Brief Report

Magnetoencephalography and normal pressure hydrocephalus: A case report

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Abstract

In a case study of an 82-year old male spontaneous magnetoencephalography recordings revealed lower magnetic fields at frontal and frontotemporal regions compared to central and posterior regions. This finding correlated well with the significant ventricular distention, and specifically the enlargement of the frontal horns of the lateral ventricles, observed in presurgical computed tomography. The regional pattern of magnetoencephalography signal decrease in normal pressure hydrocephalus seems to be quite different from that encountered in brain atrophy. In the latter case, a more generalized distribution of low magnetic fields is observed, possibly reflecting the high sensitivity of magnetoencephalography to activity originating in sulci. Acquired data suggest that magnetoencephalography may be able to differentiate between normal pressure hydrocephalus and brain atrophy. Furthermore, magnetoencephalography could potentially constitute a non-invasive, non-imaging tool, useful in the selection of patients with normal pressure hydrocephalus suited to undergo shunt surgery.

Keywords

Magnetoencephalography; normal pressure hydrocephalus; ventriculoperitoneal Shunt; brain atrophy; computed tomography

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1. Introduction

Hydrocephalus is a medical condition in which there is an abnormal accumulation of cerebrospinal fluid (CSF) in the ventricles or cavities of the brain. This may cause increased intracranial pressure inside the skull and progressive enlargement of the head, tunnel vision, convulsion and mental disability. Hydrocephalus can also cause death. Although it does occur in older adults, it is more common in infants. The most common cause of hydrocephalus is CSF flow obstruction, hindering the free passage of cerebrospinal fluid through the ventricular system and subarachnoid space. Hydrocephalus can also be caused by overproduction of cerebrospinal fluid [1]. Bilateral ureteric obstruction is a rare, but reported, cause of hydrocephalus. Based on its underlying mechanisms, hydrocephalus can be classified into communicating and non-communicating. Both forms can be either congenital or acquired. In adults over 60 years of age the symptoms of hydrocephalus include memory loss, increasing loss of reasoning skills, difficulty in walking, poor balance and coordination, as well as a frequent urge to urinate or loss of bladder control. To relieve pressure on the brain caused by CSF accumulation, ventriculoperitoneal (VP) shunting is often employed. This is a surgical procedure in which a VP shunt, i.e. a medical device, is placed inside one of the brain's ventricles to divert fluid away from the brain and restore normal CSF flow and absorption [2].

Normal pressure hydrocephalus (NPH) is a type of hydrocephalus that usually occurs in older adults. NPH is different to other types of hydrocephalus in that it develops slowly over time. The drainage of CSF is blocked gradually and excess fluid builds up slowly. The slow enlargement of the ventricles means that, unlike other types of hydrocephalus, NPH is often associated with little or no increase in intracranial pressure. Nevertheless, NPH can still cause symptoms. In most cases of NPH the cause of blockage to the CSF absorptive pathways is unclear [2]. Although computed tomography (CT) is able to visualize the anatomical changes of NPH, magnetic resonance (MR) imaging is the best imaging modality to depict anatomical changes and the diagnosis can further be supported by CSF flow studies. Liebig *et al.* [3] have reviewed the imaging techniques employed in diagnosis and differential diagnosis of communicating hydrocephalus.

Magnetoencephalography (MEG) exhibits extremely high temporal resolution (better than one millisecond) and complements other brain activity mapping techniques, such as electroencephalography (EEG), positron emission tomography (PET), and functional magnetic resonance imaging (fMRI). MEG and EEG signals possess important differences [4]. Compared to EEG, MEG is characterized by a better spatial resolution because magnetic fields are less distorted by the skull and scalp than electric fields. In contrast to the scalp EEG which is sensitive to both tangential and radial components, MEG detects only the tangential components of a current source in a spherical volume conductor. Scalp EEG can detect activity both in the sulci and at the top of the cortical gyri, whereas MEG is most sensitive to activity originating in sulci. Finally, MEG is reference-free, while scalp EEG relies on a reference that makes data interpretation difficult. The decay of magnetic fields as a function of distance is more pronounced than for electric fields [5]. Therefore, MEG is more sensitive to superficial cortical activity.

