Chapter 4

# The Role of Skull Mechanics in Mechanism of Cerebral Circulation

Yuri Moskalenko, Gustav Weinstein, Tamara Kravchenko, Peter Halvorson, Natalia Ryabchikova and Julia Andreeva

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/50887

## 1. Introduction

Skull as a complicated mechanical construction, consists from 28 different bones, connected by sutures of different structural kinds - from smooth (face cranium) to teeth-like hardness (brain cranium). Basically, skull can be selected as face skull and brain skull. The last is composed from 8 bones with complicated connections between them, and namely brain skull will be described in the chapter presented.

Structure of "brain skull" (or simply – skull) is the most complicated, it is changeable and individual depending on age, sex and race. The most pronounced mechanical changes of skull properties are observed in babies and juniors which are connected with brain growing. Later, structural changes of the skull are concerned with structure of bone sutures, which tissues loss their elasticity with age. Volume of internal cavity of the skull of adult persons is balanced closely with volume of intracranial media so precisely, that the internal relief of skull bones reflects the structure of the brain and its vascular system. This confirms the idea, that skull plays protector function for brain, and it is well known.

However, this precisely high balance of internal skull volume and intracranial media volumes, due to natural variations of brain skull configuration, might be a reason of some diminishing of the skull internal volume to compare with intracranial media. Variations of the skull configuration, which actually diminish intracranial cavity, may be the most pronounced at middle ageing, when capabilities of the skull internal volume for adaptation also diminish due to decrease of the possibility of change of suture structure. Result of this may be some compressing of tissues, filled cranial cavity, first of all, liquid media blood and cerebrospinal fluid (CSF), which are responsible for circulatory-metabolic supply of brain functioning. As a consequence, some neurological symptoms may appear indicating that volume of intracranial cavity is really smaller, than optimal volume of intracranial media.

The most reasonable way to treat of such neurological disturbances is to increase of internal skull volume. That is why the first method to treat such neurological disorders was neurosurgical skull trepanation which was practiced for numerous Centuries. It is confirmed by archeological findings of human skulls with trepanation performed on living persons. The long history of skull trepanation since 2000 B.C. reviewed in many publications [1, 2, 3].

This method have been used also at middle centuries, which is confirmed by one of art master pieces, named "Treatment of foolishness" - painting of Bosch (1475), presented process of trepanation to remove "the stone of foolishness" from the skull. All these examples show, that the role of trepanation, as method of treatment of some neurological pathology, was reasoned to increase of intracranial volume, and this had been understood Centuries ago.

It is well known, that one the most important physiological function of the skull is protecting brain from external mechanical disturbances. However, some negative role of close correspondences of brain and cranial cavity volumes may be the change of balance between these volumes in different living situation, and it becomes significant, when comparative increase of intracranial volume of media is taking place. Result of this, first of all, may be decrease of activity of Cerebro-Spinal Fluid (CSF) which compresses brain blood vessels and, in some cases, brain tissue, too. All these could evoke functional insufficiencies, as headache and some neurological symptoms. The high significance of balance between intracranial cavity volume and the media filled it, is critically important in connecting with fact, that brain at all situations needs intensive and stabile blood supply, because brain metabolism is founded on aerobic principle. For aging population, the limitation of intracranial volume becomes more important and could be reason of pronounced decrease of cerebral blood flow (CBF) resulted in dementia.

Skull trepanation up to the present time is actively using when volume of intracranial media is increased by some reasons (closed brain injury, brain tumor), indicator of which is the increase of intracranial pressure.

It is necessary to mention, that so strong restrictions of intracranial cavity volume limit also possibilities for ranges of adaptation to different living situations and, diminish living capabilities. Therefore, it is reasonable to predict, that in process of evolution of mammals some protecting accommodations of intracranial volume, which are not diminish its protector function have been developed. The basis of these mechanisms should be founded on the possibility of some increase of intracranial volume compensation of change of volume media, filled the skull. Investigations at this direction become appear from the beginning of XX Century.

Primary, it was have shown, that some volume reserves is follows from the possibility of free replacements of CSF between cranial and spinal cavities and spinal cavity could accept some volume of cranial CSF due to elasticity of vertebral lumbal sack [4, 5, 6, 7]. In the middle of XX Century one more possibility, based on feature of the skull, have been discovered. It has been shown by palpation, that skull represents a complicated mechanical moveable system. This skull feature found practical application in osteopathic medicine and is used for diagnostic purposes and evaluation of results of osteopathic treatment up to the present time [8, 9]. These observations have shown, that for the skull bones the slow periodics are of special.

The next important finding have been made during observation of neurosurgical patients, which have been shown, that skull as structural unity is characterized by the special property – Cranial Compliance, which was studied by injection into the skull of neurosurgical patients of artificial (mock) CSF and dependence "Pressure/Volume" for skull has been established [10].

The next step in the evaluation of the role of skull in mechanism of cerebral circulation was made not physiologists or physicians, but mathematicians, who in process of mathematical modeling of the cerebra-circulatory system inside closed skull, have established, that only if skull will accept some additional volume of blood during systolic increase of central arterial pressure, cerebrovascular system in coupling with CSF system could function [11]. This study permits to predict, that brain circulatory support system include as active element skull bio-mechanics.

Thus, this chapter will to describe the role of peculiarities of skull biomechanics as an active component of complicate physiological mechanisms, responsible for brain physiological mechanism, responsible for circulatory-metabolic supply of brain functioning.

## 2. The role of skull pulse expanding in mechanism of circulatory supply of brain function

The system of cerebral metabolic supply is dependent on the interaction of a number of elements some of them are determined by the skull properties. One of the most significant in this direction is clarifying the role of CSF movement to this system inside cranium and significance at this process of the bio-mechanical properties of the skull. Critical position in the role of the skull in support of circulatory-metabolic supply of brain functioning determined by the ability of the skull to accept an additional volume of blood during the phase of systolic increase in central arterial pressure.

Indeed, arterial blood pressure consists of two components. One is the steady state of flow through the brain, determined by the basal tone of the brain blood vessels. The second occurs with each heart- beat, which initiated by arterial pressure increases and so drives the pulse volume into the cranium. It is this component that is influenced by the level of cranial compliance, which in turn depends on the volume flexibility of the skull.

This increase in arterial pressure is short – about 0.1s. This means that the cranium needs to accommodate the increase in systolic blood volume very quickly in order to use it to drive cerebral circulation. This possibility, predicted by mathematical simulation of the cerebrovascular system [12], should be follow from biomechanical properties of the skull as united bio-mechanical system.

That is important statements, because from the beginning of XIX Century up to the second part of XX Century the most of investigators belong to conception, named "Monroe-Kelly" doctrine, which on the base of majority of anatomical investigations, declare, that skull is fully rigid cavity. However, when this statement has been included to the model, it didn't function. However, when some possibility for pulse change of intracranial volume has been included to the model, it starts to work. It was the first indicator, which shows the importance of pulse change of internal skull cavity. Some years later the presence of pulse dependence on "Pressure-Volume" relation for the skull have been shown by invasive technique [13].

