Fluid Dynamics of the Cranium in Traumatic & Neurodegenerative Processes

Michael L. Kuchera, DO, FAAO, FNAOME
Professor & Chairperson, Dept OMM
Marian University - College of Osteopathic Medicine

Insights Regarding “Cranial Compliance” & “CSF Mobility” (Evidence Based Measures)

Thanks to IsoTechnologies (Neuromuscular Engineering) & the former PCOM Human Performance & Biomechanics Lab

FUNCTIONAL GOALS OF INTRA-CRANIAL FLUIDS

- Transport nutrition to & within brain tissue
- Maintain water balance in brain tissue
- Distribute blood & CSF in brain under stress and in traumatic situations
- Evacuate wastes from brain tissue
Functional Implications of Fluid Distribution & Cranial Compliance

- Homeostatic response to physiological fluid volume changes within the cranium
- Protection / Accommodation response to trauma (or other events) that might increase intracranial pressure
  - (Research: Heisey et al)

Overview: Osteopathy/Homeostasis

- Physiological links to Osteopathy in the Cranial Field (OCF)
- Prioritize research & technology to build and evolve the evidence base needed for proper discussion
- Discussion: High impact topics
  - Head trauma
  - Neurodegenerative disorders

Does A Manual Medicine Approach Have Any Impact?

- Use non-invasive protocol...pose hypotheses & measures without need to debate “belief” or not. Structure → Function? Relevant change?
- Document any physiological changes made in vascular & CSF dynamics
  - Calculation: CSF mobility (CSF_{mob})
  - Calculation: Cranial Compliance (CC)
- Document OMT technique parameters used (site, pressure, duration, etc) so others can reproduce any outcomes
Head Trauma - TBI (CDC/USA)

1.7 million people sustain a TBI / year (More???)
- Most common in men 15-24yr
- Also: Children < 5yr or geriatric > 75yr

Recovery begins when swelling, bleeding and/or infection in the brain start to heal → maybe 12-18 mon

Head Trauma (TBI & Concussion) Care:

Estimated Average Annual Number of TBI in the United States, 2002-2006

Hosp
21,000

ER
275,000

1,365,000

Emergency Department Visits

Is there a role for OMT?
Osteopathic focus on somatic dysfunction of head

Condition: Mild⇒Severe
Mechanism of Injury
Pathophysiology
- Fluid/Swelling
- Metabolites
- Bleeding
- Infection

TBI: Joining Forces?

Body Attempts to Heal
(Homeostatic Mechanisms)
- Drainage of Fluid & Waste/Metabolites
- CSF-Venous Drainage
- Cranial Compliance
Clinical Examples Related to Issue

- Traumatic Intra-cranial Injury
- Hydrocephalus
- Intracranial Hemorrhage
- Hydrocephalus
- Cerebrospinal Fluid (CSF) Infections

Problem

Too Much Intra-Cranial Fluid

Symptoms:

- Headache
- Dizziness
- Nausea/Vomiting
- Lethargy
- Fatigue
- Sleep Disturbances
- Concentration & Memory Loss
- Irritability
- Visual Changes

Clinical Examples Related to Issue

- Homeostatic Mechanisms
  - Increase cranial sutural compliance
  - Down-regulate CSF production by the choroid plexus &/or
  - Up-regulate absorption/drainage mechanisms … via
    - Lymphatics (spinal & cranial nerves - eg: CNI)
    - Arachnoid granulations → Venous sinuses

Improved Symptoms & Resolution

- Head trauma is a “container – fluid imbalance” problem
- OMT/OCF has measurable effect on total fluid (CSF)
- Gather Evidence Base now; underlying mechanism later
- Measure relationships & changes in vasculature, total fluid, and cranial compliance
Neurodegenerative Disorders – Alzheimer / Parkinson / Multiple Sclerosis

Is there a role for OMT?
Again: Osteopathic focus on somatic dysfunction of head

Mention Correlations in the Literature

- Trauma → Parkinson Ds
- Liberation Therapy: Venous (“Roto-Rooter”) Procedure (Zamboni)
- Alzheimer Disease (Balin) research re C pneum
- Recent description of the “Glymphatic System” & its potential for translational research questions

Chronic Cerebrospinal Venous Insufficiency (CCSVI)

One Proposed Treatment: “Liberation Therapy” (Zamboni)
FYI: Clinical trials have not gone as well as hoped
- Flawed reasoning?
- Wrong selection of candidates?
- Treatment of venous system at wrong site?

