Child's Nervous System (2019) 35:913–916
https://doi.org/10.1007/s00381-019-04139-7

BRIEF COMMUNICATION

Does the prone sleeping position affect the intracranial dural venous flow?

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Received: 8 August 2018 / Accepted: 21 March 2019 / Published online: 30 March 2019

Abstract

Purpose There are few studies documenting the effect of posture on intracranial dural venous flow. The aim of the present study was to explore alterations caused by the prone position using magnetic resonance (MR) venography.

Methods A total of eight patients (five men and three women) underwent non-contrast MR venography in both supine and prone positions.

Results In the prone position, an increase in intracranial dural venous flow was found in all patients in the non-dominant transverse and sigmoid sinuses. An increase in venous flow to the straight sinus was observed in 75% of the patients. Flow to the superior ophthalmic vein decreased in three patients. No postural flow alterations were observed in any of the patients in the superior sagittal, dominant transverse, and sigmoid sinuses.

Conclusion Based on results of the study, in the prone sleeping position, part of the intracranial venous flow may be preferentially drained through the straight and non-dominant transverse sinuses.

Keywords Intracranial venous flow · Prone position · Dural sinus · MRV

Introduction

The intracranial dural venous circulation involves the superficial and deep drainage systems; the former includes the superior sagittal (SSS), transverse, and sigmoid sinuses and the latter includes the straight and transverse sinuses. In humans, the transverse sinus functions both as superficial and deep drainage system and is morphologically asymmetrical. The right transverse sinus receives the majority of drainage from the SSS, while the hypoplastic left sinus from the straight sinus [1, 10, 11]. The morphology of these sinuses has been hypothesized to be defined by development of the brain and postural hemodynamic changes [9]. Similarly, postural changes have been shown to alter the dural venous circulation [3]. Several investigations have shown that the internal jugular veins are the primary pathway of intracranial venous flow in the supine position, while these veins are collapsed in the standing position with the flow shunted to an alternative venous pathway [2, 4, 8]. In contrast, flow velocity of the straight sinus was not observed to sustain postural alterations [7]. However, to our knowledge, there has not been a study documenting postural alterations of the intracranial dural venous flow in the prone sleeping position.

The aim of the present study was to explore such alterations using magnetic resonance (MR) venography.

Materials and methods

The present study included patients who presented to our hospital on an outpatient basis. A total of eight patients comprising five men and three women in the age range of 16–59 years (mean age, 40 years) were recruited. The patients had complaints of headache, dizziness, and tinnitus. Initial examinations with axial T1- and T2-weighted MR imaging, T2-gradient echo, fluid-attenuated inversion recovery, and diffusion-weighted sequences confirmed that none of the patients had dural sinus thrombosis, cerebral infarction, encephalitis, brain tumors, traumatic brain injury, or hydrocephalus. The patients further underwent non-contrast MR venography

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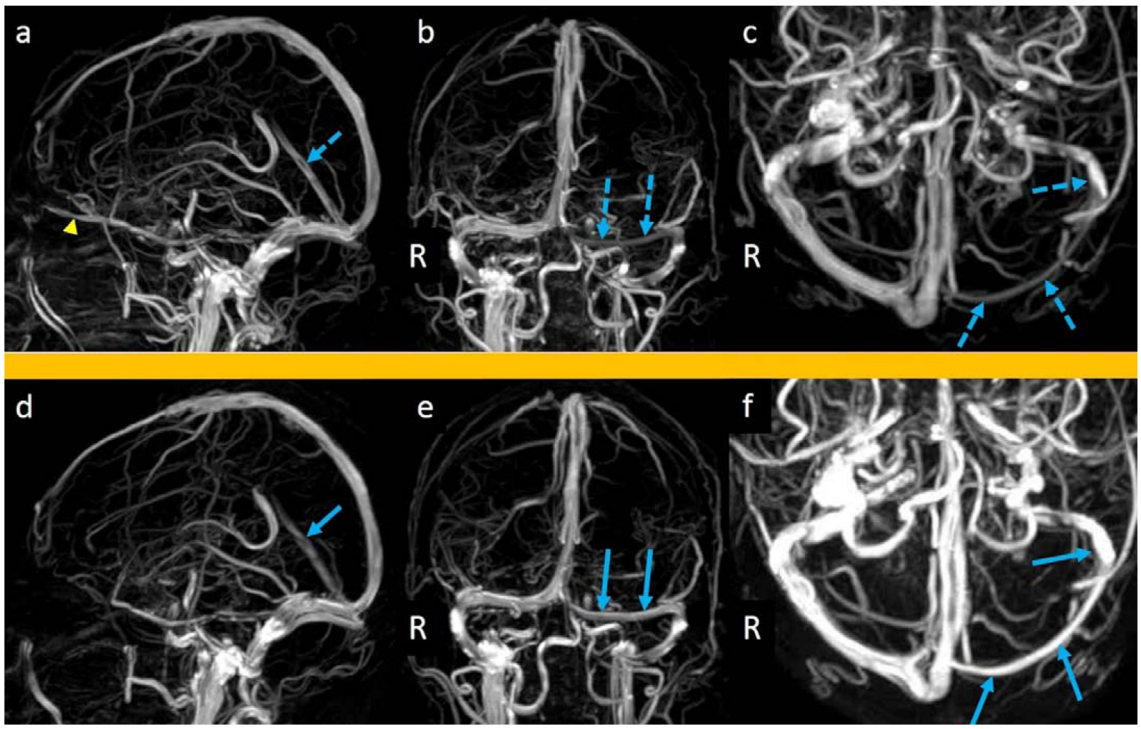