Follow this data, the skull could be accepted as a nearly rigid container with limited capabilities to accommodate internal volume changes in response to increases in arterial pressure. However, because investigations of Marmarou have been provided when comparative slow changes of intracranial pressure as respond to infusion to the skull artificial CSF, when volume compensation is provided also by CSF outflow to some spaces, connected with the skull by comparatively narrow gapes spinal cord, volumes, determined by arachnoid membranes of cranial nerves.

Therefore, it was important to evaluate skull itself volume reserves, in other words dynamic skull volume capabilities. Really, it is important to have the possibility to accept by the skull an extra volume of blood following the systolic increase in arterial pressure, which is in addition to the steady state level of the brain blood flow. The most rapid component of change of arterial blood pressure is evoked in systolic phase duration about 0.1s. During this time any replacements of CSF inside skull couldn't be provided [14].

There are skull expansions due to, perhaps, articular comparative mobility of skull bone in sutures of invisible value; investigations have shown, that these changes of articular bone position are less then 0.5 geometric degree [15], and this, as it follows from calculation, could increase internal volume of skull up to 3-6 ml.

Calculation of additional – systolic blood volume, which should accept cranial cavity may be provided, taking into account, than brain "portion" of stroke volume is about 10 ml. That is means, that steady stroke volume is 5 -7 ml and pulse component is 5-3 ml (Fig.1). Namely this the last volume of blood should accepted by skull during systolic phase of cardiac cycle. Comparatively to total volume of cranial cavity this volume is very small. Averaged size human brain is about 1200 ml. This value should be closely to internal volume of the skull. This means, that expand of internal volume of skull about 0.3% of initial volume to accept systolic portion of blood, could give the additional blood, which is necessary for normal functioning of circulatory –metabolic brain supply. Taking into account, that heart rate is usually 60-70 beats per minute, this additional blood volume will be about pulse evaluation due to of skull expanding could be about 110-130 ml per minute. It is known, that normal brain blood made using some relatively simple calculations. As well it was established in the middle of the last Century, brain takes 50-65ml of blood volume flows through 100g of brain mass in 1 minute [16].

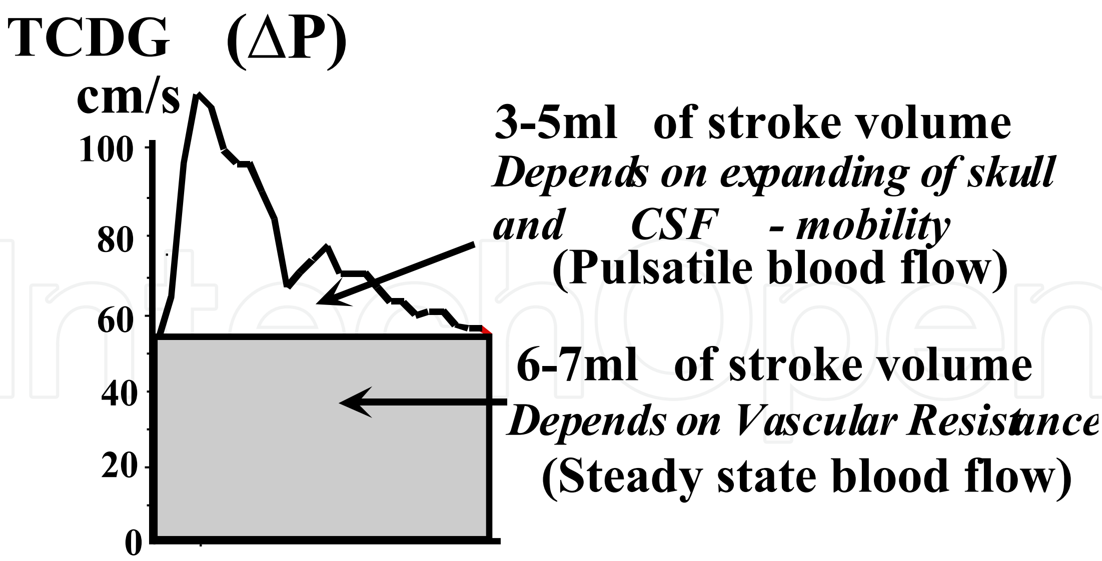



**Figure 1.** Distribution of steady state and fluctuating of stroke volume at normal physiological conditions.

This means, that through an average sized human brain (1200g) – about 600ml flows every minute and 110-130 ml of blood is about 20% of total brain blood supply. In case of skull is completely rigid, this additional stroke volume will by out from cerebral circulation, because additional blood couldn't inflow to the skull due to contra-pressure, determined by unchangeable volume of cranial cavity. Therefore, brain blood flow may be diminished up to 15-20%. Direct evidence of the presence of pulse skull expanding have been received by coupling of Rheoencephalogram (REG) – method, based on recording of electrical impedance between electrodes, placed in fronto-mastoid position to human head and transcranial dopplerogram (TCD) of basement of the Middle Cerebral artery [17]. REG reflect changes of intracranial blood/CSF volume, because electrical resistance of these media are significantly less to compare with brain tissue and pulse blood volume fluctuations inside skull if they are have taken place, will change common electrical resistance between electrodes [14]. TCD reflect pulse changes of linear velocity inside intracranial large arteries [18], which by Poiseuille low are proportional to volume fluctuations of these arteries, surrounded by CSF. Volume fluctuations of large brain arteries could be compensated by skull expanding due to transmitting of arterial to surrounding CSF pressure, which is a real source of forces for brain expanding.

Computed aid analysis of simultaneously recorded REG and TCD pulse give the possibility to establish "Pressure-Volume" dependence for the skull for systolic phase of pulse cycle [17], which show, that this dependence is nearly to linear and in normalized coordinates equal to line with angle to horizontal coordinate 30-40$^{o}$(Fig.2a) Linearity at the most cases of this dependence indicate, that pulse changes of intracranial pressure and volume are linear, which is permits to conclude, that SCF replacements inside skull during systolic part of cardiac cycle practically absent. Therefore, the fact of the presence of systolic skull pulse expansion has taken place and it is one of element of mechanism, which is responsible for circulatory-metabolic support of brain functioning and is possible quantitative to express as value of Tang. of angle of "Pressure-Volume" dependence in normalized coordinates. This dependence corresponds also to meaning "Cranial Compliance", applied to systolic phase of cardiac cycle, or in other words, "Dynamic Cranial Compliance" (DCC). Direct evidence of the role of small increasing of intracranial volume to DCC have been received by observation on neurosurgical patients just before and after trepanation, provided for the next neurosurgery [19]. These investigation have shown, that small 6-10cm$^2$ "window" in skull bone with saved brain cover membrane, when real intracranial volume increase to a few (3-6 ml) due to deformation of brain cover membrane, could change significantly DCC (Fig.3). The significance of this mechanism was confirmed during many years experience in skull trepanation, which is used for increase of intracranial volume up to the present time.