Lymphatics & Glympathics, Iliff 2012

Eg: Postulated Glymphatic System Role
(Iliff JJ ... Nedergaard in Sci Translational Med 2012)

- CSF important role in cleansing brain tissue; the fast-acting Glymphatic System is managed by glial cells in brain for drainage. “If the glymphatic system fails to clean the brain as it is meant to [as in aging or in brain injury], waste may begin to accumulate in the brain. This may be what is happening with amyloid deposits in Alzheimer’s disease.”
- “Perhaps increasing the activity of the glymphatic system might help prevent amyloid deposition or offer a new way to clean out buildups of the material.”
- “We're hopeful that these findings have implications for many conditions, such as traumatic brain injury, Alzheimer’s disease, stroke, and Parkinson’s disease.”
Michael L. Kuchera, DO, FAAO
MU-COM; March 21, 2014

AAO Convocation: Colorado Springs
Cranium Fluid Dynamics in Trauma & Neurodegenerative Changes

Alzheimer’s: C. pneum. via CNI (Olfactory Nerve)

Implication of the Role of CSF as the “Lymphatic System” Drainage Equivalent for Brain

Research: Adopt Physiologically-Based System to Measure Homeostatic Responses of Head Region

Selected system with:
• ... demonstrated use in documenting immediate responses in function to intervention or condition
• ... potential linkage to use in clinical conditions
• ... past usage in pre-/post- OMT measures related to cranium

Moskalenko Method
• Historical use in space research
• Historical use in documenting pre-/post- OMT of cranium (Frymann)
• Linked clinically to cognitive function & dementia
Research Pilot Project Gathering Data Pre- & Post- CV4 OMT Using Moskalenko Method

Equipment: Reproducibility Related to OMT: Quantify What We Do with Hands
- IsoTOUCH® pressure sensor palpation monitoring system

I just can't believe I'm touching "the" Dr. Frymann! How does our touch compare? Is my touch anywhere near close?
Equipment: Transcranial Doppler (TCD) & Rheoencephalography (REG)

Transcranial Doppler (TCD)
Finding the Windows (Middle Cerebral Artery)

Adjust TCD power settings to identify exact site along the MCA bilaterally.

Bilateral Middle Cerebral Arteries on Transcranial Doppler
EXAMPLE: Stookey Test – Subject breathes normally while examiner applies pressure (8 lbs.) to the abdomen – This increases venous return and therefore increases both intra-cranial volume and pressure.

Comment about Zink’s Warmth Provocative Test – Key lesion in R-C.

Vascular/Fluid Physiological Changes

Moskalenko Method Selection

**TCD/REG Measurement Protocol --**

**Baseline Functions : OMT : Post-OMT Functions**

**Functional Tests to Physiologically Modulate Vascular Fluid Flow**

- Frequency Spectrum (1 minute)
- Respiratory cessation (30+ seconds)
- 7 seconds cessation after inhalation
- 7 seconds cessation after exhalation
- Hyperventilation (20 seconds)
- Stokey test (20 seconds)
- Frequency Spectrum (1 minute)

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**PRESSURE - VOLUME RELATIONSHIPS OF LIQUID MEDIA INSIDE CRANIAL CAVITY**

- CBF
- Cerebral Perfusion Pressure
- Intracranial Pressure
- Blood Flow Resistance
- Brain Blood Flow
- Volume of CSF in Cistern
- Vascular Conductivity of CSF Pathways
- Volume of Brain Tissue
- Spinal Volume of CSF

