Effects Of Volume and Flow Change On Electrical Impedance Signal: In Vitro Studies

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Abstract

Acute management of patients with traumatic brain/blast injury remains a challenge. To minimize secondary injury and improve outcome, it is critical to detect neurological deterioration early, when it is potentially reversible. On the basis of preliminary results, REG seems to be a practical, noninvasive and continuous monitoring modality of brain injuries. The REG literature reveals uncertainty about the nature of the signal—whether it reflects flow or volume. The FDA definition states: ' A rheoencephalograph is a device used to estimate a patient's cerebral circulation,' avoiding the answer.

Here we present results of in vitro studies manipulating flow/volume to model clinical conditions (such as brain ischemia and vasospasm) while recording electrical impedance signal.

A loop was created using PVC and C-Flex tubing filled with 0.9 % NaCl . This loop was comprised of a Doppler in-line flow probe connected to an ultrasound flow meter, a peristaltic pump, and two home-made bioimpedance measuring cells, one incorporating a balloon catheter. A bipolar impedance amplifier was used for measuring impedance pulse waves. Data were stored on a PC and processed off-line.

This in vitro study confirmed that

1)Balloon inflation:
•Decreased the electrical impedance pulse amplitude (identical to flow change)
•Doppler and electrical impedance signals showed identical relationship to decreased flow by balloon inflation (R^2=0.966)

2)Doubling the Flow Rate:
•Effected the pulse amplitude and mean flow of the Doppler signal (increased)
•Did *not* effect the amplitudes of the pressure or electrical impedance signals
However, the amplitude increase can be seen in the pressure and electrical impedance signals when the first derivative (dP/dt and dZ/dt) was taken.

Introduction

Acute management of patients with traumatic brain/blast injury remains a challenge. To minimize secondary injury and improve outcome, it is critical to detect neurological deterioration early, when it is potentially reversible (Rubin et al, 2009).

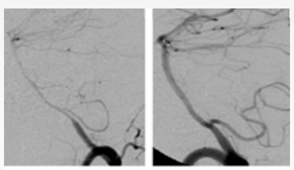
On the basis of preliminary result, REG seems to be a practical noninvasive and continuous monitoring modality of traumatic brain and blast injuries.

The REG literature has a dispute on the nature of signal, i.e. it reflects flow or volume.
FDA definition states: ' A rheoencephalograph is a device used to estimate a patient's cerebral circulation' avoiding the answer.

Since REG is an electrical impedance measurement (its units are in ohm), REG does not offer quantitative flow or volume units. The magnitude of REG pulse amplitude is a function of conductive particles between two electrodes. Since blood is a better conductor than is brain tissue, REG reflects brain blood volume change but not flow. In order to test the clinical applicability of REG, we must imitate pathophysiological conditions (ischemia/vasospasm). Therefore, our hypothesis was that electrical impedance (REG) pulse amplitude will decrease as a result of both manipulations (flow and volume decreases).

Results of in vitro studies modeling clinical conditions while recording electrical impedance signal are presented in this poster.

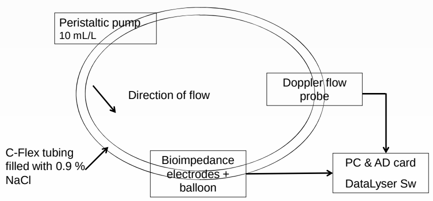
Vasospasm



Lateral digital subtraction angiogram of the basilar artery, pre- and post angioplasty.

Methods

Balloon Inflation

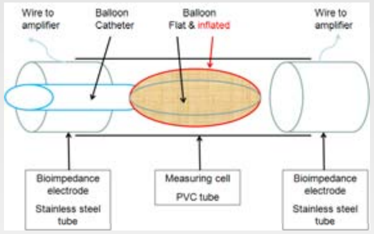


Methods – Balloon Inflation

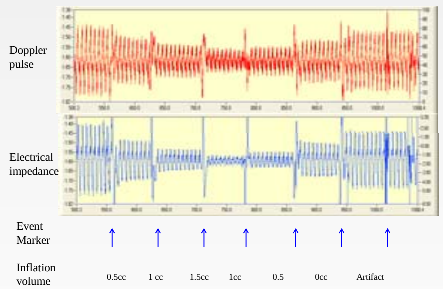
A closed loop was created using PVC and C-Flex tubing filled with 0.9 % NaCl. This loop included a Doppler in-line flow probe (4N) connected to an ultrasound flow meter (T201 Ultrasonic Bloodflow Meter, Transonic Systems, Ithaca, NY). A peristaltic pump (model P720, Instech Laboratories, Plymouth Meeting, PA) generated pulse waves in the loop at a constant rate. Two stainless steel metal tubes (14 mm in length and 3 mm internal diameter) used as electrical impedance electrodes connected to a bipolar impedance amplifier (Cerberus, Quintlab, Hungary). Measurement frequency was 125 kHz. Signals were stored in a PC using an AD card (PCI-MIO-16XE-10, National Instruments, Austin, TX) with 16 bit resolution. Data was analyzed with DataLyser software (WRAIR, Baranyi). The data sampling rate was 200 Hz.

