necessary to have dynamic slides from radiography or some model of cervical spine with subsequent possiblitity to locate of ICR.

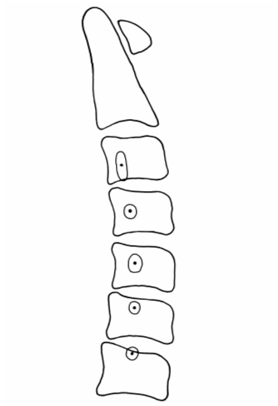

Figure1: A sketch of an idealized cervical vertebral column illustrating the mean location and two standard deviation range of disturbation of the instantaneous axes of rotation of the typical cervical motion segments. (Bogduk et all 2000)

Penning [1988] found that there is different positions centres of rotation for different cervical segments. At lower cervical levels, the ICRs were located close to the intervertebral disc of the segment but at higher segmental levels the ICR was located substantially lower than this position, like on the figure 1.
Series of clinical and simulated studies document the correlation between abnormal localisation of ICR and algic vertebral syndromes of cervical spine with higher muscle tone of cervical muscles. It seems that relationship between painfull area of soft and hard tissues is fully correlating with abnormal localisation of ICR of vertebra and also with abnormal movement stereotypes (Amevo et al. 1992) and we hope that there is also correlation between abnormal position of ICR and changed shape of whole cervical region. On the based of

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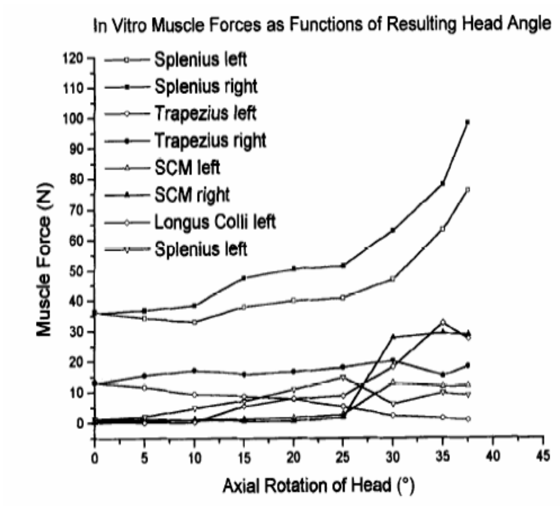
some studeis (Amevo 1992) there is most of abnormal located centres of rotation in the upper and middle cervical spine, exactly C2-3 and C3-4 and it is presumbly that there is not direct relationship between segmental level of abnormal located ICR and attendant blocation of facet joints. This means that change of position of ICR (COR) isn´t probably caused by pain but it is the result of muscle tone change with secondary initiated blocation of cervical segments. If we consider about existing muscles in cervical region it´s important to know that position of ICR is fully dependent on muscle tone.Two origines of each pair of muscles determine the position of hard tissue of body. For example, Bernhardt published his model study where had been eight muscles as a eleastic cabels connected to the physical model of cervical spine and head. According EMG dates and examples with mathematical finite element model there had been made physical model of cervical spine with dynamic muscles with their specific lenght and strenght. If there is higher muscle tone or muscle contracture, there will be permanent tension toward some origin of muscle on hard tissue, e.g. inclination to change of ICR position. Next graph, assumed from Bernhardt (1999), illustrate muscles of cervical region and change of their tension during axial rotation of head.



Graph 1: Muscle forces relative to head angle. (Bernhardt 1999)

For these reasons ICR (COR) is used like reliable parameter of quality of vertebral movement of the cervical spine and possibilities of classification of attendant abnormality.

For typical formative characteristics of zygapophyseal joints there is a relatively large range of motion of these joints to the rotary direction, but a smaller range of transitional movement. The difference between rotary and transitional movement is also significant in locating of ICR. Van Mammeren (1990) was deal by monitoring ICR of separate vertebrae during their movement in the sagittal plain and found out that ICR is independent on kind of sagittal movement (flexion or extension), that the ICR is allready on one place so that ICR is relatively stable in time. It means, if there is no any expressive check on kinematic of the cervical spine e.g. injury of other manual or diseaded action, the ICR of one vertebra and person is relatively unchanging (miminally during 10 week as doclarated by Van Mameren study).

The compression forces exerted by muscles and by gravity, and the resistence to compression exerted by the facets and disc of the segment determine the location of the centre of rotation. The shear forces exerted by gravity and muscles, and the resisitance to these forces exerted by the intervertebral disc and facets determine the magnitude of translation. The moments exerted by gravity and by muscles, and the resistence to these exerted by tension in ligaments, joint capsules and the anulus fibrosus determine the amplitud of rotation. Displacement of an ICR from its normal location can occur only if the normal balance of compression loads, shear lodads, or moments are disturbed.