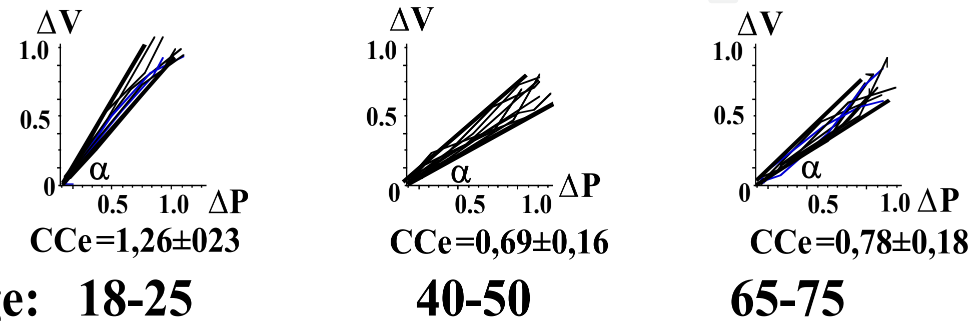



**Figure 2.** Averaged changes of DCC for different age groups, showing the decline in CCe in the middle-age group.

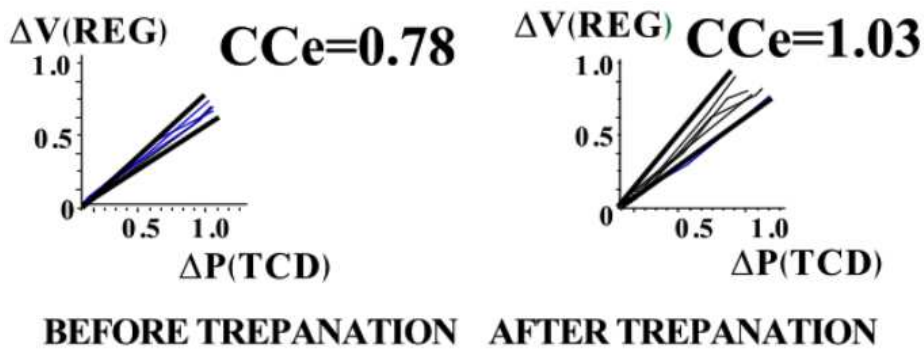



**Figure 3.** Averaged DCC values before and after trepanation. Changes in the biomechanical elasticity of the skull allow the cranium to accept additional blood with each pulse stroke.

All above data permits to conclude, that without property of rapid expanding of the skull when DCC =0, brain blood flow will decrease with the same indices of arterial and venous central pressure to significant value – up to 15-20%., which is significant for brain functioning. The known data shows, that even some less significant decrease of DCC may in some cases reflect to brain activity. This suggestion is confirmed by observations, which shows, that DCC gradually decrease up to age 40-50 and, then increase again-Fig. 2b,c [20]. That abnormal decrease of angle of normalized curve widely vary for different persons and its pronounced values are correlate with some neurological symptoms (headache, decreased working capabilities). It is important to mention, that an increase of DCC after 55-60 Years (Fig.2c) is not connected with the skull properties. It is determining by aging decrease of brain mass, which have been shown by MRI investigations [22]. Investigations, provided with aging persons, after 65-70 by comparing results of blood flow measurements, and DCC measurements and determination level of dementia level by psychophysiological computerized method "Prognosis", show (Fig. 4), that level of decrease of cognitive brain function and DCC are proportional but not closely correlate with values of level of brain blood that even small [17]. It is possible to conclude, that biomechanical properties of the skull determine its expanding due to pulse increase of intracranial pressure permits to accept additional volume of blood during systolic increase of central arterial pressure, with play sometimes significant role in supporting circulatory-metabolic supply of brain functioning.

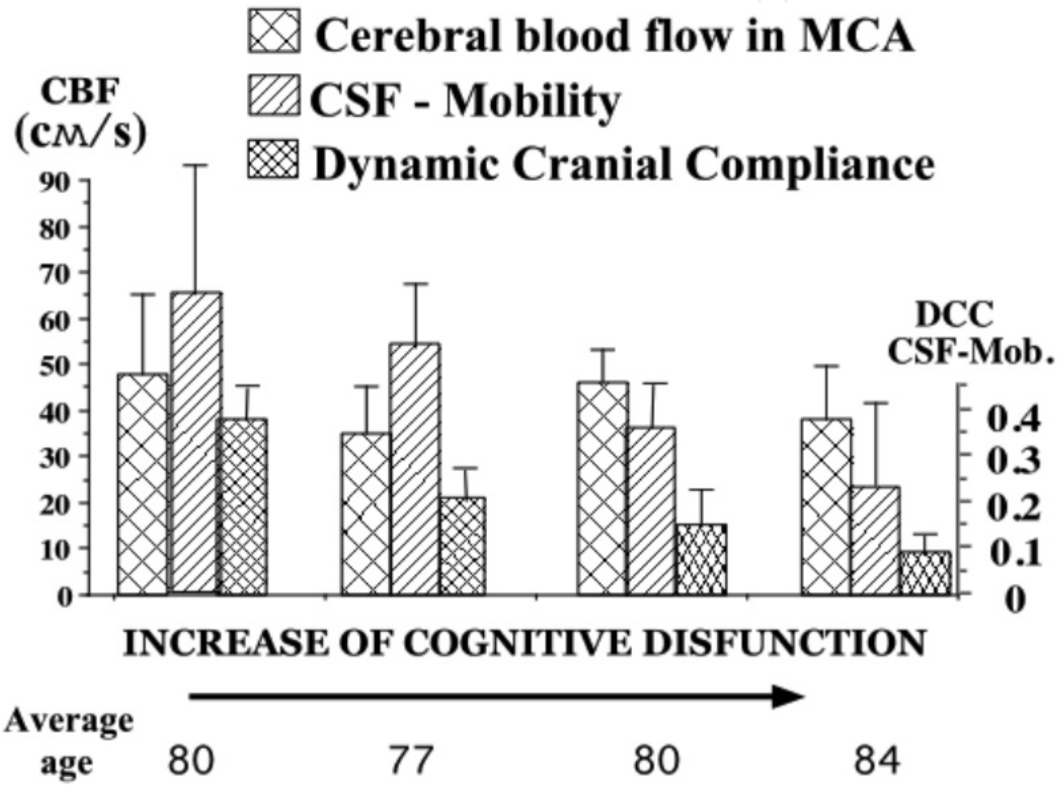



**Figure 4.** Dependence between value of DCC , Cerebral blood flow and CSF – mobility in aging human groups which are different by level of cognitive disfunction.

