Anti-decubitus bed mattress may interfere with autoregulation 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]

[1] Department of Intensive Care, University of Maastricht, Maastricht University Medical Center, Maastricht, Netherlands.
[2] Department of Clinical Neurosciences, Division of Neurosurgery, University of Cambridge, Cambridge, UK.
[3] Division of Anaesthesia, University of Cambridge, Cambridge, UK.
[4] Physiology and Transplantation, University of Milan, Milano, Italy.

Correspondence to:
Tas J, Msc
Email: Jeanette.tas@mumc.nl

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.

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 cerebral vascular reactivity with these signals [1]. Additional information about brain vessel reactivity and compensatory reserve can be computed with such signals. The pressure reactivity index (PRx) may inform clinicians at the bedside about trends in global cerebral autoregulation (CA) status [2]. At the moment a randomized controlled phase II intervention trial (acronym COGiTATE; www.cppopt.org) will evaluate the feasibility and effectiveness of PRx guided 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 the unexpected influence of the cyclic anti-decubitus matrass inflation and deflation on invasive ICP, ABP and PRx calculation in TBI patients.

During retrospective data inspection in one of our TBI patient recordings we noticed a sudden 10 minute cyclic increase 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 minutes and around 1.5-2 mmHg for both signals. The PRx became positive during these periods indicating sudden impaired CA (**figure 1).** Further scrutiny of previously monitored patients, we noticed similar peaks in 8 out of 38 TBI patients (21%) during the period 2016-2019.

We hypothesized that the peaks were caused by the de-and inflation of the anti-decubitus bed mattress (type 750 ESRI NV, Belgium) which has a default frequency cycle of once per 10 minutes. Changing the setting to 25 minute cycles or switching to a static mode had a direct effect on the signals **(figure 2).** Supplemental **figure S1** shows in detail how this mattress works. To obtain a better understanding of the effect of the bed mattress we filmed the upper body part of a TBI patient showing the cyclic peaks. The film 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.

ICP peaks

We constructed a 'phantom' to investigate consisting of a Neurovent ICP sensor inserted into a 500 ml

soft plastic (closed) bottle filled with water and put it on the 30^0 head up upper (static) part of the bed mattress. The bed mattress was set at the static mode and subsequent into 10 minute cycles. The cyclic ICP peaks appeared with similar configurations 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 we hypothesize that the mattress might squeeze local structures on top of it, induce a hydrostatic effect by tilting or a combination of effects. 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 from top of the head until the shoulders in a TBI patient with cyclic peaks. With this intervention the artefactual ICP peaks disappeared.

ABP peaks

Besides ICP peaks we also detected cyclic peaks in the ABP signals. These peaks had a similar duration and were in phase with the ICP signal **(figure 2)**. However, the pattern of the ABP peaks over time was less obvious visible due to higher absolute values and more fluctuations in the signal. Therefore, we transduced the central venous pressure (CVP) in one TBI patients clearly showing cyclic peaks of around 3 mmHg. Different from 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 assumption is violated (**figure S3**). We hypothesized that the peaks in ABP were predominantly caused by an upward change in patients' body compared to the (fixed) transducer. When we fixed the zero transducer to the patient's body the cyclic peaks disappeared. We cannot exclude that besides this positioning cause also local (physiological) effects of the bed mattress contribute to the cyclic changes.

Autoregulation (correlation based) measurements

As mentioned in the text, the observed changes in the absolute ABP and ICP signals are small and seem of limited clinical relevance. However, these cyclic phenomena become clinically relevant as a correlation analysis (like the PRx coefficient) is heavily influenced by simultaneous signal changes. And since the ABP and ICP peaks seem to have a different origin, the PRx values during these periods are artefactual and should be disregarded.

The peaks are present in only 21% of our monitored patients. It is unknown whether individual differences in trauma or brain pathology, anatomy or body position have effect on the presence of the peaks.