Fig. 1 Lateral (**a**, **d**), anteroposterior (**b**, e), and basal (**c**, **f**) views of magnetic resonance venography of a 25-year-old man, performed in the supine (**a**–**c**) and prone position (**d**–**f**), showing an increased flow in the straight sinus (**a**, **d**) and non-dominant transverse and sigmoid sinuses (**b**, **c**, **e**, **f**). Note that the flow in the superior ophthalmic vein (**a**, arrowhead) decreases in the prone position (**a**, **d**). R, right; Dotted arrow, sinus flow in the supine position; Solid arrow, sinus flow in the prone position

in both supine and prone positions, consecutively. Both scans were performed with the patient's neck adjusted in the same curvature, with the neck not flexed, not extended, and not rotated in both face-up and face-down position against the examination table. The following parameters were standardized for both positions: repetition time, 7.58 ms; echo time,

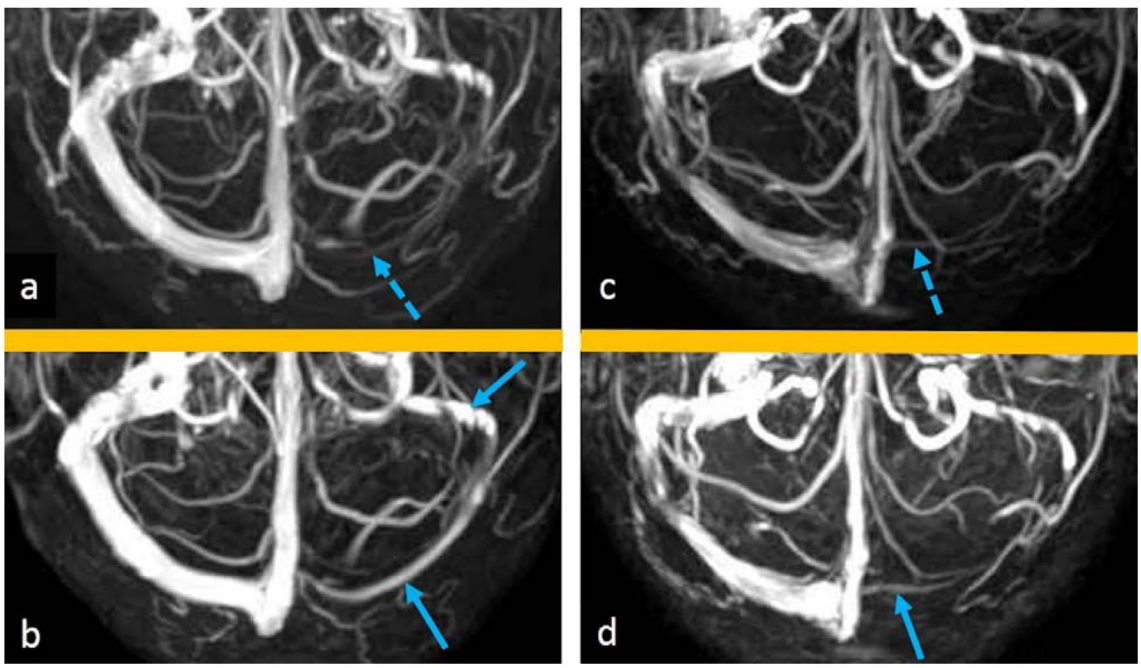

Fig. 2 **a**–**d** Basal views of magnetic resonance venography of two patients taken in the supine (**a**, **c**) and prone (**b**, **d**) position showing a considerably increased flow in the non-dominant transverse and sigmoid sinuses in one patient (**a**: dotted arrow; **b:** arrow), while in the other, only a slight increase is found, which is limited to the proximal part of the non-dominant transverse sinus (**c**: dotted arrow; **d:** arrow)