During diastolic part of cardiac cycle biomechanical properties of the skull also play role in supporting of cerebral blood circulation due to energy, collected during systolic increase of central arterial pressure. In this phase the role of CSF replacements is increase. In the beginning, they, in coupling with skull biomechanics, provide the distribution of pulse blood volume inside skull and, then, support pulse outflow of venous blood from the skull.

Thus, evaluation of DCC for the skull during each cardiac cycle is comprised of the initial interval as a rapid and nearly linear increase of arterial pulse pressure which lasts from 0.05 - 0.15s and perfectly reflects "Pressure-Volume." dependence, or DCC, which is determined by the equivalent elasticity of the cranium due to the biomechanical of the skull structure elements

It is important to emphasize that changes of the steady component of brain blood flow, determined by the perfusion pressure, are independent of the pulsatile component. The total brain blood supply is determined by the superposition of the steady state perfusion pressure (average level of arterial pressure) and the components of blood flow, which are in turn determined by the biomechanical properties of the skull and the mobility of cerebrospinal fluid within the skull.

## 3. Slow fluctuation of skull bone motion

Data, which could be predict, that there are slow fluctuations of skull bone have been known more than a Century. However, the first direct observation concerned skull bone motion has been received by palpation of human skull [23], and it developed the special branch of medicine, - "Osteopathy", founded by Dr. A. Still, and actively spreading in USA since the end of XIX Century. This phenomenon consists in periodical with changeable amplitude and frequency skull bone movements, in range 6-12 cycles per minute. The high similarity of these fluctuations with respiratory movements was a reason to name these fluctuations as "Primary Respiratory Mechanism", or PRM. Decades of studies of PRM by palpation permits to describe peculiarities and consequences of involving of particular skull bone to motion, which are regular at normal conditions and different for pathology. During this time a number of conceptions and hypotheses of physiological nature of PRM have been formulated to explain the origin of these phenomena [24, 9]. Some of them were unreal from positions of biophysics and physiology, but at the present time there are acceptable conceptions which could be regarded as working hypothesis. From classical osteopathic positions, initial point of PRM is liquids disturbances in cranium, which slightly move the brain and acts to brain membrane in region of occipital and basis bone. This initiates movements of other skull bones.

One of the explanations of peculiarities PRM was based on reciprocal tension of brain membranes, which is popular up to the present time. However, brain membranes have no contractive elements and this is a current problem to accept of this conception, but skull membranes could play the role of passive "modulator" [25], which determine connection between movements of particular skull bones. Summary, the acceptable the conception, founded on the fact, that for cerebrovascular system is typical periodical changes of vascular tone. The consequent of these changes is intracranial pressure fluctuations, which may be a real physical force for deformation of skull pattern as united biomechanical system. Combination of fluctuations of intracranial pressure with additional role of skull membranes as passive modulator looks at the present time the most acceptable conception for slow periodical skull bone motions.

The experimental study of the skull bone motions started with cadaver observation, where skull bone motions were initiated by saline injection into the skull. These investigations give negative results. Later it was understood, that postmortem changes in sutures make skull as a solid body. Then instrumental investigations of living skull bone motion in animal experiments have been fulfilled [26, 27]. Human observation under physiological conditions on the base of modern technology, have been appeared at the end of XX Century. Firstly, direct observations demonstrated, that skull represents a complicated mechanical moveable system. This suggestion is based on investigations, represented device with needles inserted through cover skull tissues in human head and fixed in skull bone. Invisible movements of upper end of the needle were registered by means of small mirror fixed there, which are deflected laser beam, focused to the mirror [28].

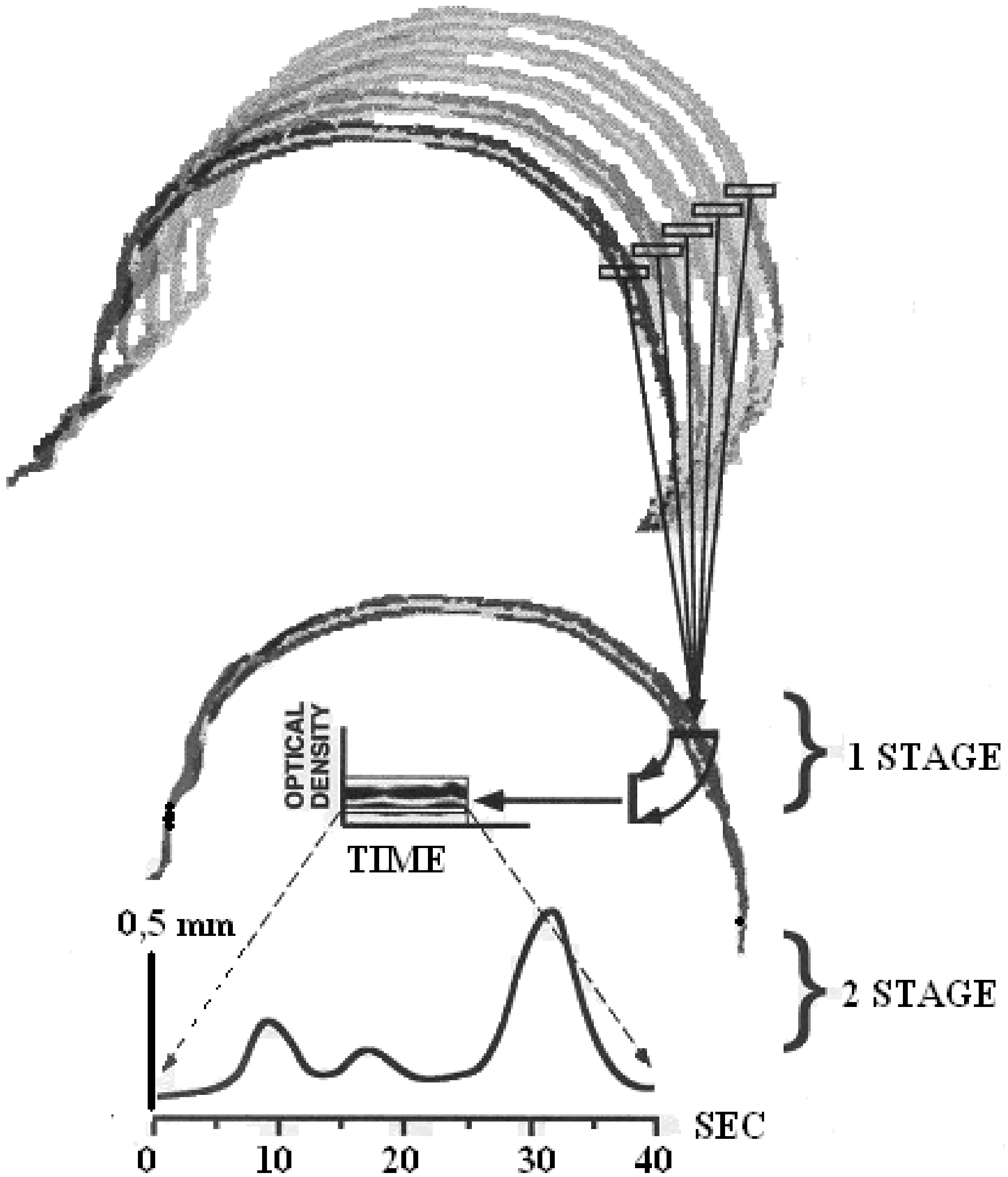
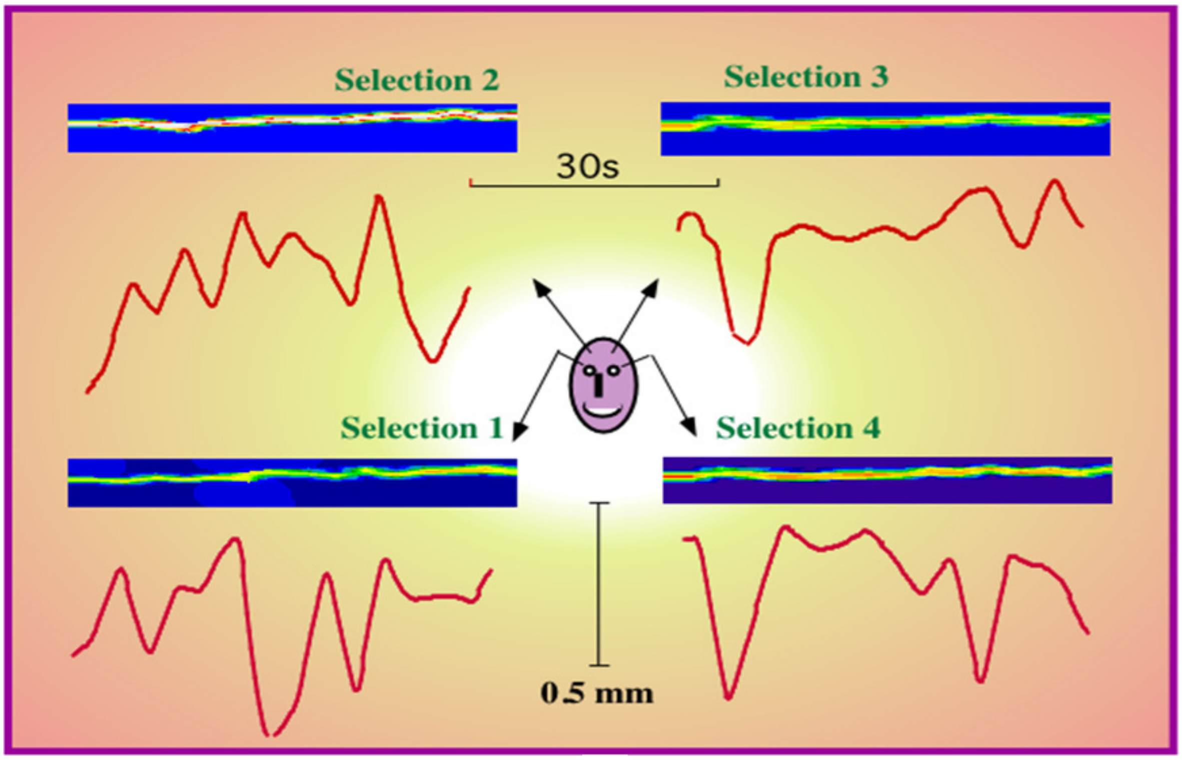



