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(54) **NON-INVASIVE METHOD OF ESTIMATING INTRA-CRANIAL PRESSURE (ICP)**

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(52) **U.S. Cl.**

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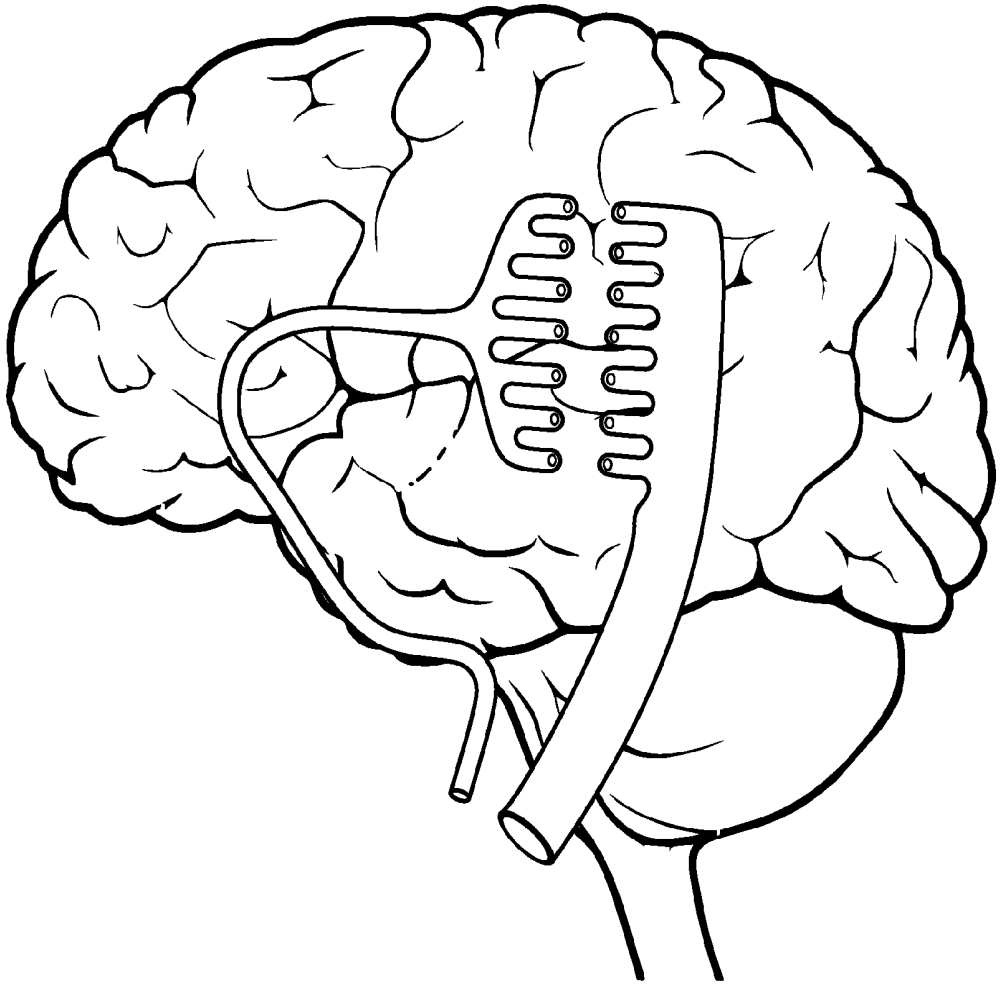
(57) **ABSTRACT**

A non-invasive method of estimating intra-cranial pressure (ICP). The method including the steps of: a. non-invasively measuring pressure pulses in an upper body artery; b. determining central aortic pressure (CAP) pulses that correspond to these measured pressure pulses; c. identifying features of the ICP wave which denote cardiac ejection and wave reflection from the cranium, including Ejection Duration (ED) and Augmentation Index of Pressure (PAIx); d. non-invasively measuring flow pulses in a central artery which supplies blood to the brain within the cranium; e. identifying features of the measured cerebral flow waves which denote cardiac ejection and wave reflection from the cranium as Flow Augmentation Index (FAIx); f. calculating an ICP flow augmentation index from the measured central flow pulses; g. comparing the calculated ICP pressure augmentation index (PAIx) and flow augmentation index (FAIx) to measure (gender-specific) pressure and flow augmentation data indicative of a measured ICP to thereby estimate actual ICP; and h. noting any disparity between ED measured for pressure waves and ED measured for flow.