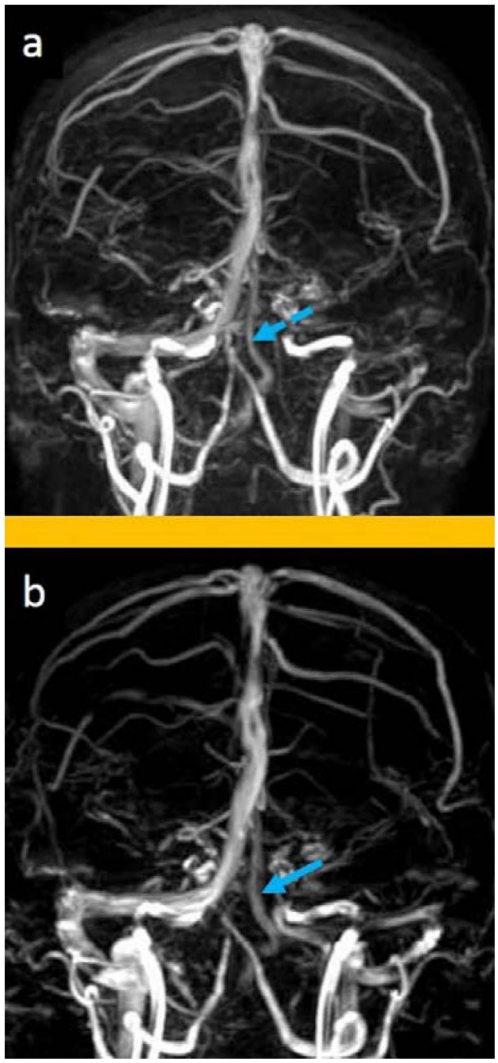

Fig. 3 Anteroposterior views of magnetic resonance venography of a 48-year-old man taken in the supine (**a**) and prone (**b**) position showing an increased flow in the occipital sinus in the prone position (**a** and **b**, arrow)

4.35 ms; field-of-view, 250 mm × 250 mm; flip angle, 10°; and scan duration, 4 min 30 s. All the scans were obtained using a 3.0 T MR scanner (Achieva R2.6; Philips Medical Systems; Best, The Netherlands). Imaging data were transferred to a workstation (Virtual Place Lexus64, 64 edition; AZE; Tokyo, Japan) and analyzed independently by two of the authors (S.T. and H.I.).

The present study was performed in accordance with our institution's guidelines for human research. Informed consent was obtained from all patients prior to participation in the present study.

Results

In seven (88%) of the eight patients, the right transverse sinus was dominant, while the left transverse sinus was dominant in one. In the prone position, an increase in venous flow was found in all patients in the straight and non-dominant transverse and sigmoid sinuses (Fig. 1). In six (75%) patients, flow in the straight sinus was found to increase in the prone position, while flow in the non-dominant transverse sinus was observed to increase in all, with varying degrees (Fig. 2). In three (38%) patients, flow in the superior ophthalmic vein was found to decrease, while in one subject, flow in the occipital sinus was found to increase in the prone position (Fig. 3). In the SSS, dominant transverse and sigmoid sinuses, postural flow alterations were not noted in any of the patients.

Discussion

In the present study, an increase in flow was observed in the prone position, as compared with the supine position, in most of the straight and non-dominant transverse and sigmoid sinuses. Furthermore, in three of eight patients, flow in the superior ophthalmic vein, connecting to the deep venous drainage system, decreased in the prone position. In contrast, flow in the SSS and dominant transverse sinus did not decrease in the prone position. Therefore, we assumed these observations suggest that in the prone position, for some reasons, venous outflow from the brain increases.

Healthy human infants tend to sleep in the prone position rather than the supine position [12].However, the prone sleeping position is a known risk factor for sudden infant death syndrome (SIDS) [6]. A plausible explanation for occurrence of SIDS may be frequent and considerable elevations in intracranial pressure during physiological sleep exacerbated by impairment of venous return through the non-dominant transverse sinus that may function as buffer for pressure shock [13]. However, the readers should be cautioned that these are merely preliminary and non-quantitative observations in adults. They may not apply to children and especially to newborns and infants with their unique venous circulation that may include a well-developed occipital sinus.