**Figure 5.** Principle of transforming individual regions of image series into the amplitude-time plot: (a) input of the image series into a computer and specification of the analyzed region; (b) collocation of images and creation of the intermediate image; and (c) transformation of the intermediate image into the amplitude-time plot.

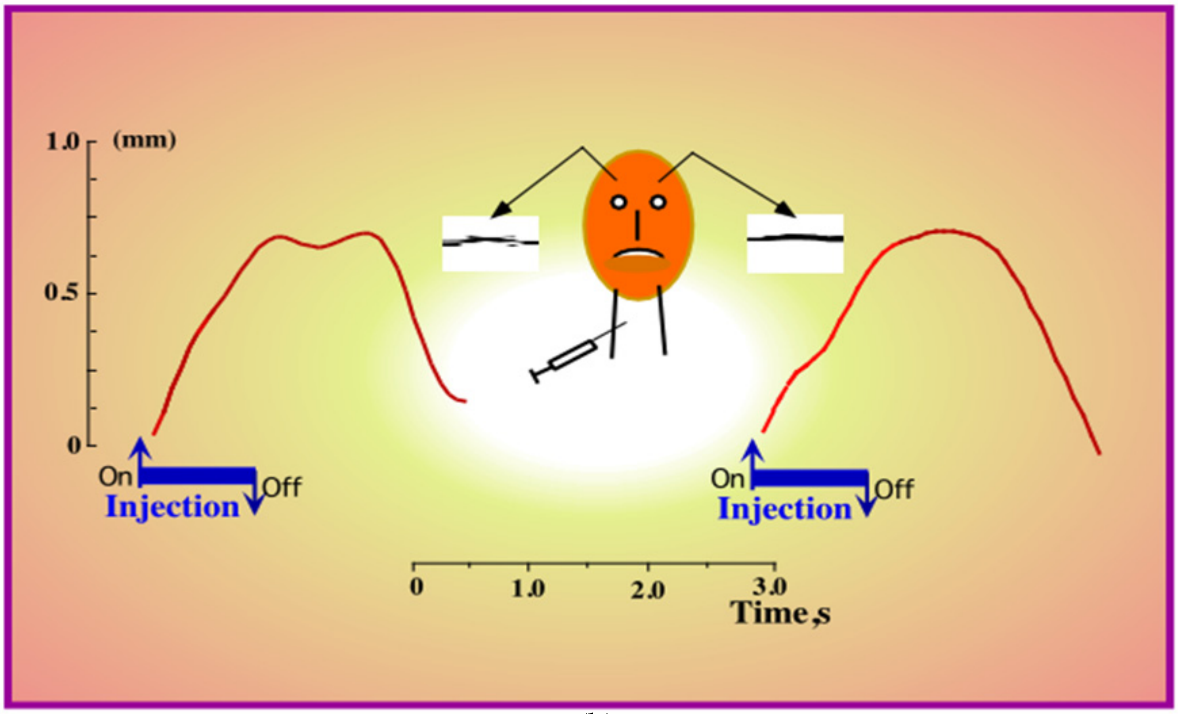
Approximately at the same time investigations, based on skull bone image analysis have been provided, using method of image computer analysis of serial MRI or X-Ray pictures – 30-45 single shots. Serial images of the skull were recorded by means of the Siemens-PolyStar angiographic system in 23 patients Principle of this method have been based on inserting to computer memory a number of equal fragments of skull bone image and, after an increase of their contrast superposition, small deviations of position of these fragments in united skull it is possibly as time dependent graph.(Fig. 5) These passive observation have shown, that, for normal physiological conditions, movements of skull fragment images, selected at of both MRI and X-Ray pictures, are periodical with irregular amplitude, fluctuating in ranges about 0.1-0.4 mm and frequency 5-12 cycles per minute (Fig.3 and Fig.6a).