Challenge was the inflation of a balloon catheter (PTCA Dilatation catheter, NCR14 9/4.0, Boston Scientific, SCIMED, Maple Grove, MN) with a syringe in 0.5 cc steps.
Data processing: Pulse amplitude measurements (minimum – maximum distance) were made at 0 (no inflation), 0.5, 1.0 and 1.5 cc inflation. Eight pulse amplitudes were measured and averaged.

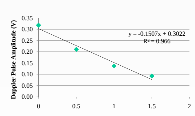
Bioimpedance Measuring Cell



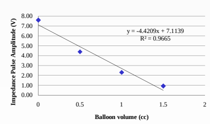
Effect of balloon inflation on Doppler flow and electrical impedance pulse amplitudes (2009 June 17 #2)



Balloon Volume And Doppler Pulse Amplitude



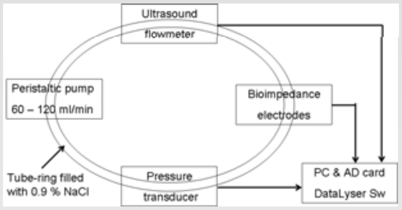
Balloon Volume And Impedance Pulse Amplitude



Results

1)Balloon inflation decreased the electrical impedance pulse amplitude, identical to flow change.
2)Balloon catheter inflation elicited decreased flow.
3)Doppler and electrical impedance signals showed identical relationship to decreased flow (R^2=0.966) .

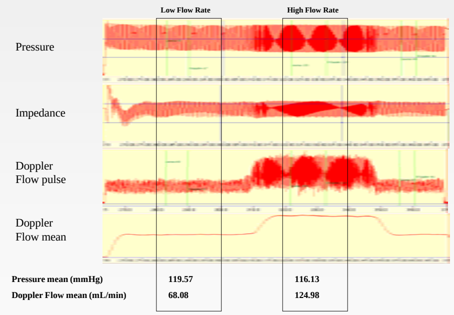
Methods- Flow Change



A closed loop was created with PVC and C-Flex tubing filled with 0.9 % NaCl. This loop included a Doppler in-line flow probe (4N) connected to an ultrasound flow meter (T201 Ultrasonic Bloodflow Meter, Transonic Systems, Ithaca, NY); a disposable pressure transducer (Argon Medical Devices, Athens, TX) connected to a Blood Pressure Analyzer (Digi-Med, Micro-Med, Louisville, KY); a peristaltic pump (Masterflex, L/S, Cole-Palmer, USA) with flow rate set to 60 and 120 mL/min; and two stainless steel metal tubes (14 mm in length and 3 mm internal diameter) used as electrical impedance electrodes connected to a bipolar impedance amplifier (KR-Ea RHEO Preamp, OTE Galileo, Italy). Measurement frequency was 45 kHz and the resistance between the two electrode tubes was above 10 ohm (maximum balance). Signals were stored in a PC using an AD card (PCI-MIO-16XE-10, National Instruments, Austin, TX) with 16 bit resolution. The data sampling rate was 200 Hz.
Data was analyzed with DataLyser software (WRAIR, Baranyi). Electrical impedance and pressure values were calculated by taking the first derivative of the impedance pulse amplitude; next, the negative values were converted to positive ones and then finally a running integral was calculated with a 5 second time window.

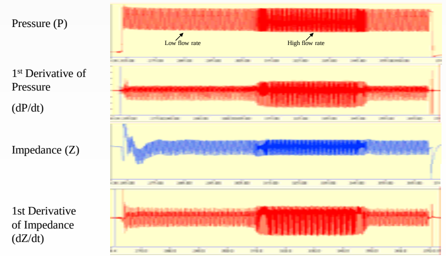
NB: Doppler flow pulse was used as reference in data processing.

Results



Increased flow resulted ONLY in increased pulse amplitude and mean flow of the Doppler signal

Pressure And Impedance Traces With Low And High Flow Rate



The pressure and impedance signal amplitudes were not effected by changes in pump flow rate. However, amplitude differences were observed when the 1st derivative was taken.

Results

Doubling the Flow Rate:
• Effected the pulse amplitude and mean flow of the Doppler signal (increased)
•Did *not* effect the amplitudes of the pressure and electrical impedance signals
•However, the amplitude increase can be seen in the pressure and electrical impedance signals when the first derivative (dP/dt and dZ/dt) is taken.

Comparison Of Doppler Flow And Electrical Impedance During Low And High Flow Rates

		Doppler Flow			Impedance		
	Pump Flow Rate	Display	Amplitude	Mean	Amplitude	1st Derivative (dZ.dt)	Integral of 1st Derivative
	mL/min	mL/min	mL/min	mL/min	a.u	a.u.	a.u.
mean	60	67	68.13	3.58	2.83	0.09	0.44
SD			17.3	0.005	1.51	0.05	0.004
mean	120	124	124.98	4.15	2.83	0.18	0.91
SD			47.9	0.01	1.54	0.09	0.003
ratio	2.00	1.85	1.83	1.16	1.00	2.00	2.07

The effects of increased flow rate were comparable between Doppler and Impedance when the impedance derivations were calculated.

Conclusion

Results of in vitro electrical impedance studies are:
1) Modeling vasospasm/brain ischemia detected decreased pulsatile volume and flow.
2) Doppler and electrical impedance signals showed identical relationship to decreased flow.
3) Electrical impedance pulse change reflected volume change.
4) However, the increased flow resistance caused by balloon inflation also decreased flow.

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