Anti-decubitus bed mattress may interfere with cerebrovascular pressure reactivity measures due to induced ICP and ABP cyclic peaks

Journal of Clinical Monitoring and Computing (2021) 35:423–425
https://doi.org/10.1007/s10877-020-00471-5

LETTER TO THE EDITOR

Anti-decubitus bed mattress may interfere with cerebrovascular pressure reactivity measures due to induced ICP and ABP cyclic peaks

Tas Jeanette[1] · Borg Melisa[1] · Smielewski Peter[2] · Czosnyka Marek[2] · Beqiri Erta[4] · Ercole Ari[3] · Aries Marcel[1]

Received: 31 October 2019 / Accepted: 22 January 2020 / Published online: 8 February 2020

Abstract

Severe traumatic brain injury (TBI) patients are monitored with continuous arterial blood pressure (ABP) and intracranial pressure (ICP). The pressure reactivity index (PRx) is a frequently used correlation coefficient between ABP and ICP to inform clinicians at the bedside about trends in global cerebrovascular pressure regulation status. We present an unexpected influence of cyclic anti-decubitus mattress inflations and deflations on invasive ICP, ABP and PRx calculations in our TBI patients. This might affect autoregulation guided management. In our database, 23% (9/39) of the patients show recurrent peaks in the monitoring signals. We hypothesize that these peaks are caused by (a combination) of hydrostatic change, local (cervical) compression and/or incorrect sensor zeroing due to positional changes induced by the anti-decubitus mattress. This warrants further investigation by the manufacturer and exploration of data filters.

Keywords Anti-decubitus bed mattress · ICP · Prx

To the Editor,

International guidelines suggest to monitoring severe traumatic brain injury (TBI) patients with continuous arterial blood pressure (ABP) and intracranial pressure (ICP) to assess the cerebral perfusion pressure with these signals [1]. Additional, information about brain vessel reactivity and compensatory reserve can be computed. The pressure reactivity index (PRx) may inform clinicians at the bedside about trends in global cerebrovascular pressure reactivity status [2]. Currently, a randomized controlled phase II intervention trial (acronym COGiTATE; www.cppopt.org) evaluates the feasibility and safety of PRx guided management of cerebral perfusion pressure therapy in severe TBI patients [3]. PRx is computed as the moving correlation coefficient between spontaneous slow waves in ABP and ICP [2, 4]. In this letter, we present an unexpected influence of cyclic anti-decubitus mattress inflations and deflations on invasive ICP, ABP and PRx calculation in TBI patients.

During retrospective data examination in one of our TBI patients recordings we noticed a sudden onset of regular, periodic (10 min cycle) increases in the ICP (intraparenchymal Neurovent P-TEMP sensor, Raumedic AG) and ABP signals (radial artery, Edward Lifesciences). The duration and amplitude of the peaks was around 3.5 min and 1.5–2 mmHg, respectively, for both signals. PRx became positive during these periods suggesting sudden deterioration of cerebrovascular pressure reactivity (Fig. 1). Upon further scrutiny of previously monitored patients, we noticed similar patterns occurring in 9 out of 39 TBI patients (23%) admitted in our unit during the period 2016–2019.

We hypothesized that the peaks were caused by the repetitive deflation and inflation of the anti-decubitus bed mattress (type 750 ESRI NV, Belgium) which has a default cycling frequency of once per 10 min. Changing the setting to 25 min cycles or switching to a static mode had indeed

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10877-020-00471-5) contains supplementary material, which is available to authorized users.

✉ Tas Jeanette
jeanette.tas@mumc.nl

[1] Department of Intensive Care, University of Maastricht, Maastricht University Medical Center, Maastricht, The Netherlands

[2] Brain Physics Laboratory, Division of Neurosurgery, Department of Clinical Neurosciences, University of Cambridge, Cambridge, UK