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

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Figure legends

Figure 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 autoregulation. However, during the ICP peaks the PRx temporarily gets values > 0.5 indicating autoregulation impairment. 'PRx filtered' is the computed PRx value from the high pass filtered ABP and ICP signal, removing frequencies < 0.004. The filtered signal shows a stable PRx trend. ICP = intracranial pressure; ABP = arterial blood pressure; PRx = pressure reactivity index; TBI = traumatic brain injury.

Figure 2. The ICP signal is recorded with different bed mattress settings in a TBI patient. During the first period, the bed mattress is set at 10 minutes cycles. During the second period, the cyclic deflation-inflation is temporarily switched off. During the third period, the bed mattress is set at 25 minutes cycles. The figures at the bottom are magnifications of each period spanning 100 minutes periods. ICP = intracranial pressure; TBI = traumatic brain injury.

Supplemental material

Figure S1. The mattress has transverse alternating A and B cells, and a static head region covering the upper 30 centimetres. When the A cells inflate, the B-cells deflate until the A and B cells are on a similar level (starting position, period I). Then both the A and B cells start to inflate to the maximum inflation (period II). During period III, both cells start deflating together to the starting position whereupon the A cells further inflate and the B-cells further deflate (period IV). A whole period of inflation and deflation is one bed mattress cycle. This bed mattress cycle repeats - depending on the bed mattress setting - every 10, 15 or 25 minutes. The period that A and B cells together in- and deflate (period I-IV) is similar to the width of the peaks that we detected in our ICP signal (around 3.5 minute).

Video S2. A 64 times speed up recording of a patient's neck and upper body (written consent provided by the family). Three cycles of inflation and deflation are shown. The patient's head and neck moves upwards and backwards and the lower body moves upwards.

Figure S3. A recording from a TBI patient showing cyclic ICP peaks. In the first part of the recording the ICP peaks are visible every ten minutes. In the second period a hard plate is placed underneath the patient's pillow covering the patient's head and neck until the shoulders. Shown is that the peaks are dampened. ICP = intracranial pressure