However, skull bone motion should be recorded it in conditions, closely to real physiological experiment, when skull bone motions are evoked by some external procedure, which may be fixed by intensity of intervention and its duration. Such conditions could be provided by observation of skull bone movements during angiographic procedure, taking for analysis cases with absence of clear pathology in cerebrovascular tree. During angiographic procedure, when into the skull through Internal Carotid Artery 20 ml of X-Ray contrast solution during one sec. is injected with pressure significantly higher than arterial pressure. During such procedure, about 15-18 X-Ray shots were made, which permits to evaluate by image analysis of skull bone motions with amplitude up to 0.7-0.9 mm, at the end of the phase of increasing of intracranial volume evoked by injection of solution, and decrease after 2.5-3.0 sec, when X-Ray solution has passed through brain vascular tree, and intracranial volume normalized (Fig.6 ). Taking into account, that average volume of intracranial cavity is about 1200ml, its increase on peak of X-Ray solution injection will be 1.0-1.5%. Taking this value into account it is possibly to suggest, that slow skull bone articular periodic fluctuations, accepted firstly manually and later instrumentally, represent about 0.2 – 0.4% of intracranial volume. At the present time stages of these skull motions are described in details [29, 30]. The fact, that skull bone movements are reciprocal, have been confirmed by simultaneous recording of REG with "lobe-occipital"(REG1) and "bi-temporal"(REG2) position of electrodes. How it follows from Fig 6 Graph, with REG1-REG2 coordinates, that received two-dimensional pictures rather wide, which may be if comparative distance between electrodes is changed. That means, that every couple of electrodes moves reciprocally (Fig.7)

Thus, at the present time is confirmed, than slow skull bone motion are taking place and their motions are reciprocal. Similar slow fluctuations involve spinal cavity, too. In PRM phase of increasing volume of skull initiate to replacement of some volume of CSF to spinal cavity, which is possible, because volume-pressure changes are slow enough and CSF returned to the skull, when intracranial pressure decrease. The fact which confirmed this statement, have been received in experiments with animals [31] and demonstrated reciprocal slow volume changes in the skull and spinal cavity. Similar observations in humans have been received recently [21].




(a)




(b)

**Figure 6.** Fig.6 Cranial bone movements obtained by serial X-ray imaging (a) in a physiological state and (b) in the case of injection of radiopaque solution. The analyzed sections are shown in the center. (A) Consecutive image series showing changes in section shadows in the specified regions of cranial bones. (B) Changes in cranial bone positions in the specified sections shown in the amplitude-time plot. In all curves, the starting points of the time count are brought into coincidence and the time scale is the same.

Mechanism of slow skull bone fluctuations is complicated and its study needs to establish why intracranial pressure is fluctuating. A real force for this may be activity of contractive structure inside the skull. Between different tissues and structures, filled cranial cavity, only one is capable of active change its mechanical properties due to external source of energy – that is smooth muscles of brain blood vessels. Because two facts – the presence of slow intracranial fluctuations and the presence only one contractive element inside cranial cavity – blood vessels wall smooth musculature, are confirmed, it is necessary to find possible linkage between two these processes.

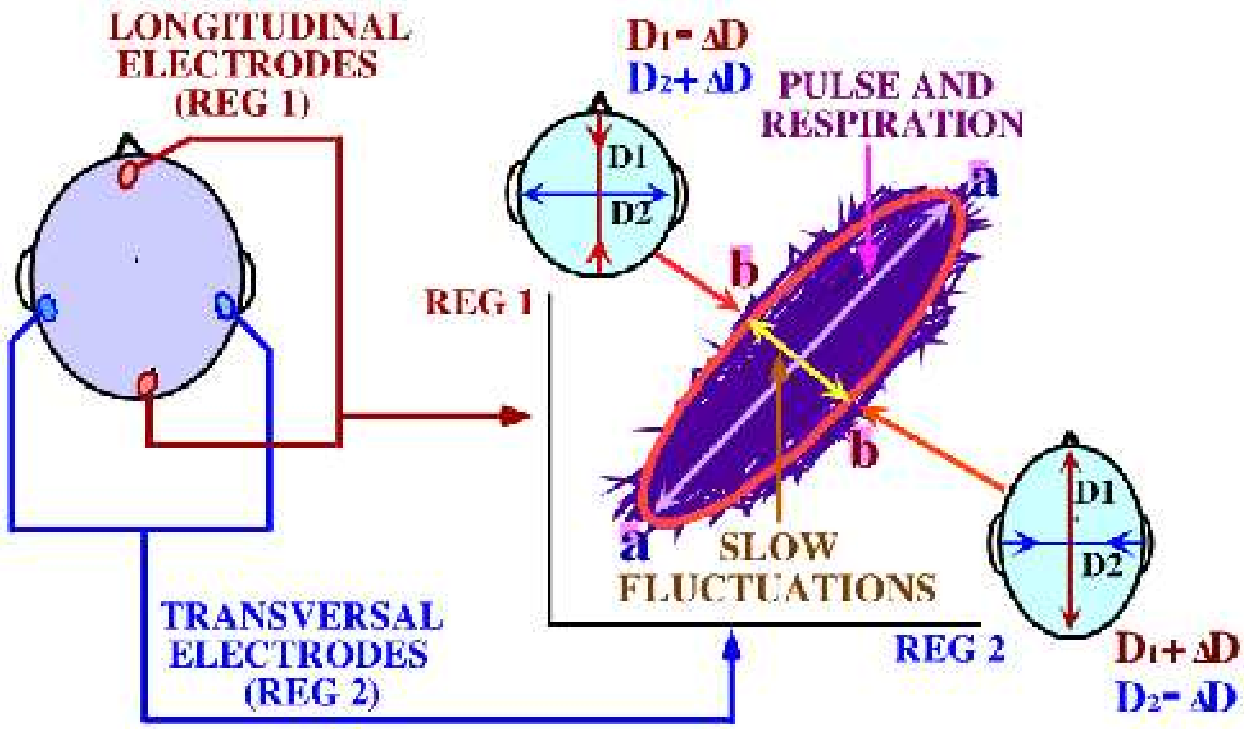



**Figure 7.** Diagram of the experiment which demonstrates reciprocal skull bone motions. The 2-min recordings of REG by "cross" electrode position are represented on two-demention diagram (dark violet). This gives an ellipse due to REG fluctuations superposition. The axes of the ellipse reflect pulse and respiratory waves (long axe a-a) and reciprocal skull bone movements (short axe b-b).

