ORIGINAL PAPER

Former and present aspects in neuro-skull architecture

M. C. NICULESCU, V. NICULESCU, ADELINA JIANU, M. ZĂVOLAN, A. MOTOC

Department of Anatomy, "Victor Babeş" University of Medicine and Pharmacy, Timişoara

Abstract

The classical authors considered the functional resistance of the neuro-skull to consist of arcs at the arch level, rafters at the base and pillars at the joint of the arcs and rafters, those last also connecting the neuro-skull framework and that of the viscero-skull. The new outlooks replace the term pillar with that of resistance node and assemble the arcs and rafters within common structures, named resistance belts. The belts are: one in transversal, three sagittal, two in frontal plane and two oblique positions. At the intersection of the belts, the resistance nodes are placed.

***Keywords*:** arcs, rafters, pillars, resistance belts, resistance nodes.

Background

Strengthening functional structures of the skull, parts of its architecture, awaked the interest to many researchers, among them the most representatives are Sicher, Felizet, Tandler, Dubecq, Testut, Benninghoff, Braus, Fr. Rainer and Gr. T. Popa, the last two belong to the Romanian School of Anatomy [1].

Lately, the study about the functional architecture of skull was resumed by V. Niculescu, M. Niculescu *et al.*, who elaborated new concepts through their studies.

Calvaria has a structural homogeneity until the cranial base is heterogenically composed by the alternation of compact and spongy bone layers, made by apertures, cavities, canals, sutures which all of them are increasing the resistance and elasticity of the skull, we do not miss also the epicranium aponevrosis and dura mater with its falx cerebri, tectorium cerebelli and falx cerebelli [2].

Neural and visceral craniums are binded by bone structures and also muscular bands represented by masticator muscles.

Classic, the functional resistance structures that offer strengthen to the neurocranium are: vault arches, rafters of the base, pillars at the meeting between arches and rafters. Pillars are binding the resistance structures of the neural and visceral cranium.

In the new outlook the neurocranium was compared with a postal parcel surrounded by bands or strengthening belts made by vault arches, and rafters of the cranial base which are continuing one with the other. The meeting of arches and rafters are giving in a new concept knots which are replacing the pillar concept.

The new approach adds a series of assignation referred to the resistance functional structures and new terms for certain structures, all integrated in the new concepts. In the following part we present in order: the resistance arches, the resistance rafters, the pillars or the resistance knots.

Resistance arches

They are situated at the vault or calvaria and grouped into sagittal, transversal and sutural arches.

Sagittal arches are medio-sagittal and two latero-sagittal, right and left. Each latero-sagittal arch is composed by a superior part with its concavity below, and inferior horizontal part.

The superior part is doubled by an accessory latero-sagittal arch situated under the main arch, deserves the name of arch, instead, the inferior horizontal part does not deserve the name of arch because is linear.

The last horizontal part, called by us lateral transverse arch, has two parts: external or lateral one which is passing through the zygomatic arch and a cranial or medial one, situated in the same plane, which goes through the cranial base, at the infratemporal crest level of the sphenoid.

The lateral transverse arch (Niculescu V *et al.*) is a new concept of the Nomina Anatomica. The latero-sagittal arch is losing its inferior part and transversal arches becomes four instead of two [3].

Transversal arches, described by Gr. T. Popa, are anterior and posterior. The new concept describes four transversal arches, two arches from classical literature and two lateral transversal arches, right and left.

Sutural arches are two anterior corresponding to the coronal suture and posterior corresponding to the lambdoid suture.

The middle part of the medio-sagittal arch corresponding to the sagittal suture is a sutural portion, thus the medio-sagittal arch is partial a sutural arch.

The medio-sagittal arch called fronto-occipital arch starts from the frontal pillar, goes along the frontal crest

and the sagittal suture (the sutural part of the medio-sagittal arch) through the occipital crest and ends to the occipital pillar, represented by the occipital protuberance.

Latero-sagittal arches, right and left, starts each one from the zygomatic pillar, follows the temporal line of the frontal, the interior temporal line of the parietal and arrives at the mastoid pillar, from where it turns in front through the longitudinal root of the zygomatic process and then the zygomatic arch, to finally join the zygomatic pillar. Some authors are describing an accessory latero-sagittal arch too, below the last one.

Transversal arches, anterior and posterior, described by Gr. T. Popa are making a common structure between anterior and posterior extremities of sagittal arches. The anterior transverse arch is corresponding to the transversal crest of the frontal, fronto-facial crest of Poirier, between zygomatic pillars and passes through the frontal pillar.