Many homeostatic sensors in CSF:

- $V$ - volume, $P$ - pressure, $l$ - linear blood velocity
- $b$ - blood, $a$ - arterial, $v$ - venous blood, $c$ - cerebrospinal fluid

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**Additional Moskalenko Study: Neck Pathology**

**INFORMATIONAL MEANING OF STOKEY MANEUVER**

- Healthy person
- Person with neck pathology

**REST**

- Distribution of heart beats, energy, evaluated as compensatory SCF movements inside cranial vault between cranial and vertebrobasilar systems

**STOKEY MANEUVER**

- Depressed metabolism evaluated by CSF movements in cranial vault.
Principles: Deciphering Meaning of Intracranial Blood Volume Slow Fluctuations

Moskalenko Method:
Intracranial volume-pressure relations by analyzing TCD & REG changes during a cardiac cycle.
(a) Equalize amplitudes.
(b) Isolate TCD & REG changes on ascending and descending phases of the cardiac cycle.
(c) Transform coordinate axis from “amplitude/time” to “TCD/REG”.
(d) Change orientation of abscissa for descendant phase of cardiac cycle and its phase in the united graphic.
(e) Calculate
Moskalenko Method in Evaluating CRANIAL COMPLIANCE & CSF (Mobility)

Pressure-volume relationships during the cardiac cycle → three interdependent intervals of each pulse cycle (reflecting different processes inside the cranium):

1. ELASTIC PHASE (Proportional to Cranial Compliance): Rapid, nearly linear, increase of pulse pressure lasts 0.05-0.15s and perfectly reflects cranial elastic properties (index CCe).
2. COMPENSATORY PHASE: Follows pulse pressure peak; represents a compensatory process which reflects CSF movements (index CCC).
3. Outflow Phase: The third and final interval of the pulse cycle represents the venous blood outflow from the cranium (index CCO).

CSF into Venous Sinuses to Exit Cranium (85% via Jugular Foramen): One OMT Technique is Venous Sinus Drainage
“Venous Sinus Drainage” OMT
Pressure applied to related firm/tender sites

Test: “Venous Sinus Drainage OMT”

- Pressure sites used for sagittal sinus venous drainage
- Position of hands at sites performing part of “Venous Sinus Drainage” technique

Changes of TCD/REG Pulse Pattern as Result of Application of VENOUS SINUS DRAINAGE TECHNIQUE
(Note increase in compensatory phase)

BEFORE TREATMENT  AFTER TREATMENT
Can measure CC & CSFm in right & left hemispheres using Moskalenko method

- Results of the calculations including cranial compliance on each hemisphere side and CSF flow for the cardiac cycle of a 26-year-old healthy man recorded at rest, in a comfortable horizontal position.
- Asymmetry right to left in both CC and in CSFm

Physiological Functional Challenges

Responses to holding breath & the Stookey test in a healthy young adult male. (Correspond to rest conditions in previous Figure.)

CHANGES OF CIRCULATORY–METABOLIC INDICES AND SKULL BIOMECHANICS WITH BRAIN ACTIVITY DURING AGING

Y. E. MOSKALENKO, N. A. RYABCHIKOVA, G. B. WEINSTEIN, P. HALVORSON and T. C. VARDY

Sechenov Institute of Evolutionary Physiology and Biochemistry of the Russian Academy of Sciences (Thorez Prosp. 44, St. Petersburg 194223, Russian Federation)
Dept. of Higher Nervous Activity, Biology Faculty, Lomonosov Moscow State University, Vorobyevi Gory (Moscow 119899, Russian Federation)
yurimos@mail.ru
Received 22 September 2010; Accepted 25 April 2011
CSF Mobility & Cranial Compliance Change with Age (Moskalenko Group)

- Changes of indices reflecting CSF mobility and CC at different ages demonstrating right and left hemisphere asymmetry.