From the side of cerebrovascular system, the fact of its slow periodic contraction, which are reason for similar changes of intracranial pressure, have been established in the first part of XX Century [7]. Later, it was shown, that brain blood volume, recorded by REG method and oxygen availability in brain tissue periodically changes in low frequency band [32]. It was establish, that oxygen availability fluctuations are very local and reflect, perhaps, in nervous tissue metabolic processes, but REG fluctuations reflect comparative wide brain region and show changes of brain blood volume. With purpose to find the correlation between this and other slow fluctuations, which are special for intracranial media, simultaneous recordings of REG in both hemispheres, TCD and chest movements were provided at a group of healthy persons 20-30 Years. It has been shown, that spectrum of all these processes is characterized by three kind of fluctuations (Fig 8). The first, the most pronounced peak is heart pulsation.

REG changes during this peak are one more confirmation of the skull pulse expanding. The second peak is corresponds to respiratory movement of chest. One more peak – low frequency corresponds to similar fluctuations, recorded by TCD and corresponds to slow fluctuation of central arterial pressure – Traube-Hering-Mayer waves. Between this peak and peaks, reflect chest respiratory movements, only on REG spectrum it is possible to see some one – three peaks, which didn't correspond to any peaks of respiratory and TCD records and belong to REG only. This is permits to think, that these peaks represent the origin of slow intracranial volume fluctuations, which corresponds to slow cranial bone motions, named as PRM. Generally, mechanism of slow fluctuation it is possible to present as scheme shown on Fig.9, which demonstrate, that very small, below one geometric degree comparative fluctuations of skull bone position could significantly change internal volume of cranial cavity and source of forces for these changes are fluctuations of intracranial pressure of different origin, mainly due to vascular tone fluctuations.

The next and perhaps the last question in analyzed chain is the origin of slow cerebrovascular fluctuations, depended mainly on vascular tone. It is not yet definite answer to this question. However, it looks real prediction, that the fluctuations reflect control processes in the cerebrovascular system, because to vascular wall continuously acts different factors, everyone of which could change vascular tone. This is, first of all, different kinds of innervation – adrenergic, cholinergic, peptidergic and purinoergic nature [33], different mediators, nonorganic ions, autocoids, change of intravascular pressure and others [34]. Simultaneous, under normal living conditions, acting to vascular wall of numerous factors is the most real reason of appearing of some non-regular fluctuating process, which could be reason of intracranial pressure fluctuating, evoked periodical skull bone movements.

However, it is not only one reason for slow changes of intracranial pressure fluctuations, which may have connection with skull bone fluctuation. One of cranial osteopathy positions describes the special phenomenon, called crania-sacral rhythm. This is means the reciprocal movements of sacral section of vertebral column and the skull. Explanation of this phenomenon, given by osteopathy is not acceptable from point of view of biomechanics. Recently a new explanation, based on two facts has been appeared. One of these facts follows from MRI observation of pulse CSF movements in sagittal section of skull and neck. The second is the data of REG, taken from sacral region of vertebral column.

If compare images, which have taken every 0.1s, it is possible to see that some portion of pulse CSF volume don't return to the skull and moves along to vertebral cord to its lumbar sack. REG records show, that cranial and sacral pulsations have reverse phases and level of REG gradually change. These data permit to formulate hypothesis, that during every pulse cycle some amount of CSF fills lumbar sack and pressure increased. Because hydrostatic forces are strong, this increase of lumbar sack could slightly erect sacral region of vertebral column, which is possible to feel by palpation. The erection may stimulate around sacral section muscles, which return it to initial position and CSF is returning back to cranium. This is, may be not perfect but some, basing on observation explanation of crania-sacral rhythms, observation of which is "classical" method of osteopathy [35].

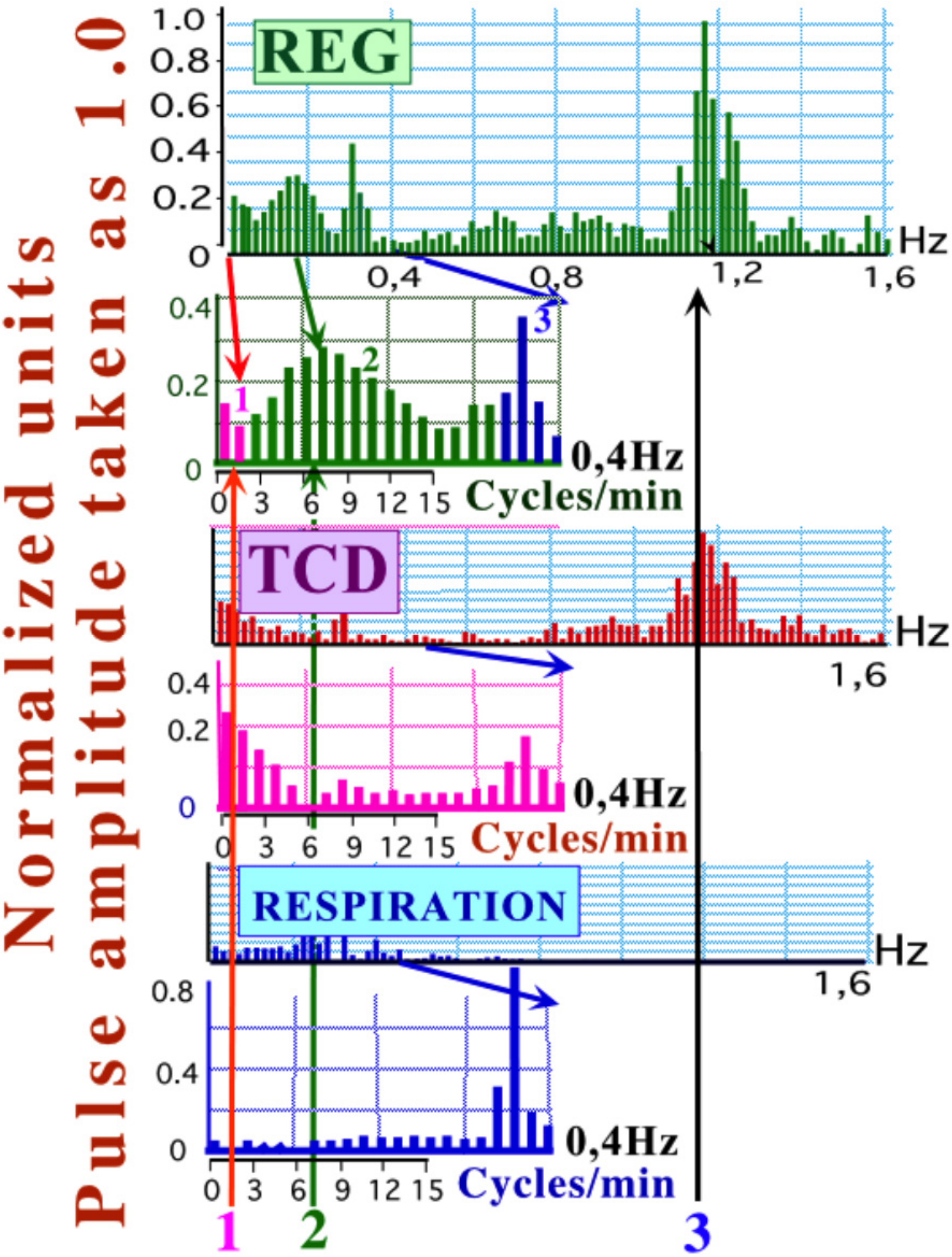



**Figure 8.** Spectral representation of healthy person, age 23, slow in range 0-1,6 Hz and range 0.04 Hz of REG, TCD and Respiration. Arrow (RED) show off central arterial pressure, Arrow Green – fluctuations of intracranial origin and BUE arrow show component of chest respiratory movements.