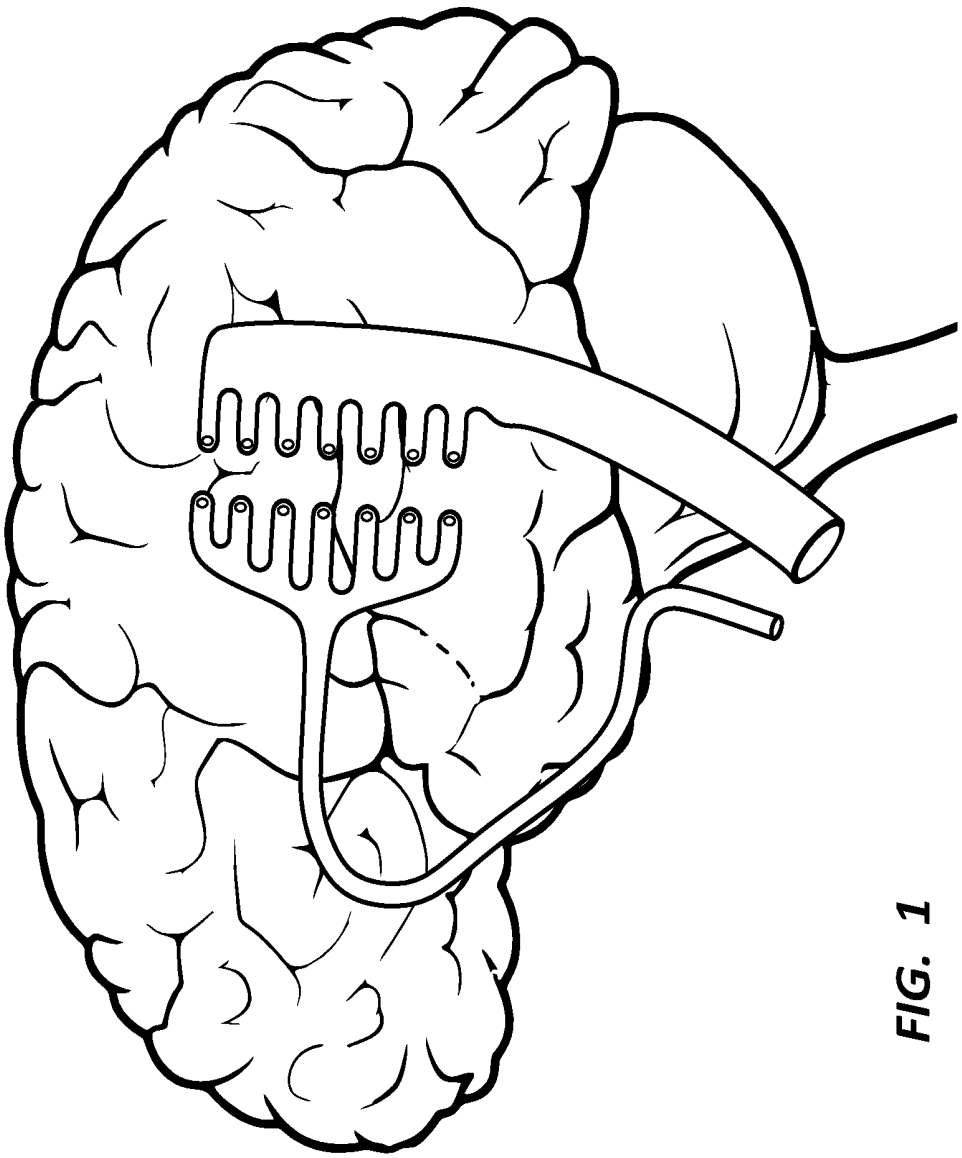


FIG. 1

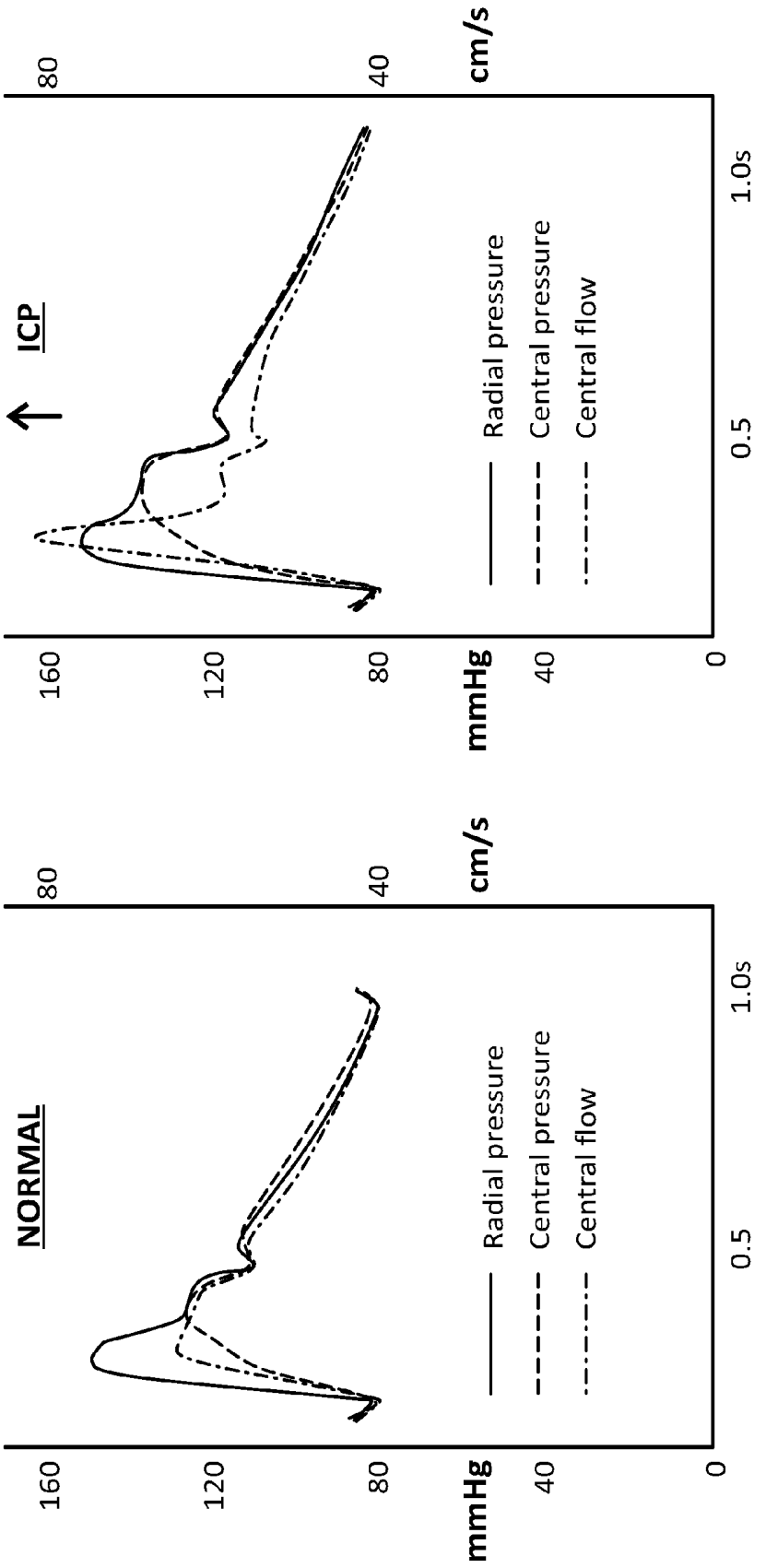

NORMAL
160
120
80
40
0
mmHg
80
40
cm/s
0.5
1.0s
Radial pressure
Central pressure
Central flow

