Study of the Dynamics of Transcephalic Cerebral Impedance Data during Cardio-Vascular Surgery

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Abstract. Postoperative neurological deficits are one of the risks associated with cardio vascular surgery, necessitating development of new techniques for cerebral monitoring. In this study an experimental observation regarding the dynamics of transcephalic Electrical Bioimpedance (EBI) in patients undergoing cardiac surgery with and without extracorporeal circulation (ECC) was conducted to investigate the potential use of electrical Bioimpedance for cerebral monitoring in cardio vascular surgery. Tetrapolar transcephalic EBI measurements at single frequency of 50 kHz were recorded prior to and during cardio vascular surgery. The obtained results show that the transcephalic impedance decreases in both groups of patients as operation starts, however slight differences in these two groups were also observed with the cerebral impedance reduction in patients having no ECC being less common and not as pronounced as in the ECC group. Changes in the cerebral impedance were in agreement with changes of haematocrit and temperature. The origin of EBI changes is still unexplained however these results encourage us to continue investigating the application of electrical bioimpedance cerebral monitoring clinically.

1. Introduction
Coronary artery disease (CAD) is rated as the first cause of death in world[1]. Many patients with CAD require coronary artery bypass surgery in order to reduce angina and the risk of death. However major neurological and neurophysiological deficits have been reported after cardiac surgery for cardiopulmonary bypass [2]. Different etiologic mechanisms have been reported to be responsible for these deficits [3-5]. One common problem associated with cardio vascular surgery is hypo-perfusion, but irrespective of the origin of the problem a reliable and easy to use method for monitoring the brain during a cardiac bypass surgery would be advantageous. EBI could be one candidate for such purpose.

1.1. Electrical bioimpedance cerebral monitoring (EBCM)
Electrical bioimpedance (EBI) is a safe, non-invasive method currently clinically available for different applications like skin cancer screening[6], impedance pneumography or body composition assessment [7]. It has been shown that following an incident of neurological damage like stroke or
cerebral hypoxia the electrical properties of the cerebral tissue changes as a result of changes in the
tissue structure and composition which is detectable by electrical bioimpedance[8-11].

1.2. Monitoring hypo-perfusion
Hypo-perfusion reduces the blood flow at first changing the electrical properties of cerebral, if hypo-
perfusion extends over time cerebral hypoxia or even ischemia may occur, thus modifying further the
changes in the electrical properties of brain tissue.

Under the assumption that EBI measurements could be used to monitor the status of the brain
during cardiopulmonary bypass (CPB), in this paper the dynamics of EBI measurements from two
groups of patients undergoing cardio vascular surgery with and without ECC have been analysed
together with other physiological variables to study the possibility of using cerebral impedance from
EBI recordings.

2. Materials and Methods
Tetrapolar EBI measurements were recorded from two groups of patients undergoing cardio vascular
surgery. Cardiovascular surgery can be done with or without the use of heart-lung-machine,
eextracorporal circulation (ECC). This study includes seven (n=7) patients with ECC and six (n=6)
patients without ECC. It has been done with an ethical approval from the regional ethical review board
of Gothenburg.

2.1 EBI recordings
Transcephalic EBI measurements were recorded at the single frequency of 50 kHz. Recordings started
at least 30 minutes prior to start of the cardio vascular surgery and continued for the whole operation.

2.2 Haematocrit and temperature recordings
Together with EBI and cerebral impedance measurements haematocrit (HCT) and temperature were
also recorded from all patients.

3. Results
3.1 EBI dynamics with and without ECC
In figure 1, it is possible to observe that after a relatively stable baseline recorded for 20-30 minutes,
the recorded cerebral EBI decreases during surgery for the seven patients undergoing the cardio
vascular surgery with ECC. For the Non-ECC cases it can be seen in figure 2, that in half of the
patients the changes are very small, less than 1 Ohm, while in the other 3 impedance reduction from
baseline is as large as the changes seen in the ECC cases.

Figure 1. Cerebral EBI for patients with ECC

Figure 2. Cerebral EBI for patients without ECC
3.1 Haematocrit and temperature
In both groups the pre-operation haematocrit level \( HCT_{PRE\_OP} \) was very similar with a mean group value of 115 for the ECC group and 124 for the non-ECC group. While in the non-ECC group the mean HCT level decreased slightly to 113, in the ECC group the level decreased down to 81. In Table 1 and 2, the differences between HCT levels before the surgery and during the surgery for each patient are listed. As it can be seen, the HCT level of patients with ECC exhibit higher changes than to those without ECC. Haematocrit decreases as the operation starts.

![Figure 3](image)

**Figure 3.** Temperature over time for patients undergoing the operation with and without ECC

4. Discussion
The results indicate that the cerebral impedance drops as the operation starts. The reduction in the cerebral impedance can be easily observed not only on patients having ECC but it can also be seen in half of the patients not having ECC. A general reduction on the haematocrit level has been also reported for both cases, but more pronounced in the ECC patients. Since Geddes and Saddler have shown that resistivity is exponentially related to haematocrit [12], the reported reduction might be partially responsible for the observed reduction in the measured cerebral impedance.

A temperature increase over 2.5 ° Celsius is seen in the ECC group. Since the resistivity of ionic conductors depends on temperature and changes of around 2%/°C on EBI can be expected as reported in [13] it is very likely that the temperature change also contributes to the change of cerebral EBI.

### Table 1. Changes in the hematocrit value in each patient before the operation and during the operation (with ECC)

| Patient Nr | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean |
|------------|---|---|---|---|---|---|---|------|
| \( HCT_{PRE\_OP} - HCT_{PER\_OP} \) | 27 | 43 | 61 | 30 | 31 | 41 | 34 |

### Table 2. Changes in the hematocrit value in each patient before the operation and during the operation (without ECC)

| Patient Nr | 1 | 2 | 3 | 4 | 5 | 6 | Mean |
|------------|---|---|---|---|---|---|------|
| \( HCT_{PRE\_OP} - HCT_{PER\_OP} \) | 4 | 7 | 8 | 14 | 16 | 19 | 11.3 |
5. Conclusion
For EBCM to become a monitoring tool for prompt detection of Brain damage during Cardiovascular surgery, it is required to establish a reference baseline for comparison and if the baseline value changes due to external factors of the surgery like haematocrit levels or temperature the reference value must be compensated properly to keep the possibility of performing a fair comparison between EBI recording that would allow changes produced by the hypo-perfusion.

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