The posterior transverse arch passes along the superior nuchal lines of the occipital between mastoid pillars and through the occipital pillar.

Sutural arches are two: anterior – corresponding to the coronal suture between the zygomatic pillar and posterior – corresponding to the lambdoid suture, between mastoid pillars.

Resistance arches of the vault are consolidated by sutures which become real resistance arches, thanks to modality of gearing to. Most of those sutures are serrated. Thus, the greater sphenoid wing and the temporal squama with their borders, cut to the internal compact layer damage, are impeding the lateral shifting of the frontal and parietal.

Resistance rafters

There are functional resistance structures of cranial base: the fronto-ethmoidal rafter, uneven and sagittal, spheno-frontal rafters (right and left), each of them with a principal and accessory part, obliquely laterally and anterior oriented, temporal rafters (right and left), obliquely, posterior and laterally oriented and the occipital rafter, described by some authors as a unique rafter, and by others as a paired rafter.

Next, we discuss about occipital rafter which deserves the name just for its posterior part. Classic, the occipital rafter starts from the sphenoidal body by two arms which represent the anterior part of the same rafter. Next to the foramen magnum, each arm is divided into three: a medial branch which turns around the foramen magnum to form a resistance circle with the opposite side; a middle branch for the condyle pillar; and a lateral branch for the resistance mastoid knot. The posterior uneven, single part of the occipital rafter projects below from the resistance circle of the foramen magnum to the resistance occipital knot (the occipital protuberance) [4].

Because the anterior part is double, and the posterior part is single, explain why certain authors describe the occipital rafter as a paired rafter and others as a unique one.

Our opinion is that the anterior part of the occipital rafter and the circle around the foramen magnum become parts of the resistance structures of the cranial base, next to the sphenoidal body. By that, only the posterior part of the classical occipital rafter remains simply occipital rafter. According to that description, the lateral branch of the classical occipital rafters becomes occipito-mastoid rafter.

The fronto-ethmoidal or frontal rafter is situated between frontal pillar and sphenoidal body, along the crista galli, by a sagittal direction.

The occipital rafter, sagittal oriented, like the last one, starts from the sphenoid body through two arms parallels, very closed, which follow the occipital basilar process borders. At the foramen magnum each arm divides in three: lateral branch directs to mastoidian pillar, the middle branch is for the condylar pillar, and the medial branch turns around the foramen magnum for meeting the opposite side, and these branches form a great resistance circle what surrounds the foramen magnum. The unique occipital rafter starts from the posterior point of the foramen magnum and goes along the internal occipital crest until the occipital pillar. Thus the occipital rafter is double before the foramen magnum and unique behind it.

The spheno-frontal rafter, right and left, is situated between sphenoidal body and zygomatic pillar along the lesser sphenoidal wing and spheno-frontal suture. That rafter is doubled by an accessory rafter, which follows the free border of the lesser sphenoidal wing between the sphenoidal body and the zygomatic pillar with a common lateral part to the spheno-frontal rafter.

The temporal right and left rafter are obliquely, posterior and laterally oriented, along the temporal rock axel, between the sphenoidal body and the mastoid pillar.

The one side temporal rafter direction continues the spheno-frontal rafter direction of the opposite side, to form an “X” common rafter, with crossing arms at the sphenoidal body level.

The most resistant structure of the cranial base was considered to be at first the sphenoidal body, and during the time the sphenoidal body and the basilar process of the occipital, then recently, only the basilar process of the occipital, which is rarely fractured. The fractures appear just between the resistances functional structures. It’s must to say that the fracture lines at the calvarias level, situated between the resistance arches, affect the internal compact layer first [5].

Pillars or resistance knots

Historically looking, the pillar concept marks the union place between the vault arches and rafters of the cranial base and also the meeting of the functional resistance structures of the visceral and neural cranium.

We are proposing a new concept of resistance knot which is most expressive and morphologically real. Resistance knots are: principals and accessories.

Principal resistance knots are: the frontal, occipital and two paired knots: zygomatic and mastoid (right and left for both of them).

Accessory resistance knots or pillars are: the pterygoid condylar pillars (right and left for both of them). We are proposing other two resistance knots: bregmatic and lambdatic.

The bregmatic knot is situated at the meeting between the medio-sagittal arch and the anterior sutural arch.

The lambdatic knot corresponds to the crossing level of the medio-sagittal arch and posterior sutural arch.

There were described six principal pillars and four accessory pillars.