If the veretebra is moved in the sagittal plane form extension to flexion or back there is a theoretical point around which a vertebra is moved and this point is placed in the middle of the lower vertebra. This point (ICR) is possible to find by relatively easy geometry like on the figure 2.

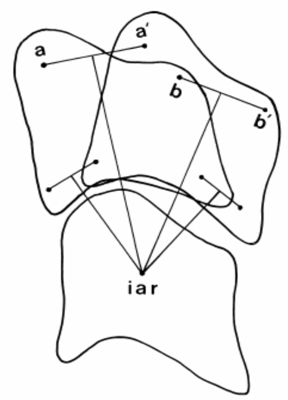


Figure 2: A sketch of a cervical motion segment illustrating how the location of its ICR can be determined by geometry. (Bogduk et al 2000)

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Mathematical analysis of ICR [COR] shows that the location is a function of three basic variables: the amplitude of rotation (ϕ) of a segment, its translation (T), and the location of its centre of rotation (CR) In mathematical terms, with respect to any universal coordinate system X; Y, the location of the ICR is defined by the equations:

$X_{ICR} = X_{CR} + T/2$ (1)
$Y_{ICR} = Y_{CR} – T/[2 \tan (\tilde{\phi}\ 2)]$ (2)

where (X_{ICR}, Y_{ICR}) is the location of the ICR, and (X_{CR}, Y_{CR}) is the location of the center or reaction.

For creation of ICR are needed dynamic slides from radiography in various movement planes as the basic input data. For detailed processing of position of ICR (COR) there is important to work with finete element model which is able to work with dynamic muscle forces. Nowadays it is a big problem because it´s too hard to make a model with right origines of all cervical muscles with their right lenght and strenght. A lot of studies calculate with muscle function but most of them has unrealistic origines, especially as a one poit but a lot of muscles have origines as a line on the bone.

Discussion

Panjabi [Panjabi, White 2001] talk about balance, especially when the one segment should be in one position, it is necessary to have full balance between all active planes and directions of motion. The sketch of balance for each of points (bodies, segments, vertebrea) go out of 2nd. Newton testament, i.e. all forces and kinetic moments acting on object must be in bilateral balances so that the main position of object was maintainced. For maintain balance of each segment, sum of all of acting forces and moments must be equal to zero. Because it is important to consider about present applied forces in three dimenzional co-ordinative system, here is a possible mathematical equation in the context of 3D system:

$\Sigma F_x = 0$, $\Sigma F_y = 0$ $\Sigma F_z = 0$ (3,4.5)

$\Sigma M_x = 0$ $\Sigma M_y = 0$ $\Sigma M_z = 0$ (6,7,8)

These equations are the main equation for illustration of influence of the muscle forces on the cervical structures.
ICR [COR] and „balance equations „ are the most important parameters for evaluation quality of cervical movement models because, if the vectors illustrating tension and compressive forces will be wrong, there would be wrong motion of vertebra around ICR and whole model will be too unrealistic. For creation of good model of the cervical spine, it is necessary repeatedly investigate disturbation of all forces including position of ICR.
This approach [ICR, balance equations] to validation of models has been used to good effect in the most detailed model of the cervical spine developed to date. A lot of models generate normal ICRs at lower cervical segments but errors obtain at upper cervical segments. This calls for a refinement of the forces exerted across upper cervical segments, in terms of the magnitude or direction of the vectors of the upper cervical muscles or the details of upper cervical vertebral geometry. Clinically more relevant is the potential application of ICR in cervical diagnosis. To date, it has been firmly established that abnormal ICR correlate with neck pain. However, the abnormal ICRs do not necessarily lie at the symptomatic segment. Therefore, they do not reffect damage to that segment. Rather, abnormal ICRs seem to reflect secondary effects of pain. Abnormal position of ICR is due to muscle spasm, impairment of ligament tension, or altered compression stiffness of the disc.

Conclusion

Position of ICR is fully dependent on physiological balance between tension, shear and compressive forces as well as forces moment. Literature mention (Amevo, Aprill, Bogduk 1992) that change of the ICR position, e.g. in dorsocaudal direction, is the important sign of dorzal muscle tone decrese. This changing of muscle tone leads to incidence of eccentricall load in vertebral segments and also change of position of ICR. Changed posiotion of ICR leads to restriction of range of motion in sagital and rotary direction. The truth is, that identification of muscle tone changing (especially in deep located cervical muscles) is relatively inpracticable, electromyografic registration is impossible in this cervical region. Influence of muscles on the shape of cervical region is evident according changing of kinematics of single vertebrae, another say: Although the traction of muscle tone isn´t visible his effect is perceptible.

Aknowledgement

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