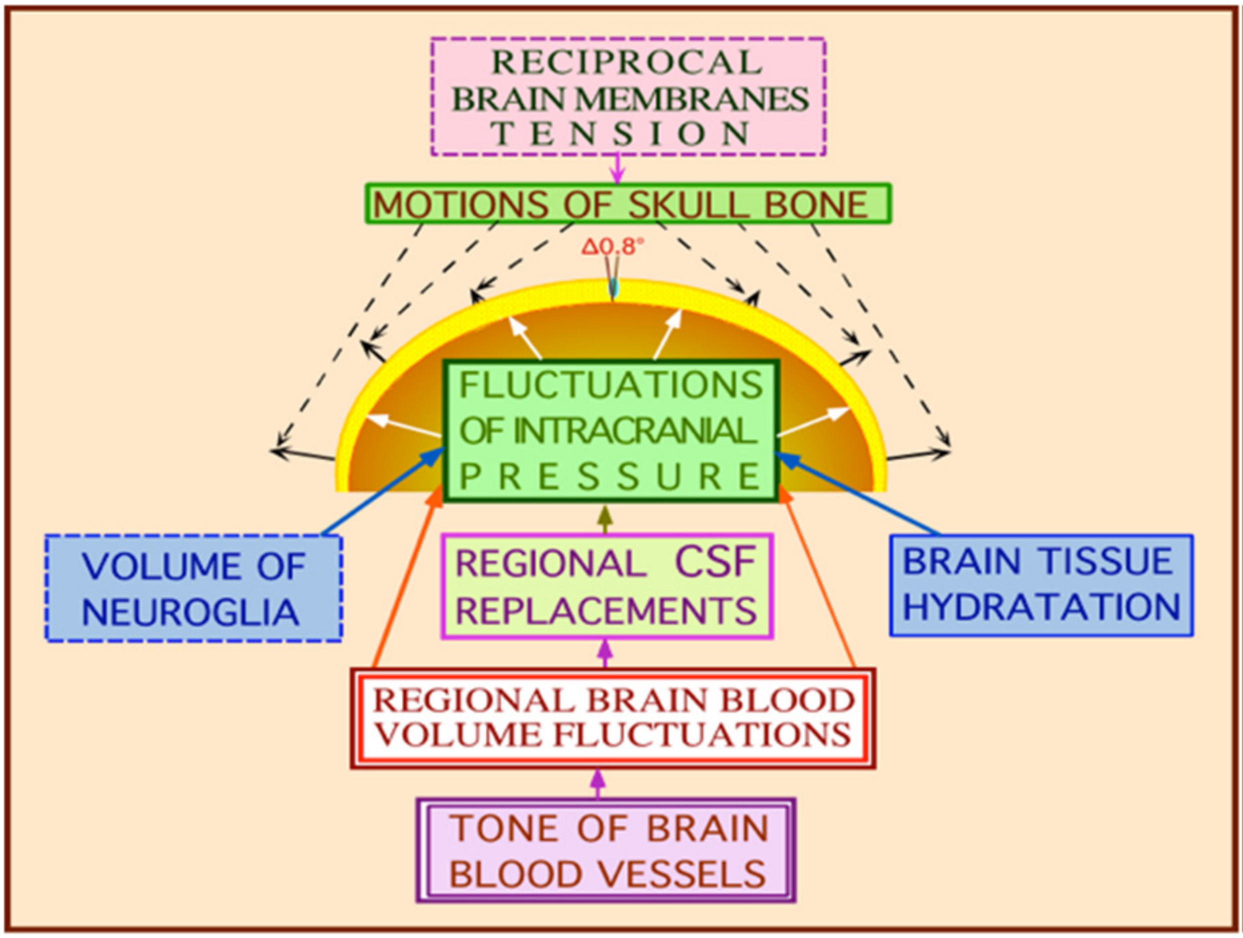



**Figure 9.** Schematic representation of skull move motion, iniciated intracranial pressure , roun indicate physiological origin (BROW) but may be pathological origin – (BLUE).

## 4. Conclusion

All above presented data show, that skull, its brain part is a moveable system. For the skull bone two kinds of movement are special. The first is rapid, during 0.1-0.15s skull expanding by pulse increased arterial pressure. This is too short time to involve CSF to balance intracranial blood volume and increase of volume of arteries mainly on skull basement increase pressure into the skull, which causes deforming its pattern by articular movements of bones in sutures which totally increase internal volume of skull by not much value – about 0.2-0.3% to compare with total volume cranial cavity. However, it is enough to accept additional 3-6 ml of blood, which are extremely important for maintain circulatory-metabolic supply of brain functioning. If this kind of skull mobility diminishes by some reason, brain circulatory insufficiently could appear, which may be reason of some such pathology situation, as brain dementia of circulatory origin. That is why on early steps of civilization, skull trepanation served as method of treatment.

Other kind of the skull bone movements is based on slow fluctuation of skull bone position, evoked by internal forces, finally expressed as periodical changes of intracranial pressure, which include processes in vertebral cord also. Actually, cranio-spinal space is represented as nearly united system. Intracranial liquid system is an initial movement of this slow fluctuation process. It is not yet final point of view how developing all connected with this processes and origin of this initial liquids movement is not clear yet. However, the fact of slow skull bone motions is looks definite confirmed.

Although the current role in skull bone movements play mechanical properties of sutures, because separate bone of skull are mechanically too strong to be deformed by arterial pressure forces or other origin forces, which occur inside cranial cavity. Thus, final result of the skull expanding of slow skull bone motions are depends on not structure and biomechanics of some particular suture, but of skull, as united complicated bio-mechanical system. Biomechanical properties single elements composed skull as united moveable system and this is a new property, which is appeared on systemic level. Mechanical properties of the united mechanical system may be different, to compare with any single elements.

## Author details

Yuri Moskalenko*, Gustav Weinstein and Julia Andreeva
*Institute of Evolutionary Physiology and Biochemistry, Russian Academy of Sciences, Sankt Petersburg, Russian Federation*

Tamara Kravchenko
*Russian School of Osteopathic Medicine, Moscow, Russian Federation*

Natalia Ryabchikova
*Biological Faculty Moscow State University, Moscow, Russian Federation*

Peter Halvorson
*ITAG, PA, USA*

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* Corresponding Author

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