The present study has certain limitations. First, the sample size of our investigation was insufficient for validating the results. Second, imaging data were obtained only from non-contrast venography, which in comparison with contrast venography produces less clear images [5]. Furthermore, data were not quantitatively analyzed. Nonetheless, the consistent outcomes reported through this preliminary study can aid in enhancing knowledge of the alterations in the intracranial dural venous flow in the prone sleeping position.

Conclusion

In the prone sleeping position, part of the intracranial venous flow may be preferentially drained through the straight and non-dominant transverse sinuses.

Author contributions All the authors equally contributed to the study.
Satoshi Tsutsumi projected the study.
Hisato Ishii and Yukimasa Yasumoto collected the imaging data.
Hideo Ono and Hisato Ishii analyzed the imaging data.
Satoshi Tsutsumi wrote the manuscript.

Compliance with ethical standards The present study was performed in accordance with our institution's guidelines for human research. Informed consent was obtained from all patients prior to participation in the present study.

Conflict of interest The authors have no conflict of interest concerning the materials or methods used in this study or the findings presented in this paper.

References

1. Durst CR, Ornan DA, Reardon MA, Mehndiratta P, Mukherjee S, Starke RM, Wintermark M, Evans A, Jensen ME, Crowley RW, Gaughen J, Liu KC (2016) Prevalence of dural venous sinus stenosis and hypoplasia in a generalized population. J Neurointerv Surg 8(11):1173–1177
2. Gisolf J, van Lieshout JJ, van Heusden K, Pott F, Stok WJ, Karemaker JM (2004) Human cerebral venous outflow pathway depends on posture and central venous pressure. J Physiol 560(Pt 1:317–327
3. Grady MS, Bedford RF, Park TS (1986) Changes in superior sagittal sinus pressure in children with head elevation, jugular compression, and PEEP. J Neurosurg 65(2):199–202
4. Holmlund P, Jobansson E, Qvarlander S, Wåhlin A, Ambarki K, Koskinen LD, Malm J, Eklund A (2017) Human jugular vein collapse in the upright posture: implications for postural intracranial pressure regulation. Fluids Barriers CNS 14(1):17
5. Kramer LA, Cohen AM, Hasan KM, Heimbigner JH, Barreto AD, Brod SA, Narayana PA, Wolinsky JS (2014) Contrast enhanced MR venography with gadofosveset trisodium: evaluation of the intracranial and extracranial venous system. J Magn Reson Imaging 40(3):630–640
6. Matthews T (2002) Sudden infant death syndrome–a defect in circulatory control? Child Care Health Dev 28(Suppl 1):41–43
7. Mosso M, Schmid-Priscoveanu A, Straumann D, Baumgartner RW (2008) Absence of gravity-dependent modulation of straight sinus flow velocity in healthy humans. Ultrasound Med Biol 34(5):726–729
8. Niggemann P, Kuchta J, Grosskurth D, Beyer HK, Krings T, Reinges M (2011) Position dependent changes of the cerebral venous drainage-implications for the imaging of the cervical spine. Cent Eur Neurosurg 72(1):32–37
9. Okudera T, Huang YP, Ohta T, Yokota A, Nakamura Y, Maehara F, Utsunomiya H, Uemura K, Fukasawa H (1994) Development of posterior fossa dural sinuses, emissary veins, and jugular bulb: morphological and radiologic study. AJNR Am J Neuroradiol 15(10):1871–1883
10. Rhoton AL Jr (2002) The cerebral veins. Neurosurgery 51(4 Suppl):S159–S205
11. Schuchardt F, Schroeder L, Anastasopoulos C, Markl M, Bäuerle J, Hennemuth A, Drexl J, Valdueza JM, Mader I, Harloff A (2015) In vivo analysis of physiological 3D blood flow of cerebral veins. Eur Radiol 25(8):2371–2380
12. Togari H, Kato I, Saito N, Yamaguchi N (2000) The healthy human infant tends to sleep in the prone rather than the supine position. Early Hum Dev 59(3):151–158
13. Yokota A, Matsuoka S, Ishikawa T, Kohshi K, Kajiwara H (1989) Overnight recordings of intracranial pressure and electroencephalography in neurosurgical patients. Part II: Changes in intracranial pressure during sleep. J UOEH 11(4):383–391