CASE REPORT

Processed EEG and non-invasive cerebral oximetry (cerebral rSO_2) monitoring in transcatheter aortic valve implantation

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ABSTRACT

Transcatheter aortic-valve implantation (TAVI) has been suggested as a less invasive treatment for high-risk patients with aortic stenosis. Ischemic events remain a troublesome risk following TAVI. The use of neuromonitoring with cerebral rSO2 and Processed EEG may contribute to detect and correct imbalances in the oxygen demand-to-delivery ratio.

We describe two clinical cases of TAVI procedure-related complications with cerebrovascular repercussions that reflected on cerebral oximetry and electrical activity as detected by NIRS and processed EEG. Cerebral rSO2 and processed raw EEG monitoring is relevant and useful in this setting, enabling clinicians to identify and possibly take preventive/corrective actions on the peri-operative setting, in order to minimize secondary damage due to ischemic/hypoxic events.

Key words: Processed EEG; Cerebral Non-Invasive Oximetry- rSO_2; Aortic Stenosis; TAVI; Neuromonitoring

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INTRODUCTION

Aortic stenosis, a progressive narrowing of the aortic valve, is one of the most common valve problems in developed countries. Surgical aortic valve replacement with cardiopulmonary bypass is the treatment of choice for symptomatic aortic stenosis but carries a significant risk of morbidity and mortality, particularly in high-risk patients.[1] Transcatheter aortic valve implantation (TAVI) has emerged as the treatment of choice for high-risk and inoperable patients with severe symptomatic aortic stenosis.[2]

Clinically apparent neurologic injury is higher in patients undergoing TAVI compared with surgical aortic valve replacement (AVR) at 30 days and 1 year[3] and mainly occurs during an early high hazard phase in the first days following implantation.[4] The most likely mechanisms of neurologic injury after TAVI are cerebral embolization and hypoperfusion. Silent neurologic injury is also a potential complication after TAVI, suggested by high incidence of acute cerebral ischemic lesions detected on diffusion weighted magnetic resonance imaging (DW-MRI).[5]

Mixed venous oxygen saturation (SvO_2) is still the 'gold standard' for the determination of the systemic oxygen delivery to consumption ratio in cardiac surgery patients. Recent data suggest that regional cerebral oxygen saturation (cerebral rSO_2) determined by near-infrared spectroscopy (NIRS)

Figure 1: INVOS® monitor showing asymmetry in the values and a fall of 27% from the baseline value in the left hemisphere.

Figure 2: Contrast cerebral CT scan of the same patient. It shows a right temporal acute hematoma

Figure 3: Processed EEG index value sudden drop to zero (white arrow).

Figure 4: CNIO (Cerebral rSO2) showing low values bilaterally, with significant drop from baseline (white arrows)

is closely related to SvO_2. Cerebral non-invasive oximetry (CNIO) by NIRS, offers the possibility to non-invasively determine the cerebral oxygen balance and might reflect not only regional but also the systemic oxygen balance.[6] Decreases in rSO_2 >20 % from baseline have been associated with cerebral ischemia and increased peri-operative morbidity. Processed electroencephalography and bispectral index (BIS) analysis measure electrical activity in the brain and possibly correlate with the oxygen supply and demand balance.[7]

As described above, monitoring oxygen demand-to-delivery ratio intraoperatively, by both cerebral rSO_2/NIRS and processed EEG/BIS, may offer an "opportunity window" to evaluate brain function and to detect and correct mild imbalances that would possibly correlate with poor outcomes after procedure and would go unnoticed otherwise. The aim of this report, is to describe the clinical cases of two patients that underwent TAVI under neuromonitoring with both CNIO (rSO_2) and Processed EEG (BIS), during which two different major adverse events were detected and echoed by this monitors, reflecting the importance of their widespread use during these procedures.

CASES REPORT 1

A 61 years old man, status ASA IV, underwent TAVI with a transfemoral approach. During the procedure, an acute cerebral inter-hemispheric asymmetry and significant reduction on cerebral left hemisphere oximetry (Cerebral rSO_2) was detected by INVOS®/NIRS cerebral oximeter monitor (Figure 1), rising the suspicion of an ischemic/hemorrhagic cerebral event. No drugs or surgical interventions were done at this time that would explain the sudden drop in left cerebral oximetry. A cerebral CT scan (Figure 2) was performed afterwards, showing an image compatible with a right temporal hemorrhagic event. The patient emerged from anaesthesia but developed and remained with neurologic sequelae.

CASES REPORT 2

An 80 year old woman, status ASA IV, underwent a transapical TAVI. During the procedure, an acute change in patient neurologic status occurred mirrored by Processed EEG monitor, with BIS Index suddenly dropping to zero (Figure 3) and non-invasive cerebral oximetry (rSO_2) values on INVOS monitor being significantly lower than baseline (Figure 4). The status change was communicated to the surgeon and an iatrogenic ventricular rupture, with absolute cardiac output failure, was then detected. It was successively repaired and procedure was concluded. The patient died 30 days later from untreatable cardiogenic shock.