FIG. 2A

ICP
160
120
80
40
0
mmHg
80
40
cm/s
0.5
1.0s
Radial pressure
Central pressure
Central flow

FIG. 2B

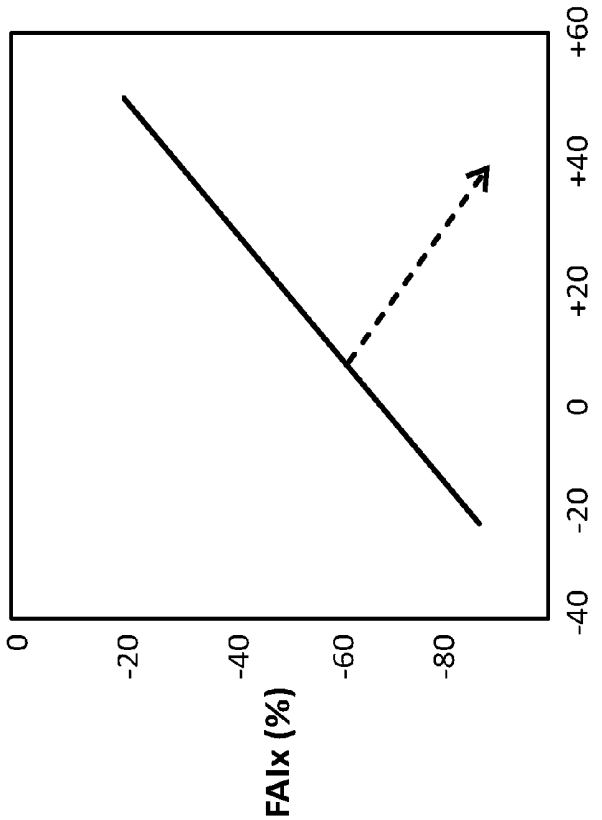

0
-20
-40
-60
-80
FAIx (%)
-40
-20
0
+20
+40
+60
PAIx (%)

FIG. 3B

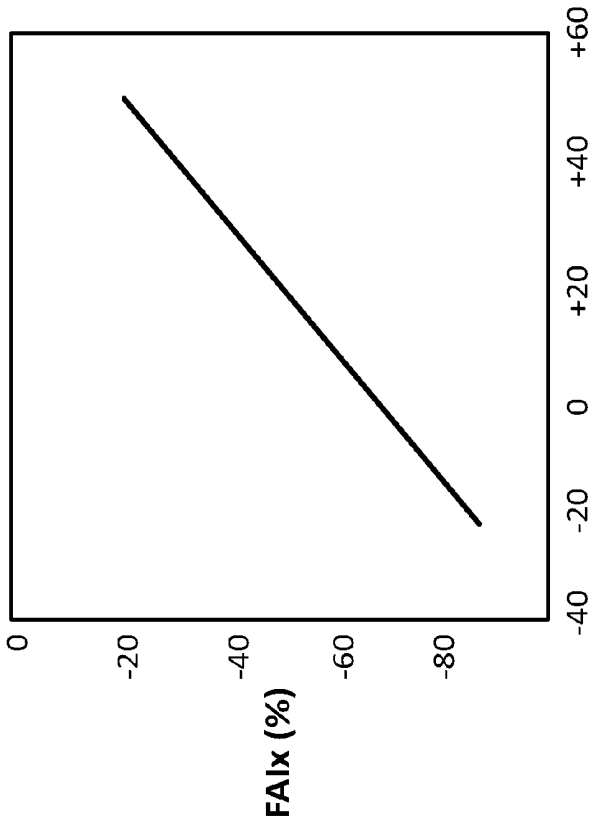

0
-20
-40
-60
-80
FAIx (%)
-40
-20
0
+20
+40
+60
PAIx (%)

FIG. 3A

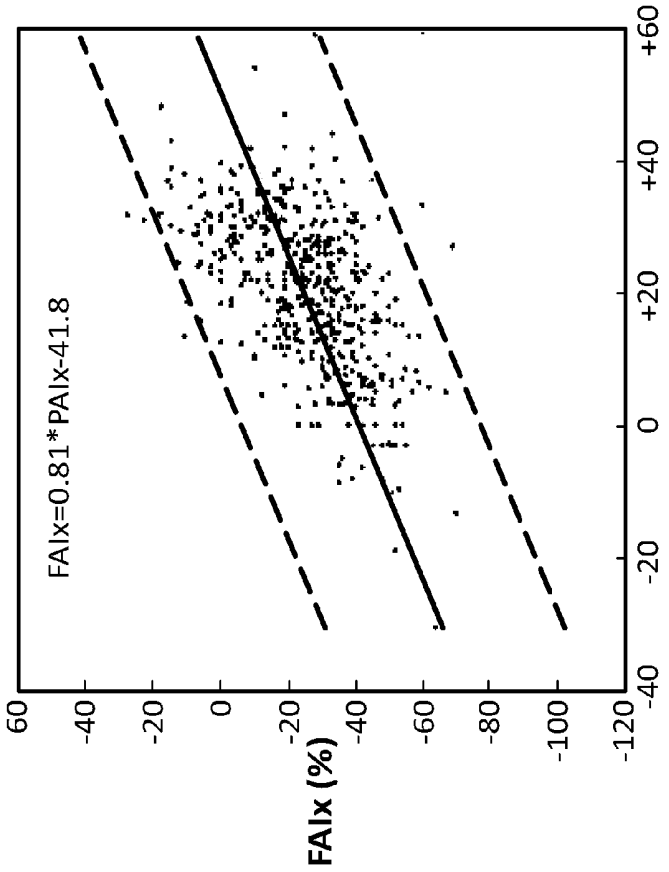

FAIx=0.81*PAIx-41.8
FAIx (%)
PAIx (%)
60
-40
-20
0
-20
-40
-60
-80
-100
-120
-40
-20
0
+20
+40
+60