The frontal pillar or knot is situated at the glabella and nasal part of the frontal, at the meeting of medio-sagittal arch (which starts here) anterior transversal arch (which is crossing it), fronto-ethmoidal rafter (which lies between the frontal pillar and the sphenoidal body).

The occipital pillar or knot corresponds to the occipital protuberance and represents the end of the medio-sagittal arch and the occipital rafter, crossed by the posterior transverse arch.

The zygomatic pillar or knot, right and left, are corresponding to the zygomatic bones. The anterior transvers arch layes between the two zygomatic pillars, the anterior sutural arch sends its extremities towards them and the latero-sagittal arches start and end to them. The spheno-frontal and accessory rafters are lying between them and the sphenoidal body.

The mastoid pillar or knot, right and left, consists of the mastoid part of temporal bone. Temporal rafters, lateral branches of the occipital rafters and extremities of posterior sutural arches are all coming to the mastoid pillar and also latero-sagittal arches are passing through them. The posterior transverse arch is lying between the two mastoid pillars.

Accessory pillars or knots are: two anterior or pterygoidians and two posterior or condylars.

The pterygoid pillars, right and left, are made by the sphenoidal pterygoid processes and the perpendicular plates of palatine bones. These pillars are bonded to the sphenoidal body.

The condylar pillars, right and left, are made by the occipital condyles, attached to the resistance circle around the occipital foramen magnum.

The pillars, situated at the joint of the vault arches and the base rafters, assemble these resistance structures, and connect the neuro- and viscero-cranial functional architecture, which take over the mastication forces and through these pillars transmit to the vault arches and base rafters. Certain authors say that the most mastication forces direct to the occipital basilar process.

The frontal pillar, two zygomatic pillars, two pterygoid accessory pillars and two mastoid pillars, they all have a great role only transmitting mastication forces at the functional resistance structures of visceral and neural cranium.

Mastoid pillars, occipital pillar and also condylar accessory pillars have a great role in head movements.

Condylar pillars transmit the head weight to the vertebral column, through the atlanto-occipital joint.

After Fr. Rainer, with all functional structures (arches, rafters and pillars), cranial cavity would remain slight without the double layers: one external – epicranium apponevrosis, a fibrous layer which covers the vault and one internal – dura mater, which tapestrieds the cranial cavity, sticked to the periostum.

Dura mater disunites from the periostum just at the foramen magnum; dura mater adherence is greater at the base, in special at the bone prominent and vascular apertures, filling in these.

The extensions of dura mater, falx cerebri, falx cerebelli and the tectorium cerebelli and of pituitary gland cross the cranial cavity staying stacked to its walls and resist to the forces which try to split the neurocranial components.

The mastication forces are transmitted to the neuro-skull resistance structures, through the classical structures, but also through a vertical median pillar, represented by the bony part of the nasal septum made by vomer bone and the perpendicular ethmoidal plate, which takes over the forces from the palatine vault and directs them to the sphenoidal body, the resistance centre of neuro-cranial functional architecture.

Neural and visceral cranium is banded by bone structures and also muscular bands, by masticatory muscles like this: the forces are transmitted from the inferior mandibular arch and Gonion, through the maseter muscles to the latero-sagittal arch, and through the medial pterygoid muscle to the pterygoid resistance knot. This knot takes over the forces from the mandibular condyle through the lateral pterygoid muscle. The forces from the mandibular coronoid process go to the latero-sagittal arch through the temporal muscle. The pterygoid knot and the latero-sagittal arch belong to the neurocranial architecture.

Resistance centre of the cranial base

It is represented by a functional complex made by the sphenoidal body, the basilar process of the occipital and the resistance circle around the foramen magnum.

Through that functional complex passing almost all resistance belts of the neurocranium.

Resistance belts

It is a new concept which defines structures incorporating vault arches and rafters to the cranial base [6].

Resistance belts are: one transversal belt and more belts disposed into a sagittal, frontal and oblique plane.

Transversal resistance belt

The transversal, horizontal belt is situated at the meeting of the calvarias and the cranial base. It is made: anteriorly by an anterior transversal arch between zygomatic resistance knots, which is crossing the median line at the frontal resistance knot level, laterally at right and left side, by the lateral transversal arch (the inferior horizontal part of the latero-sagittal arch) with its two parts, medial and lateral, both between the two zygomatic resistance knots (anterior) and mastoid knots (posterior) and posteriorly by the posterior transversal arch which binds the mastoid

resistance knots by crossing the occipital resistance knot.