Figure 1

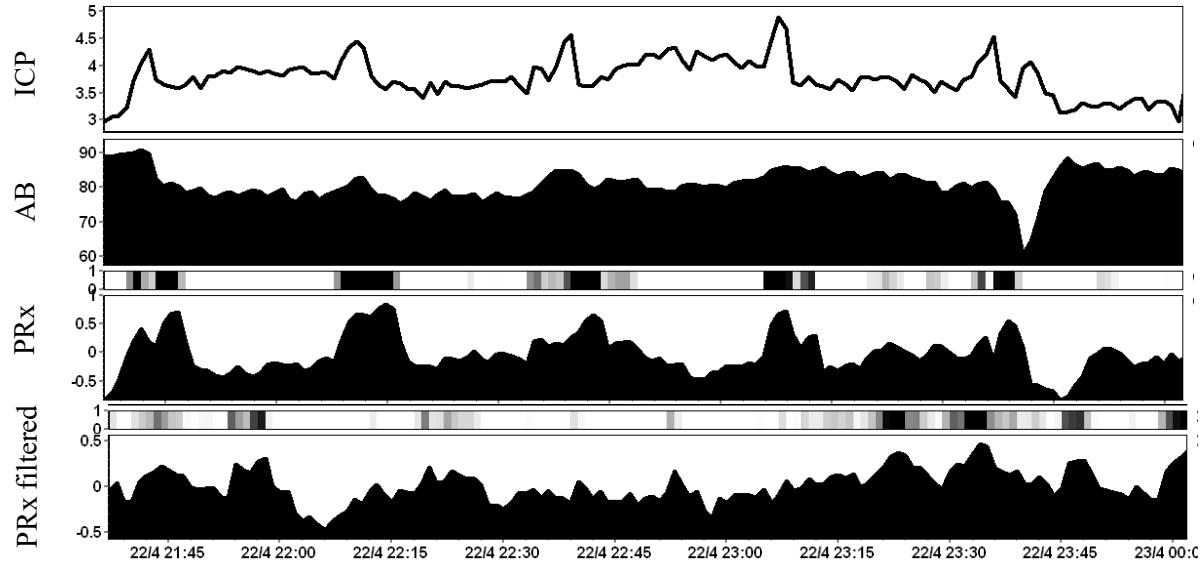

ICP
AB
PRx
PRx filtered
5
4.5
4
3.5
3
90
80
70
60
1
0
0.5
0
-0.5
22/4 21:45
22/4 22:00
22/4 22:15
22/4 22:30
22/4 22:45
22/4 23:00
22/4 23:15
22/4 23:30
22/4 23:45