FIG. 4B

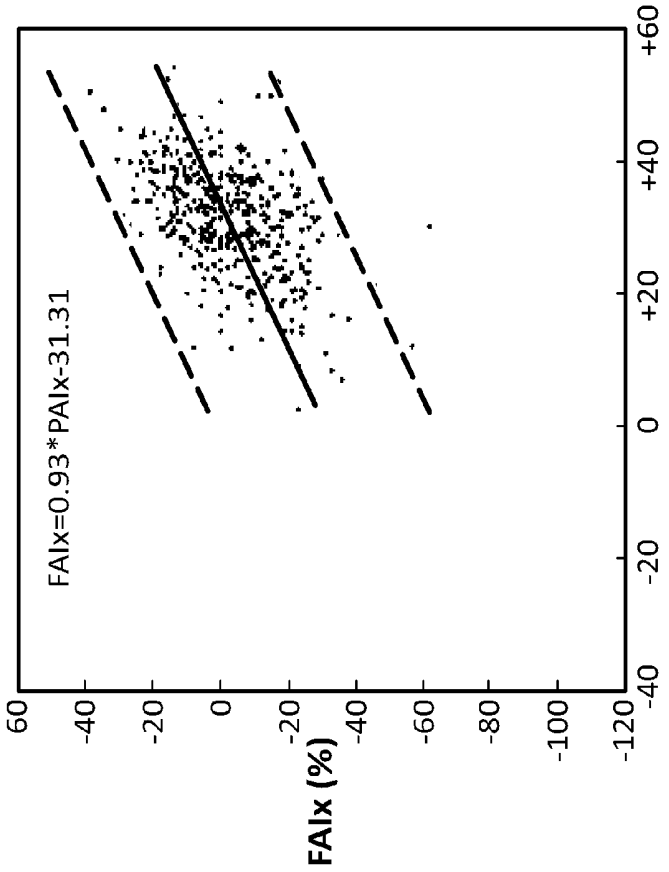

FAIx=0.93*PAIx-31.31
FAIx (%)
PAIx (%)
60
-40
-20
0
-20
-40
-60
-80
-100
-120
-40
-20
0
+20
+40
+60

FIG. 4A

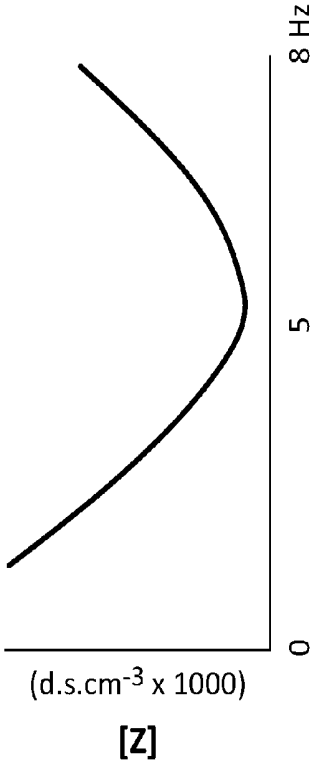


FIG. 5B

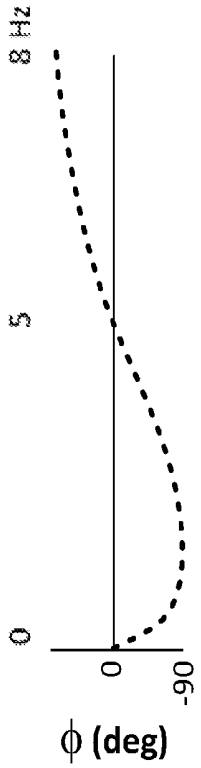


FIG. 6B

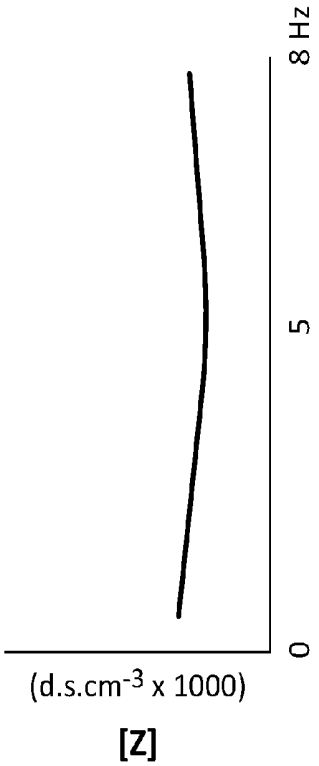


FIG. 5A

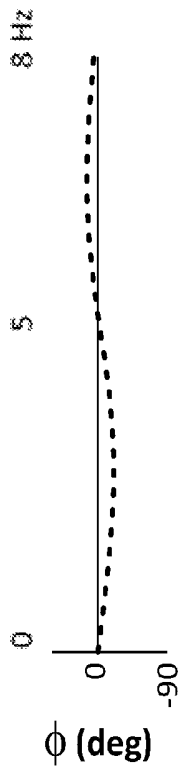


FIG. 6A

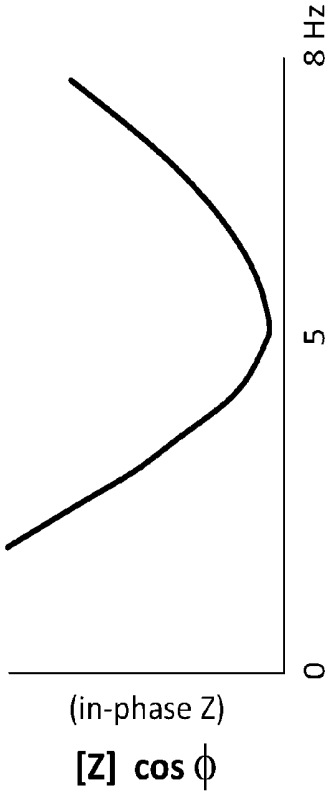


FIG. 7B

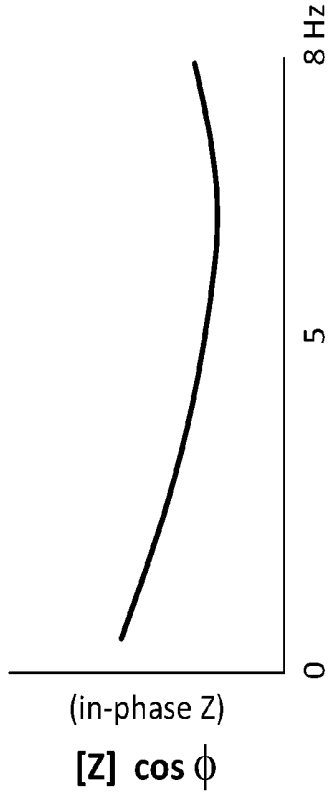


FIG. 7A

NON-INVASIVE METHOD OF ESTIMATING INTRA-CRANIAL PRESSURE (ICP)

