Evaluation of Intracranial Pressure in Different Body Postures and Disease Entities

Morten Andresen, Amer Hadi, and Marianne Juhler

Abstract We currently do not have sufficient knowledge regarding appropriate boundaries between "normal" and "abnormal" intracranial pressure (ICP) in humans. Our objective in this study was to quantify the effects of postural changes on ICP in normal and ill subjects. As a model for normal patients, we included adult patients scheduled for complete removal of a solitary, clearly demarcated, small brain tumor and performed long-term ICP monitoring using a telemetric device. The ill subjects included required invasive ICP monitoring as part of their diagnostic workup or monitoring of the effect of shunt treatment at our department. All patients were included prospectively for a session of monitored changes in body posture. In our preliminary results from 19 patients, we were able to statistically distinguish between patient groups and assumed body postures, highlighting the need for the further characterization of the effects of postural changes on ICP to inform diagnostic and therapeutic decisions.

Keywords Normal values • Reference range • Hydrocephalus • Idiopathic intracranial hypertension

Introduction

Deviations in intracranial pressure (ICP) are used to distinguish between healthy and ill subjects. Evaluation of the type, form, and magnitude of these deviations informs our current understanding of disease entities such as idiopathic intracranial hypertension (IIH) and normal-pressure hydrocephalus. Unfortunately, this understanding is severely hampered by insufficient knowledge of appropriate boundaries between "normal" and "abnormal," and by the amount of expected variations in ICP simply because of changes in body posture.

We previously investigated the clinical and technical quality of long-term ICP monitoring carried out in the patient's home, with the patient performing their regular daily activities [1], and found that this type of monitoring is safe and reliable even for cable-based ICP monitoring. Additionally, this method affords us a different perspective on when symptoms arise and in which situations overdrainage occurs.

If we are to realize the full potential of these monitoring sessions, we need reference ranges not only for the supine position but also for the upright position. Ideally, we would have access to these reference ranges for different disease entities and a comparative group of normal individuals. Based on these requirements, our objective in this study was to quantify the effects of postural changes on ICP in normal and ill subjects. Specifically, we investigated whether the magnitude of the change in ICP was different across patient groups, and if our group of ill subjects had a different ICP than "normals" when assuming specific body postures.

Materials and Methods

For the group of ill subjects, we included all patients with hydrocephalus or IIH requiring invasive ICP monitoring at our department from February 2013 to May 2013. All patients were monitored using the Neurovent-P or Neurovent-P-tel intraparenchymal probes, and participated in a standardized session of monitored changes in body posture.

For ethical reasons, our group of normal subjects could not consist of completely healthy subjects. Instead, we opted to define a model for the normal ICP in humans, in which we included adult patients scheduled for complete removal of a solitary, clearly demarcated, small brain tumor.

M. Andresen, MD • A. Hadi • M. Juhler, MD, DMSc
Clinic of Neurosurgery, Copenhagen University Hospital, Copenhagen, Denmark
e-mail: andresen@gmail.com

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After obtaining informed consent, a telemetric ICP monitoring device was inserted at the end of their operation, which allowed us to perform long-term postoperative follow-up, without the need for repeated surgical procedures for insertion of ICP probes. This group of patients has been described more thoroughly elsewhere [2].

In our standardized session of monitored changes in body posture, patients were monitored in the supine and vertical position, and while sitting in a chair, assuming the correct lateral lumbar puncture position. Each position was maintained for 10 min, with 1–2 min in between each standardized posture to allow for stabilization of ICP. Figure 1 shows an example of the posture-related drop in ICP upon assuming the upright position.

For each assumed body posture, the median ICP was calculated, and used as the basis for regression models evaluating the influence of patient diagnosis and body posture on median ICP.

Results

In the study period, we included 19 patients (4 normal, 9 hydrocephalus, and 6 IIH). Our normal and ill subjects had a mean age of 67 (range, 58–85) and 32 (range, 8–71) respectively.

Linear regression of median ICP based on patient posture and disease entity presented a significant model ($p<0.001$), but could not distinguish between patient groups ($p=0.98$). We then modified the model to look at differences in ICP between body postures, with the supine position as the baseline for each comparison. This analysis may be viewed as a measure of the stability of ICP in the face of postural change. This model was highly significant ($p<0.001$), with adjusted $R^2=0.88$. Both body posture ($p<0.001$) and disease entity ($p<0.001$) proved to be highly significant factors in this model.