[3] Division of Anaesthesia, University of Cambridge, Cambridge, UK

[4] Physiology and Transplantation, University of Milan, Milano, Italy

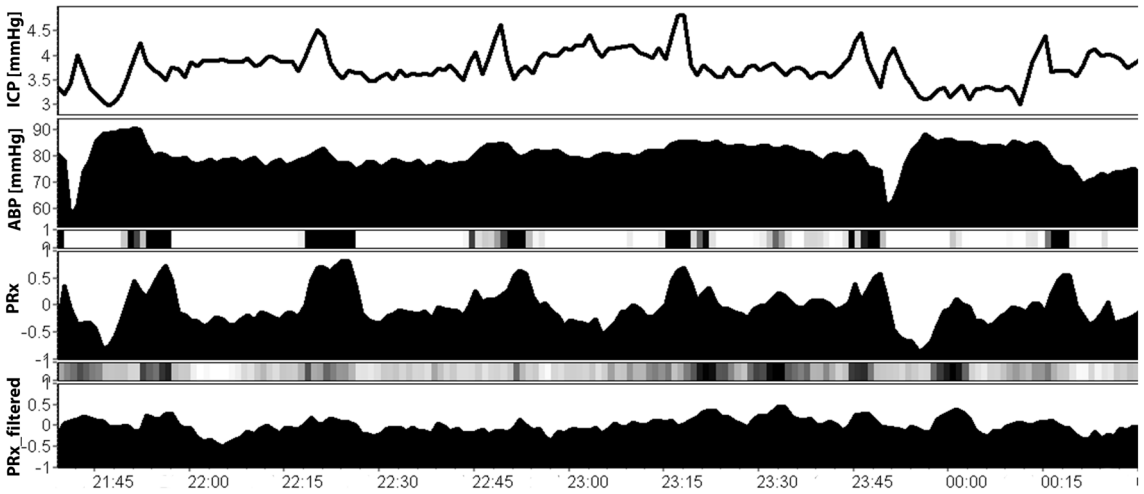

Fig. 1 A representative signal recording from a TBI patient showing cyclic peaks in the ICP signal. These peaks are difficult to observe visually in the ABP signal. The mean PRx value of this period is around 0 indicating preserved cerebrovascular pressure reactivity. However, during the ICP peaks PRx temporarily exceeds 0.5, indicating cerebrovascular pressure reactivity impairment. 'PRx filtered' is based on high pass filtered ABP and ICP signal, which removes frequencies < 0.004 Hz. The filtered signal shows a more stable PRx trend. *ICP* intracranial pressure, *ABP* arterial blood pressure, *PRx* pressure reactivity index, *TBI* traumatic brain injury

a direct effect on the signals (Fig. 2). Supplemental Fig. S1 shows in detail how this mattress works. To obtain a better understanding of the effect of the bed mattress we recorded the upper body of a TBI patient showing the cyclic peaks. The recording shows that the whole body moves around 1 cm upwards. The head region—which rests on the static part of the mattress—moves also backwards (supplemental video S2). Several hypotheses were tested to understand the cause of this phenomenon.

1 ICP peaks

We constructed a 'phantom' consisting of a Neurovent ICP sensor inserted into a 500 ml soft plastic (closed) bottle filled with water and put it on the 30° head up upper (static) part of the bed mattress. The bed mattress was set at the static mode and subsequently at 10 min cycles. The cyclic ICP peaks appeared with similar patterns as observed in our patients. However, the peaks disappeared when we put the bottle in a firm open plastic box on the head up part, excluding an electromagnetic cause of the interference. This experiment also excludes a flow or pressure phenomenon originating from the systemic circulation (induced by the bed mattress) as the peaks were induced in a closed bottle. From this experiment

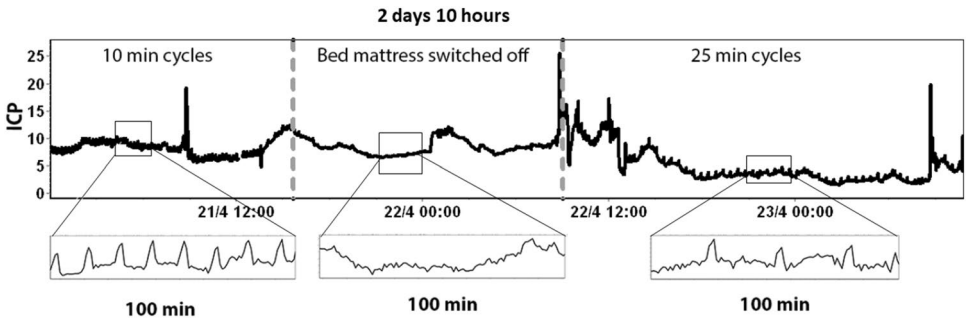

Fig. 2 The ICP signal was recorded with different bed mattress settings in a TBI patient. During the first period, the bed mattress was set at 10 min cycles. During the second period, the cyclic deflation-inflation was temporarily switched off. During the third period, the bed mattress was set at 25 min cycles. The figures at the bottom are magnifications of each period spanning 100 min periods and ICP peak height between 1.5 and 2 mmHg. *ICP* intracranial pressure, *TBI* traumatic brain injury