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to Australian Provisional Patent Application No. 2016902207, filed on Jun. 7, 2016, which is hereby incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates a non-invasive method of estimating intra-cranial pressure (ICP).

BACKGROUND OF THE INVENTION

[0003] The cranium is the bony vault at the top of the human body which contains the body's computer, the brain (FIG. **1**). The cranial cavity communicates directly with the spinal canal. This contains the spinal cord wherein nerve pathways from and to the brain pass before entering canals between the vertebrae and the rest of the body. Despite allowing free passage of electrical signals in the insulated nerves from brain to body, the combined cranial cavity and spinal canal are physically isolated from the rest of the body because foramena in the cranium and spine are physically plugged with connective tissue. This "plugging" prevents leakage of the Cerebro-Spinal Fluid (CSF) which surrounds and bathes the brain and spinal cord within the cranial cavity and spinal canal. The only physical passage between the spinal cavity, conjoined cranial/spinal canal and the rest of the body is for the major arteries and veins (notably the internal carotid artery and vertebral artery on each side of the body, and the jugular veins on each side).

[0004] This physical arrangement of brain and spinal cord protects these fragile vital organs from trauma and provides a physical syphon which helps to maintain blood flow to the brain with different body positions, particularly when adopting the upright stance. A particular problem with trauma or disease, especially brain swelling from cerebral oedema, brain tumor or bleeding or interference with CSF circulation or absorption, is rise in ICP. Rise in ICP compresses and narrows cerebral arteries and veins in the cranium and restricts cerebral flow and can cause cerebral ischemia and secondary stroke. Elevation of ICP can also, through pressure on vital brain stem centers, increase autonomic nerve activity, with sympathetic nerve discharge elevating blood pressure in the general systemic circulation.

[0005] Current methods of measuring ICP are all invasive in nature. For example, ICP can be measured directly from the cerebral ventricle through a fluid-filled catheter attached to an external monitor. ICP can also be measured and monitored by inserting a needle between lumbar vertebrae into the dural sac which contains the spinal cord (i.e. by lumbar puncture), and measuring pressure by an external manometer. The most common known procedure in neurosurgical critical care is the insertion of a Codman (or similar) micromanometer through a hole drilled though the skull and advanced into the cerebral ventricle or into the cerebral parenchyma.

[0006] Direct (i.e. invasive) continuous measurement of ICP has become routine in most major neurosurgical units which deal with brain trauma, and is accompanied by direct continuous measurement of pressure waves from the radial artery by indwelling cannula. Monitoring is usually continued for the first few days after trauma or stroke, when elevations of ICP are most common, most amenable to treatment, and most likely to aid recovery.

[0007] Direct (i.e. invasive) measurement of ICP carries procedural risk of cerebral damage, haemorrhage and infection. While attempts have been made, there are no accepted methods for measuring ICP non-invasively. More particularly, current non-invasive or minimally invasive methods, which depend on the most readily available measures (arterial pressure or intra-cerebral flow), have not been successful in elucidating presence or absence of elevated ICP, nor gauging the degree of elevation in unconscious patients following closed head trauma, stroke or brain surgery.

[0008] Ability to measure ICP non-invasively can avoid the complications of direct ICP monitoring, where a pressure sensor is inserted into the brain parenchyma or into a cerebral ventricle. This is a routine procedure for severe closed head injury cases, in whom elevation of ICP can be relieved physically by withdrawal of CSF or by craniectomy (brain decompression). Complications include further brain injury, bleeding, infection. A method for measuring ICP quickly and non-invasively would shorten the delay between injury and decompression so improving the chance of a successful outcome, in head injury patients.

[0009] Ability to measure ICP can also help to establish a diagnosis of brain death in a potential transplant donor, and so improve chances of successful recipient organ transplantation.

Object of the Invention

[0010] It is an object of the present invention to substantially overcome or at least ameliorate one or more of the above disadvantages, while preserving accuracy of the invasive method, and provide other advantages that arise from measurement of central rather than peripheral pressure, and central blood flow into and out from the cranium during the cardiac cycle.

SUMMARY OF THE INVENTION

[0011] The applicant contends that elevation of ICP can be estimated from the patterns of arterial pressure and flow waves which pass into the cranium to supply blood to the brain, and arise as a consequence of arterial narrowing and occlusion.

[0012] The applicant further contents that elevation and degree of elevation of ICP can be estimated from the patterns of pressure and flow waves in arteries (typically the carotid arteries and their major branches in the cranium) which enter the cranium to supply blood to the brain, as a consequence of their compression and narrowing on entry into the cranial cavity. The thesis is also based on change in the pattern of pressure and flow waves immediately upstream from their entry into the cranium where a site of very low wave reflection (approximating zero) changes progressively to a site of very high wave reflection (approaching 100%) when ICP rises to levels close to those seen in the peripheral circulation. Under these circumstances there is predisposition to appearance of "resonance" or "standing waves" in the general systemic circulation.