DISCUSSION

Transcatheter aortic valve implantation (TAVI) is a recent procedure, in which a bioprosthetic valve is inserted through a catheter and implanted within the diseased native aortic valve. Until now, all the studies of TAVI have been observational registry studies, without standardization of end-point definitions and without controlled populations. There is a lack and paucity of rigorous, evidence-based clinical data to substantiate the incremental benefits of TAVI, when compared to current standard therapies. Stroke and other cerebrovascular events, remain a possible and troublesome adverse event, with severe impact following TAVI; they occur more frequently among patients who undergo TAVI, than among patients who receive standard therapy. Recently, diffusion-weighted magnetic resonance imaging studies have shown new perfusion deficits in many patients after TAVI, possibly due to atherothrombotic micro and macro emboli.[5] The combination of less traumatic TAVI systems than the ones currently in use, novel cerebral protection devices and multimodal (neuro-) monitoring is taking place, in an effort to reduce the frequency of embolic neurologic/cerebrovascular events associated with TAVI. Additional randomized clinical trials are needed to compare the frequency of peri-procedural strokes/cerebrovascular events after TAVI, with frequency after surgical aortic valve replacement.

Most CNS monitors are designed to monitor cerebral hemodynamics or cerebral electrical activity. Direct and indirect monitoring of brain oxygenation can be obtained by measurement of brain tissue oxygen tension ($PtiO_2$) or the jugular venous oxygen saturation ($SjvO_2$). Both techniques have proven their value in several studies and in daily clinical practice. These invasive monitoring systems may be associated with severe complications and cannot be performed routinely in all anesthetized patients.

Non-invasive neuromonitoring is being rapidly integrated into our daily practice because of its lack of adverse effects. In the last decade, technological research has expanded the application of near-infrared spectroscopy (NIRS) to allow continuous, non-invasive, and bedside monitoring of regional cerebral oxygen saturation (rSO_2) through the scalp and skull, providing accurate information on the balance between brain oxygen supply / demand. Cerebral rSO_2 / NIRS measures oxygenation in the biological tissue, mainly at the microcirculation level (capillaries, arterioles, and venules) based on different absorption characteristics of the chromophores oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb) in the near-infrared light spectrum. Hemoglobin oxygen saturation in cerebral tissue, can be determined by measuring this differential absorption of various wavelengths of light as they follow a curvilinear path through the extra-cranial and cerebral tissue before being reflected. Because these monitors measure trends only, a baseline has to be established first, and cerebral oximetry values need to be maintained at or near the preoperative baseline. Another approach is to keep the cerebral oxygen saturation at levels within 20% to 25% of the anesthesia pre-induction value. This means that clinical intervention should be based on changes of cerebral rSO_2 from the initial baseline value.

Several studies have demonstrated an increased incidence of adverse perioperative outcomes in patients who demonstrate substantial cerebral oxygen desaturation during surgery. These negative outcomes include neuropsychological dysfunction, prolonged hospital length of stay, major organ morbidity, and mortality. Although cerebral oximetry is increasingly being used in many clinical settings, it has yet to be adopted as a clinical standard of care. However, if effective cerebral rSO_2/NIRS-guided interventional strategies could be instituted, improvement in perioperative outcomes might be possible.

Processed raw EEG data, using bispectral analysis, measures electrical activity in the brain, providing a direct correlation with depth of consciousness (hypnosis). It enables to assess consciousness and sedation independent of cardiovascular reactivity; an Index is generated so a value of 100 indicates the patient is fully awake and a value of 0 indicates the absence of brain activity; this monitoring also gives us access to other derived parameters from the EEG, from which we can interpret "brain functional status" and metabolism.

Processed EEG data and cerebral non-invasive oximetry (rSO_2) / NIRS parameters were used and combined in these cases, reflecting the balance of cerebral oxygen supply-to-demand ratio which is directly related to the relationship between cerebral perfusion / oxygenation and cerebral metabolism / function. The changes observed in both parameters correlated well with the clinical and radiological findings, procedure technical steps and complications, as well as patient outcomes. They showed to be relevant and useful tools to identify cerebral tissue hypoxia/ischemia due both to cerebrovascular events and cerebral perfusion repercussions of major systemic, cardiovascular and hemodynamic changes inherent to TAVI procedure.

CONCLUSION

Given clinical evidence shows that non-invasive cerebral oximetry (rSO_2) and processed EEG monitoring are relevant and useful, reflecting the balance of cerebral oxygen supply-to-demand ratio. They allow monitoring of the changes in cerebral cortex regional blood oxygen saturation, guiding of the anaesthetic management according to patients needs and procedural events, and identification and better management of complications.

Recent clinical experience indicates that such actions can prevent/reduce neurological injuries associated with surgery or critical care situations, and therefore, improve patient's outcome and reduce the cost of care.

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Authors' contribution:

RC: Concept, conduction of study, literature search, manuscript editing

AVS, JM, MC: Literature search, manuscript editing

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