Figure 2

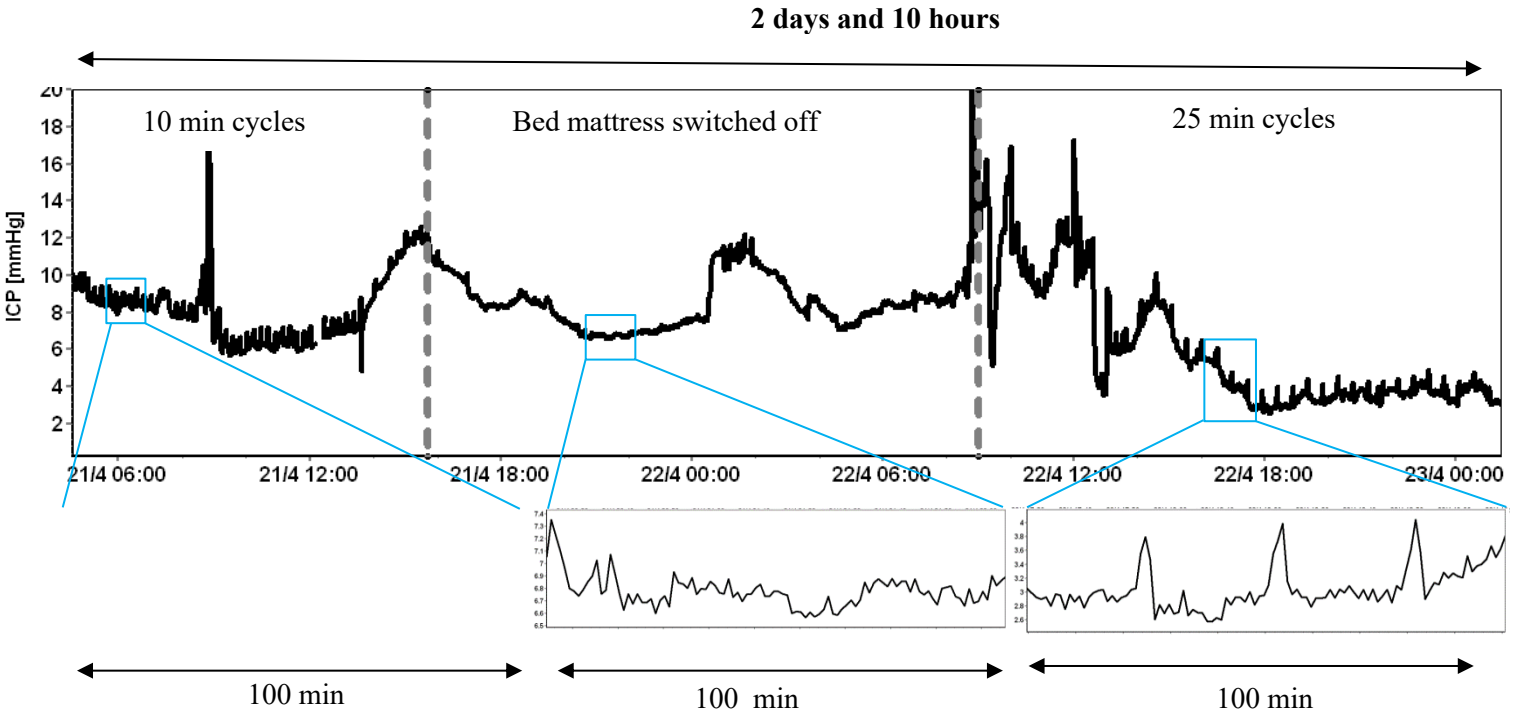

2 days and 10 hours
10 min cycles
Bed mattress switched off
25 min cycles
ICP [mmHg]
20
18
16
14
12
10
8
6
4
2
21/4 06:00
21/4 12:00
21/4 18:00
22/4 00:00
22/4 06:00
22/4 12:00
22/4 18:00
23/4 00:00
100 min
100 min
100 min

Figure S1

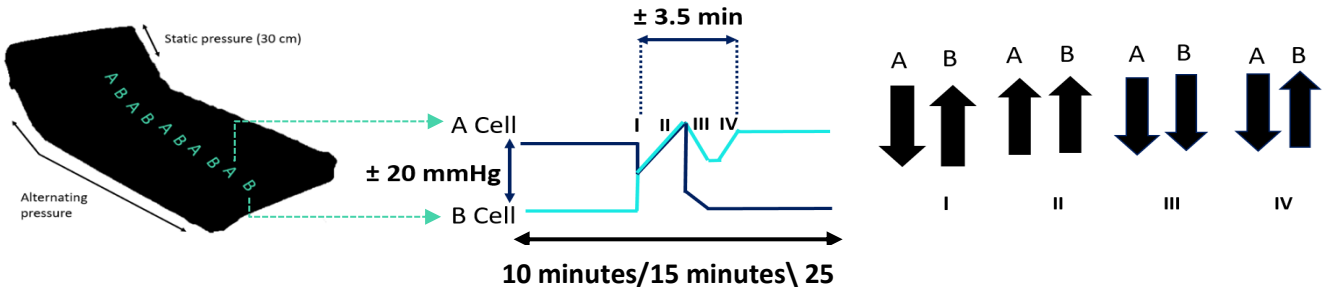
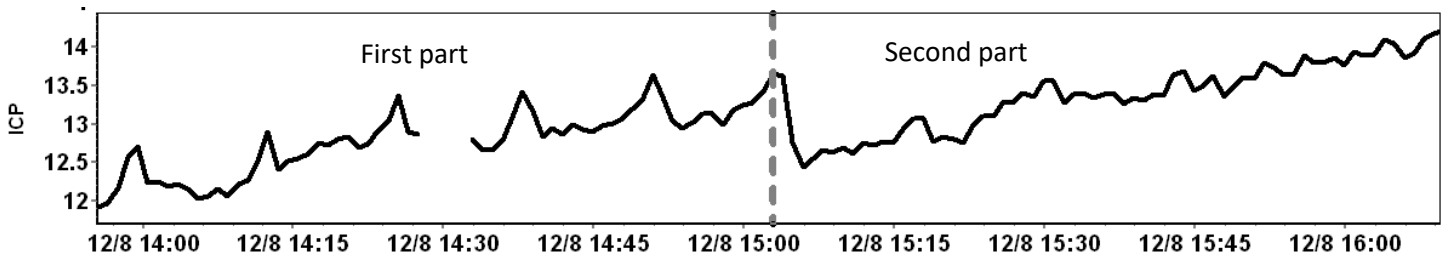

Static pressure (30 cm)
A B A B A B A B
Alternating pressure
A Cell
B Cell
± 20 mmHg
± 3.5 min
I II III IV
10 minutes/15 minutes\ 25
A B A B A B A B
I II III IV

Figure S3


ICP
14
13.5
13
12.5
12
First part
Second part
12/8 14:00
12/8 14:15
12/8 14:30
12/8 14:45
12/8 15:00
12/8 15:15
12/8 15:30
12/8 15:45
12/8 16:00