[0013] Accordingly, in a first aspect, the present invention provides a non-invasive method of estimating intra-cranial pressure (ICP), the method including the steps of:

[0014] a. non-invasively measuring pressure pulses in an upper body artery;

[0015] b. determining central aortic pressure (CAP) pulses that correspond to these measured pressure pulses;

[0016] c. identifying features of the ICP wave which denote cardiac ejection and wave reflection from the cranium, including Ejection Duration (ED) and Augmentation Index of Pressure (PAIx);

[0017] d. non-invasively measuring flow pulses in a central artery which supplies blood to the brain within the cranium;

[0018] e. identifying features of the measured cerebral flow waves which denote cardiac ejection and wave reflection from the cranium as Flow Augmentation Index (FAIx);

[0019] f. calculating an ICP flow augmentation index from the measured central flow pulses;

[0020] g. comparing the calculated ICP pressure augmentation index (PAIx) and flow augmentation index (FAIx) to (gender-specific) pressure and flow augmentation data indicative of a measured ICP to thereby estimate actual ICP; and

[0021] h. noting any disparity (suggesting non-linearality) between ED measured for pressure waves and ED measured for flow.

[0022] In one form, step a. includes measuring radial pressure pulses in a peripheral artery. In this form, step b. includes calculating the corresponding central pressure pulses from the measured radial pressure pulses, most preferably by using a transfer function. The radial pressure pulses are preferably measured in the radial artery at the wrist, non-invasively or invasively if a monitoring catheter is already in use.

[0023] In an alternative form, step a. includes measuring carotid pressure pulses in a carotid artery. In this alternative form, step b. includes measuring the corresponding central pressure pulses, for example by applanation tonometry.

[0024] The flow pulses in step d. are preferably measured in an upper body artery which supplies blood to the brain, such as the internal carotid artery, anterior cerebral artery, middle cerebral artery or common carotid artery.

[0025] In a second aspect, the present invention provides a non-invasive method of estimating intra-cranial pressure (ICP), the method including the steps of:

[0026] a. non-invasively measuring pressure pulses in an upper body artery;

[0027] b. determining central pressure pulses that correspond to the measured pressure pulses;

[0028] c. non-invasively measuring flow pulses in a central artery which supplies blood to the brain;

[0029] d. calculating an ICP pressure augmentation index from the determined central pressure pulses and the measured central flow pulses;

[0030] e. calculating an ICP flow augmentation index from the measured central flow pulses; and

[0031] f. comparing the calculated ICP pressure and flow augmentation indexes to measured pressure and flow augmentation data indicative of a measured ICP to thereby estimate actual ICP.

[0032] In one form, step a. includes measuring radial pressure pulses in a peripheral artery. In this form, step b. includes calculating the corresponding central pressure pulses from the measured radial pressure pulses, most preferably by using a transfer function. The radial pressure pulses are preferably measured in the radial artery at the wrist.

[0033] In an alternative form, step a. includes measuring carotid pressure pulses in a carotid artery. In this alternative form, step b. includes measuring the corresponding central pressure pulses, for example by applanation tonometry.

[0034] The flow pulses in step c. are preferably measured in an upper body artery which supplies blood to the brain, such as the internal carotid artery, anterior cerebral artery, middle cerebral artery or common carotid artery.

BRIEF DESCRIPTION OF THE DRAWINGS

[0035] A preferred embodiment of the invention will now be described, by way of an example only, with reference to the accompanying drawings, in which:

[0036] FIG. **1** is a schematic diagram showing the brain (yellow) within the cranium (brown) with CSF (green) between brain and cranium and a cerebral artery (red) and jugular vein (blue);

[0037] FIG. **2***a* is graph showing radial pressure (mm Hg) and central pressure (mm Hg) and central flow (cm/sec) versus time (sec) for normal (ie. non-elevated ICP) patient conditions;

[0038] FIG. **2***b* is graph showing radial pressure (mm Hg) and central pressure (mm Hg) and central flow (cm/sec) versus time (sec) for elevated ICP patient conditions;

[0039] FIG. **3***a* is a graph of flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for normal patient conditions; the relationship is linear;

[0040] FIG. **3***b* is a graph of flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for elevated ICP conditions; the relationship is linear;

[0041] FIG. **4***a* is a graph of flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for normal conditions, with actual data taken from a normal female population; linear regression line is shown±2 SD;

[0042] FIG. **4***b* is a graph of flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for normal conditions, with actual data taken from a normal male population; linear regression line is shown±2 SD;

[0043] FIG. **5***a* is a graph of Modulus of Impedance (DSCM-3×1000) versus frequency (Hz) for normal patient conditions;

[0044] FIG. **5***b* is a graph of Modulus of Impedance (DSCM-3×1000) versus frequency (Hz) for elevated ICP conditions;

[0045] FIG. **6***a* is a graph of Phase of Impedance (degrees) versus frequency (Hz) for normal patient conditions;

[0046] FIG. **6***b* is a graph of Phase of Impedance (degrees) versus frequency (Hz) for elevated ICP conditions;

[0047] FIG. **7***a* is a graph of Z cosine f (degrees) versus frequency (Hz) for normal patient conditions; and

[0048] FIG. **7***b* is a graph of Z cosine f (degrees) versus frequency (Hz) for elevated ICP conditions.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0049] An embodiment of a method of non-invasively measuring ICP will now be described with reference to FIGS. **2***a* to **7***b*. The method comprises the steps of:

[0050] a. Measuring pressure pulses in a peripheral artery (typically the radial artery at the wrist) and

producing an electrical signal representing the pressure pulses. The measured pressure pulses are denoted in black in FIG. **2***a* for normal patient conditions and in black in FIG. **1***b* for elevated ICP.

[0051] b. Deriving a Fourier transform for the measured peripheral pulses.

[0052] c. Deriving the peripheral pulse Fourier transform by a transfer function H(w) relating a Fourier transform of pressure pulses in the peripheral artery and a Fourier transform of pressure pulses in the aorta thereby producing a Fourier transform associated with the central aortic pressure pulse. The calculated central pressure pulses are denoted in pink in FIG. **2***a* for normal patient conditions and in pink in FIG. **2***b* for elevated ICP.