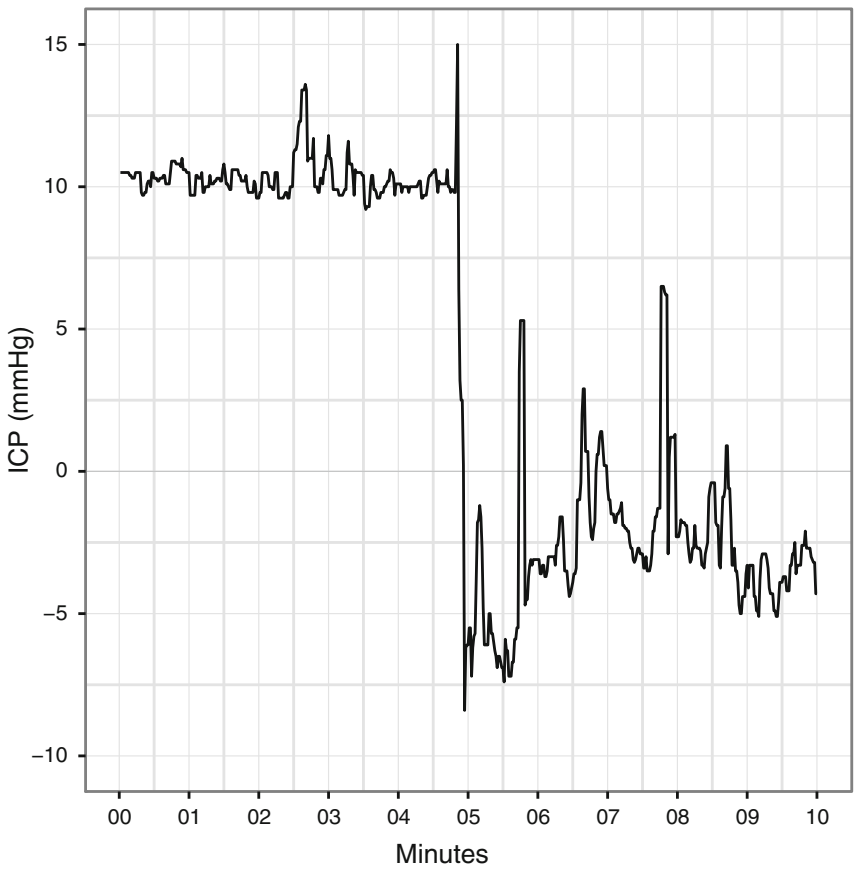

Fig. 1 Example of posture-related change in intracranial pressure (ICP) when switching from the supine to the upright position. Note how quickly a new equilibrium is attained. The example is a 1-Hz trend curve

Discussion

When considering ICP as a function of body posture, the primary focus has been on head-tilt angles in patients observed in the ICU [3–5], and to a much lesser degree the physiological changes in ICP as the result of full changes in posture from the supine to the vertical position [6], or from the supine to the lateral recumbent lumbar puncture position. This has been the case even though our patients primarily maintain the upright position during their daily life. As a result, reference ranges for ICP are usually reported for patients assuming the supine position, which may be appropriate and useful for the comatose ICU patient, but does not help to inform therapeutic decisions in our young hydrocephalic patients leading an active life.

In this study, differences in ICP between body postures enabled us to distinguish the group of normal subjects from the ill subjects consisting of hydrocephalus and IIH patients. Based on our results, normal subjects appear able to more tightly regulate ICP when switching body postures, but do not display deviations in median ICP across groups. Our results highlight the necessity for the further characterization of postural changes in ICP to improve diagnostic accuracy and the optimization of shunt treatment.

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Conflict of Interest The authors declare that they have no conflict of interest.

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References

1. Andresen M, Juhler M, Munch TN (2012) Quality and safety of home ICP monitoring compared with in-hospital monitoring. Acta Neurochir Suppl 113:187–191
2. Andresen M, Juhler M (2014) Intracranial pressure following complete removal of a small demarcated brain tumor: a model for normal intracranial pressure in humans. J Neurosurg 121(4):797–801
3. Brimioulle S, Moraine JJ, Norrenberg D, Kahn RJ (1997) Effects of positioning and exercise on intracranial pressure in a neurosurgical intensive care unit. Phys Ther 77:1682–1689
4. Mahfoud F, Beck J, Raabe A (2010) Intracranial pressure pulse amplitude during changes in head elevation: a new parameter for determining optimum cerebral perfusion pressure? Acta Neurochir 152:443–450
5. Ledwith MB, Bloom S, Maloney-Wilensky E et al (2010) Effect of body position on cerebral oxygenation and physiologic parameters in patients with acute neurological conditions. J Neurosci Nurs 42:280–287
6. Magnaes B (1976) Body position and cerebrospinal fluid pressure. Part 1: clinical studies on the effect of rapid postural changes. J Neurosurg 44:687–697