we hypothesize that the mattress exerts localized pressure on structures positioned on top of it or induces a hydrostatic effect by tilting, or a combination of both. In a TBI patient with low brain compliance changes in head position or local compression of cervical venous structures might be responsible for the observed cyclic ICP peaks. To test the latter, we put a hard plate under the patient's pillow down to the shoulders in a TBI patient with cyclic peaks in the ICP signal. With this intervention the ICP peaks disappeared (supplemental Fig. S3).

2 ABP peaks

Besides ICP peaks we also detected cyclic peaks in the ABP signals. These peaks had a similar duration and amplitude (and were in phase with the ICP signal (Fig. 2). However, the pattern of the ABP peaks over time was less pronounced, likely due to higher absolute values and higher amplitude of natural fluctuations in the signal. In contrast to the intraparenchymal ICP measurement, leveling and zeroing is needed for reliable ABP and CVP monitoring. For correct monitoring the zero level needs to remain fixed during the recording. As can be seen in the video this requirement is not fulfilled (supplemental video S2). We hypothesized that the peaks in ABP were predominantly caused by an upward movement in patients' body relative compared to the (fixed) transducer. We also measured the central venous pressure (CVP) in one TBI patient clearly showing cyclic peaks of around 3 mmHg. Indeed, when we fixed the zero transducer to the patient's body the cyclic peaks disappeared.

3 Autoregulation (correlation based) measurements

As mentioned earlier, the observed changes in the absolute ABP and ICP signals are small and seem of limited clinical relevance. However, these cyclic phenomena may become clinically relevant in the context of waveform derived parameters like PRx, which, being a simple correlation coefficient, is influenced by simultaneous, signal changes. The point here is that ABP and ICP peaks seem to be independently affected by the mattress. They are likely not related to cerebrovascular pressure reactivity mediated transmission of ABP waves to ICP.

The peaks were present in only 23% of our monitored patients. It is unknown whether individual differences in trauma or brain pathology, anatomy or body position have any effect on the presence of the peaks.

In conclusion, we have shown that the cyclic anti-decubital mattress has effects on physiological signal recordings like ICP and ABP in severe TBI patients. Clinicians should be aware of this and that widely used autoregulation correlation indices like PRx may be somewhat adversely influenced by these cyclic phenomena.

Acknowledgements The excellent medical and technical support of the medical and nursing staff of the intensive care unit at the Maastricht University Medical Center is gratefully acknowledged.

Compliance with ethical standards

Conflict of interest ICM+ software for brain monitoring (https://icmplus.neurosurg.cam.ac.uk) is licensed by the University of Cambridge (Cambridge Enterprise Ltd, Cambridge, UK). Marek Czosnyka and Peter Smielewski have a financial interest in part of the licensing fee.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Carney N, Totten AM, Reilly CO, et al. Guidelines for the management of severe traumatic brain injury, fourth edition. Neurosurgery. 2017;80:6–15. https://doi.org/10.1227/NEU.0000000000001432.
2. Czosnyka M, Smielewski P, Kirkpatrick P, et al. Continuous assessment of the cerebral vasomotor reactivity. Neurosurgery. 1997;41:11–9.
3. Beqiri E, Smielewski P, Robba C, et al. Feasibility of individualised severe traumatic brain injury management using an automated assessment of optimal cerebral perfusion pressure: the COGiTATE phase II study protocol. BMJ Open. 2019. https://doi.org/10.1136/bmjopen-2019-030727.
4. Brady KM, Shaffner DH, Lee JK, et al. Continuous monitoring of cerebrovascular pressure reactivity after traumatic brain injury in children. Pediatrics. 2009;124:e1205–e12121212. https://doi.org/10.1542/peds.2009-0550.