[0053] d. Deriving the inverse of the Fourier transform associated with the aortic pressure pulse, thereby producing an electrical signal representing a synthesised ascending aortic pulse. The above steps and calibration of radial tonometry to brachial cuff systolic and diastolic pressure are disclosed in U.S. Pat. No. 5,265,011 (the contents of which are incorporated herein by cross reference).

[0054] e. Determining the signal representing the measured peripheral pulse a point of systolic onset by taking a first derivative of the measured peripheral pulse and locating a zero crossing from negative-to-positive which precedes a maximum point on the first derivative curve.

[0055] f. Identifying a first localised systolic peak on the pressure signal within the limits of 60-140 msec from the foot of the pressure wave, and designating this as P**1**.

[0056] g. Identifying a second localised systolic peak of the pressure wave signal within the limits of 160-320 msec from the foot of the wave and designating this as P**2**.

[0057] h. Non-invasively measuring flow pulses in arteries supplying blood to the brain (typically internal common carotid, anterior cerebral, middle cerebral, basilar, vertebral) by Doppler ultrasound technique, and producing an electrical signal representing the flow pulses. The measured flow pulses are denoted in green in FIG. **2***a* for normal patient conditions and in green in FIG. **2***b* for elevated ICP.

[0058] i. Generating the following features of the flow waveform signal:

[0059] i. Peak flow velocity.

[0060] ii. Minimal flow velocity, zero flow velocity.

[0061] iii. Designating amplitude of the flow velocity waveform.

[0062] iv. Generating mean flow velocity from integration of the wave over one cardiac cycle.

[0063] v. Determining FF as (mean flow velocity minus nadir flow velocity) divided by amplitude of the velocity waveform.

[0064] vi. Designating flow pulsatility index as amplitude of the flow waveform divided by mean flow.

[0065] vii. Identifying a first localised systolic peak on the flow signal within the limits of 60-140 msec from the foot of the flow wave, and designating this as F1.

[0066] viii. Identifying a second localised systolic peak of the flow wave signal within the limits of 160-320 msec from the foot of the wave and designating this as F2, as in lg for the pressure waveform.

[0067] ix. Identifying flow velocity augmentation as difference between F1 and F2, designating augmentation as positive when F2>F1 and as negative when F2<F1.

[0068] x. Designating Flow AIx as flow augmentation÷amplitude of flow velocity waveform.

[0069] xi. Designating pressure augmentation as P**2**-P**1**.

[0070] xii. Generating pressure AIx indices as (P**2**-P**1**)÷(P**2**-P**0**) when P**2**>P**1**.

[0071] xiii. Generating pressure AIx indices as (P**2**-P**1**)÷(P**1**-P**0**) when P**2**<P**1**. FIG. **3***a* shows a plot of the flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for normal patient conditions, as well as FIG. **4***a* (females) and FIG. **4***b* (males), and FIG. **3***b* shows plots of the flow augmentation index % (FAIx) versus pressure augmentation index % (PAIx) for various known (i.e. previously invasively measured) elevated ICP conditions.

[0072] xiv. Determining peak of pressure wave after onset of the pressure wave.

[0073] j. Designating of pressure pulsatility as amplitude of the pressure wave divided by mean pressure.

[0074] k. Designating pressure FF divided by flow FF as FF ratio.

[0075] l. Designating flow AIx divided by pressure AIx as flow/pressure AIx ratio.

[0076] m. Determining harmonic content of the pressure waveform by Fourier or frequency spectrum analysis.

[0077] n. Determining cerebral impedance modulus as moduli of frequency components of pressure divided by corresponding moduli of flow frequency components (see FIGS. **5***a* and **5***b* for normal patient and elevated ICP conditions respectively).

[0078] o. Determining cerebral impedance phase as phase of frequency components of pressure minus corresponding frequency components of phase (see FIGS. **6***a* and **6***b* for normal patient and elevated ICP conditions respectively).

[0079] p. Determining in-phase impedance as Z cos f (see FIGS. **7***a* and **7***b* for normal patient and elevated ICP conditions respectively).

[0080] The steps e to p are applied to the calibrated central aortic pressure wave and the simultaneously measured internal carotid flow wave on the contralateral side. The measures taken are then compared to normal values for gender, age, heart rate, the measures being:

[0081] a. Aortic pressure systolic

[0082] b. Aortic pressure mean

[0083] c. Aortic pressure pulsation

[0084] d. Aortic pressure augmentation

[0085] e. Aortic pressure augmentation index (PAIx)

[0086] f. Aortic pressure AIx corrected for heart rate at 75/minute (PAIx 75); and

[0087] g. Pressure form factor (mean pressure−diastolic pressure)÷pulse pressure

[0088] h. Flow velocity systolic

[0089] i. Flow velocity mean

[0090] j. Flow velocity diastolic
[0091] k. Flow velocity pulsation
[0092] l. Flow velocity augmentation
[0093] m. Flow velocity augmentation index (FAIx)
[0094] n. FAIx corrected for heart rate (FAIx 75)
[0095] o. Flow velocity pulsatility index (flow pulsation÷mean flow)
[0096] p. Flow velocity form factor
[0097] q. Pressure/flow relationships as PAIx/FAIx
[0098] r. Pressure/flow relationships as cerebral vascular impedance (CVI)
[0099] s. Pressure/flow relationships as in-phase CVI (Z cos f of impedance)
[0100] t. Reflection coefficient as (ZT-ZC)÷(ZT+ZC), where ZT is terminal impedance at zero frequency (CVI in dyne.s.cm-3) and ZC is characteristic impedance calculated as average value of impedance modulus from frequency of second to sixth harmonics and after excluding values of pressure and flow in the noise level (P<0.4 mmHg), flow<1 cm/s)
[0101] u. ED from pressure wave (EDp) and from flow wave (EDf)

[0102] With reference to FIG. **3***b*, a clinician then compares the calculated ICP pressure and flow augmentation indexes (represented as dots **18**) to measured ICP augmentation index data (represented by the plots), which are indicative of a measured ICP, to thereby estimate actual ICP. The amount of actual elevated ICP is determined by selecting the known plot closest to the dots **18**.