<table>
<thead>
<tr>
<th>Age</th>
<th>CSF Mobility</th>
<th>CC</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>CSF=0.42</td>
<td>CC=0.88</td>
</tr>
<tr>
<td>29</td>
<td>CSF=0.38</td>
<td>CC=0.76</td>
</tr>
<tr>
<td>54</td>
<td>CSF=0.24</td>
<td>CC=0.72</td>
</tr>
</tbody>
</table>

CSF Mobility Changes with Age

- Changes with age of CSF mobility, calculated as the average of two indices — $\text{SQ}^*$ and $\text{T}^*$.

Dementia Stratification (78-84 y/o): Cranial Compliance & CSF

- Changes of CBF, CSF mobility ($\text{CSFm}$), and CC at rest and during voluntary breath cessation for elderly persons 78–84 yrs old, divided into 4 groups with different cognitive capabilities (Prognosis 2).

- Group I: mentally healthy, Gr II: initial dementia, Gr. III: moderate dementia, Gr IV: pronounced dementia.

- Significance: $^* p > 0.1$, $^{**} p > 0.05$. 
Hope for future Research using measures of Cranial Compliance & CSF Flow

- Transcranial Doppler & Rheoencephalography
- Work to "Computer Automate" Measures
- See if ΔPre-Post OMT
- Translational: Altered CSFm or CC in Dementia? In Multiple Sclerosis? In Head Trauma? in ADHD? ... etc

TCD/REG Measurement Protocol --
Baseline Functions: OMT : Post-OMT Functions

Would select OMT with potential to modulate physiology:
- CV4 – COMPLETED Data Being Extracted
- Venous Sinus Drainage
- OM Suture Release
- Occipital Decompression
- Sub-Occipital Release
- Sham

Repeat Functional Tests to Physiologically Modulate Vascular Fluid Flow

ABOVE: CV4 Pressure measured using IsoTOUCH® Pressure Monitoring Sensor System (Thenar Pads bilaterally); only one pad displayed above
TCD/REG & Pressure data from 40 subjects now being analyzed
The significant waves in the spectrum analysis are shown here. **The slow fluctuation and the primary cardiac wave are most important for the analysis.** The respiratory wave will be used mainly for a reference point and the 2nd harmonic is not needed for the analysis.

**Pre- CV4 OMT**
(Thenar Pressure applied over squamous occiput)

**History of concussions**

Pre = 6 cycles/min

Doubled slow wave frequency = Increased blood flow to brain

Increase in Amplitude directly proportionate to increase in cranial compliance

2nd Harmonic arrival = skull expansion; stems from energy increase of the slow fluctuation

**Post CV4 – Moskalenko Method Interpretation**
Thanks for Opportunity to Share with Colleagues at AAO Convocation

Looking forward to further discussion
Please feel free to poke holes in any weak aspects of our new ideas to make them (and us) stronger
Special Thanks: Precious Barnes, DO, MS & Frank Casella, OMS

Let’s Advance the Evidence Base. Questions?

DON’T TRUST HIM, GUY - HE’S AN AUTHORITY FIGURE.

Write mkuchera@marian.edu
Homeostasis Overwhelmed in an Infant (Chronic Imbalance)

Traumatic brain injury
Hydrocephalus
Subarachnoid hemorrhage
Stroke
Cerebral edema
OBE infiltrates

Rx for container: surgical trephination, OMT
Rx for fluid: medications, OMT

Cranium with sutures - Deformity

Eg: Hydrocephalus & Shortened Life Span

Homeostasis Overwhelmed in an Infant (Chronic Imbalance)

Improved Symptoms & Resolution

Rx for Container: Surgical/Trephination, Ventricular Shunt

Fluid and Cerebral Compliance

Nausea/Vomiting
Headache/Dizziness
Lethargy/Fatigue
Cognitive/Memory Loss
Visual Changes
DEATH

Rx for Fluid: Ventricular Shunt
Medications / OMT