Sagittal resistance belts

There are three in sagittal plane: one median and two laterals. The medio-sagittal resistance belt starts from the frontal resistance knot, goes along the medio-sagittal arch (its middle part between the bregmatic resistance knot (anterior) and lambdatic knot (posterior), which is sutural), arrives at the occipital resistance knot and than goes anteriorly through the occipital rafter, along the resistance centre of the cranial belt represented by the resistance circle around the foramen magnum and than, the basilar process of the occipital, the sphenoidal body and at last through the fronto-ethmoidal rafter arrives at the initial frontal knot [7].

The latero-sagittal *resistance belt*, *right* and *left*, starts from the zygomatic knot, along the latero-sagittal arch and the accessory latero-sagittal arch, arrives at the mastoid knot and through the lateral transversal arch (the common part with the lateral part of the transversal belt) it turns at the same zygomatic knot.

Frontal resistance belts

There are two in frontal plane: anterior and posterior.

The anterior frontal belt has a superior part represented by the anterior sutural arch between the zygomatic right and left knot, through the bregmatic knot and an inferior part made by the two spheno-frontal rafters (right and left) each of them between the zygomatic knot and sphenoidal body. The posterior belt is composed by a superior part made by the posterior sutural arch between the two mastoid knots, right and left, passing through the lambdatic knot and an inferior part made by the occipital mastoid rafters, right and left, each of them placed between the mastoid knot and the foramen magnum resistance circle.

Oblique resistance belts

Oblique belts, right and left, have each of them five parts from which only two are proper, the temporal and accessory spheno-frontal rafters and the third is borrowed from other belts [8].

The first proper part, the temporal rafter, starts from the sphenoidal body and goes to the mastoid knot.

The second part is made by the half same side of the posterior sutural arch, between the mastoid and lambdatic knots.

The third common part of both oblique belts is situated on the median line, made by the middle sutural part of the medio-sagittal arch between the lambdatic and bregmatic knots.

The fourth and fifth parts are placed on the opposite side of the first and second parts and the third part is situated on the median line.

The fourth part is made by half of the anterior sutural arch between the bregmatic and zygomatic opposite knots.

The fifth and last part is the accessory spheno-frontal rafter, between the zygomatic knot and sphenoidal body, marking part of the resistance centre of cranial base.

The two oblique belts mark together a crossing "X' resistance structure at the sphenoidal body level, which was called "X rafter".

References

[1] BENNINGHOFF A., GOERTTLER K., *Lehrbuch der Anatomie des Menschen*, 11 Auflage, Urban & Schwarzenberg, Berlin, 1975, 467–508.

[2] GRAY H., *Gray's Anatomy*, Churchill Livingstone, Edinburgh–London–Melbourne–New York, 1980, 337–392.

[3] NICULESCU V., NICULESCU M., MATUSZ P., *Proposition de changement de la Nomina Anatomica concernant les structures de résistance du neurocrâne*, Abstracts Book, XI^{e} Symposium International des Sciences Morphologiques, Barcelona, 19–23 Juillet 1993, 78.

[4] NICULESCU M., NICULESCU V., GONTEAN A., *The computed imagery of functional resistance structures of the neurocranium*, Abstracts Book, The 11th European Anatomical Congress, Timişoara, September 10th–13th, 1998, 172.

[5] NICULESCU M., NICULESCU V., MOTOC A., *Neurocranial functional architecture seen in the light of new concepts*, Archives of the Balkan Medical Union, Oradea, 2004, 119–123.

[6] NICULESCU V., NICULESCU M., *O nouă interpretare a arhitecturii neurocraniului*, Volum de rezumate, Simpozion de Anatomie, Craiova, 1992, 97.

[7] NICULESCU M., NICULESCU V., MATUSZ P. *et al.*, *Arhitectura funcțională a neurocraniului*, Timişoara Medicală, 2002, 52(1):35–43.

[8] NICULESCU V., NICULESCU M., MUNTEAN M., *Structurile funcționale de rezistență ale neurocraniului*, Cercetări experimentale medico-chirurgicale, 1997, anul IV, 1:11–18.

Corresponding author

Marius Corneliu Niculescu, Assistant Professor, MD, PhD, Department of Anatomy and Embryology, "Victor Babeş" University of Medicine and Pharmacy, 2 Eftimie Murgu Square, 300 041 Timişoara, Romania; Phone / Fax +40256–220 479, E-mail: niculescu.virgil@gmail.com

Received: November 18th, 2005

Accepted: October 15th, 2006