[0103] The data shown in FIG. **4***b* is used to estimate characteristic impedance (Zc) and terminal impedance (Zt), and from these values, calculate reflection coefficient as (Zc-Zt)÷(Zc+Zt).

[0104] The data shown in FIG. **5***b* is used to compare phase delay against FIG. **4***a* which shows phase delay under normal conditions. This is measured as average of phase delay over the same frequency band as used to estimate characteristic impedance, and with same criteria to exclude pressure and flow data in the noise level.

[0105] The data shown in FIG. **5***b* is used to compare abnormal patterns of Zcosf fluctuations against normal non-fluctuant values of Zcosf, by comparing average levels of Zcosf over the same frequency range used in FIGS. **3** to calculate characteristic impedance, as described for the above paragraph. ED from pressure wave (EDp) is compared to ED from flow wave (EDf) as a check on ability of algorithm to identify left ventricular ED accurately and independently of reflected waves.

[0106] The benefits of the non-invasive method of ICP measurement described above include:

[0107] no procedural risk of cerebral damage, haemorrhage and infection;
[0108] less requirement of direct measurement;
[0109] better discrimination in selecting patients for direct measurement;
[0110] more appropriate use of direct ICP measurement; and
[0111] better management of patients without need for invasive measurement.

[0112] Although the invention has been described with reference to a preferred embodiment, it will be appreciated by those persons skilled in the art that the invention may be embodied in many other forms. For example, in an alternative embodiment (not shown), the pressure pulses are measured in the common carotid artery. In this embodiment, the corresponding central pressure pulses are directly measured, for example by applanation tonometry.

1. A non-invasive method of estimating intra-cranial pressure (ICP), the method including the steps of:
a. non-invasively measuring pressure pulses in an upper body artery;
b. determining central aortic pressure (CAP) pulses that correspond to these measured pressure pulses;
c. identifying features of the ICP wave which denote cardiac ejection and wave reflection from the cranium, including Ejection Duration (ED) and Augmentation Index of Pressure (PAIx);
d. non-invasively measuring flow pulses in a central artery which supplies blood to the brain within the cranium;
e. identifying features of the measured cerebral flow waves which denote cardiac ejection and wave reflection from the cranium as Flow Augmentation Index (FAIx);
f. calculating an ICP flow augmentation index from the measured central flow pulses;
g. comparing the calculated ICP pressure augmentation index (PAIx) and flow augmentation index (FAIx) to (gender-specific) pressure and flow augmentation data indicative of a measured ICP to thereby estimate actual ICP; and
h. noting any disparity between ED measured for pressure waves and ED measured for flow.

2. The method as claimed in claim **1**, wherein step a. includes measuring radial pressure pulses in a peripheral artery.

3. The method as claimed in claim **2**, wherein step b. includes calculating the corresponding central pressure pulses from the measured radial pressure pulses,

4. The method as claimed in claim **3**, wherein the calculating of the corresponding central pressure pulses from the measured radial pressure pulses is done using a transfer function.

5. The method as claimed in claim **3**, wherein the radial pressure pulses are measured in the radial artery at the wrist.

6. The method as claimed in claim **1**, wherein step a. includes measuring carotid pressure pulses in a carotid artery.

7. The method as claimed in claim **6**, wherein step b. includes measuring the corresponding central pressure pulses.

8. The method as claimed in claim **7**, wherein the corresponding central pressure pulses are measured by applanation tonometry.

9. The method as claimed in claim **1**, wherein the flow pulses in step d. are measured in an upper body artery which supplies blood to the brain.

10. A non-invasive method of estimating intra-cranial pressure (ICP), the method including the steps of:
a. non-invasively measuring pressure pulses in an upper body artery;
b. determining central pressure pulses that correspond to the measured pressure pulses;
c. non-invasively measuring flow pulses in a central artery which supplies blood to the brain;
d. calculating an ICP pressure augmentation index from the determined central pressure pulses and the measured central flow pulses;

e. calculating an ICP flow augmentation index from the measured central flow pulses; and

f. comparing the calculated ICP pressure and flow augmentation indexes to measured pressure and flow augmentation data indicative of a measured ICP to thereby estimate actual ICP.

11. The method as claimed in claim **10**, wherein step a. includes measuring radial pressure pulses in a peripheral artery.

12. The method as claimed in claim **11**, wherein step b. includes calculating the corresponding central pressure pulses from the measured radial pressure pulses.

13. The method as claimed in claim **12**, wherein the calculating of the corresponding central pressure pulses from the measured radial pressure pulses is done using a transfer function.

14. The method as claimed in claim **12**, wherein the radial pressure pulses are measured in the radial artery at the wrist.

15. The method as claimed in claim **10**, wherein step a. includes measuring carotid pressure pulses in a carotid artery.

16. The method as claimed in claim **10**, wherein step b. includes measuring the corresponding central pressure pulses

17. The method as claimed in claim **16**, wherein the corresponding central pressure pulses are measured by applanation tonometry.

18. The method as claimed in claim **10**, wherein the flow pulses in step c. are measured in an upper body artery which supplies blood to the brain.

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专利名称(译)	非侵入性颅内压评估方法（ICP）		
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摘要(译)

一种估计颅内压（ICP）的非侵入性方法。该方法包括以下步骤：a。非侵入性地测量上身动脉中的压力脉冲;湾确定对应于这些测量压力脉冲的中心动脉压（CAP）脉冲; C。识别ICP波的特征，表示心脏射血和颅骨的波反射，包括射血持续时间（ED）和压力增强指数（PAIx）; d。非侵入性地测量中央动脉中的流动脉冲，该动脉向颅骨内的大脑供血;即识别测量的脑流波的特征，其表示心脏射血和来自颅骨的波反射作为流动增强指数（FAIx）; F。从测量的中心流脉冲计算ICP流量增加指数; G。比较计算的ICP压力增大指数（PAIx）和流量增加指数（FAIx）以测量（性别特定的）压力和指示测量ICP的流量增加数据，从而估算实际ICP;和h。注意到ED测量的压力波与ED测量的流量之间的任何差异。