The main aim of this work is to present a case study investigating the ability of MEG to detect abnormal magnetic fields in NPH. The

main question is: Could MEG constitute a potentially suitable tool for supporting clinical diagnosis of NPH over brain atrophy and facilitate decision making in relation to which NPH patients are most likely to benefit from VP shunting?

2. Materials and Methods

An 82-year old male was subjected to brain CT. His symptoms included headaches, dementia, urinary incontinence, and gait instability. As shown in Fig. 1, CT images presented enlarged lateral and third ventricles that were out of proportion with the enlarged cortical sulci. A MEG examination was performed before VP shunting. Following shunt insertion, the patient's symptoms were alleviated. The patient suffered a cerebral hemorrhagic episode one year later and died after surgery. Informed consent for the methodology and the aim of the study was obtained from the patient prior to the procedure.

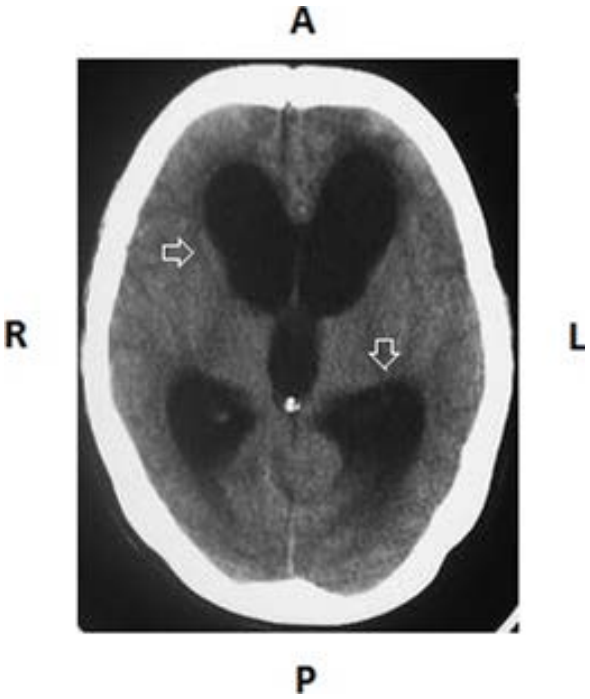

Fig. 1. CT image of the NPH patient before insertion of a VP Shunt. Arrows indicate ventricular distention and periventricular edema is apparent. A: anterior, P: posterior, L: left, R: right.

The resting state MEG recordings were carried out in a magnetically shielded room with a whole head 122-channel biomagnetometer (Neuromag-122^{TM}, Elekta, Sweden) as described in previous studies [6–8]. During the recordings the patient sat in in a chair with his head covered by a helmet-shaped dewar. To reduce artifacts, he was instructed to close his eyes and avoid blinking or otherwise moving during the recordings. The MEG sampling frequency was 400 Hz and the associated Nyquist frequency was 200 Hz, which was well above the constituent frequency components of interest in the MEG recordings, thus avoiding aliasing artifacts. The time required for each MEG recording was three minutes (bandwidth 0.03-100 Hz).

3. Results

The plotting program, xplotter, from the MEG software workstation (Neuromag-122) was used to plot data derived from continuous, spontaneous activity recordings. The scale of the planar gradiometer MEG channels was set in fT/cm. Fig. 2 shows data derived from an artifact-free, short segment (in the order of ms) of the continuous, spontaneous MEG recordings. Low MEG data are observed in the frontal region, as well as in the left and right temporofrontal regions, compared to the data originating from the central and posterior regions. MEG values originating anteriorly were lower when compared to those arising from the left and right temporofrontal regions. The MEG amplitudes recorded from the enlarged channels 31, 43, 8 and 92, shown in Fig. 2, are: channel 31 (MEG_{min} = -112 fT/cm, MEG_{max} = 14 fT/cm); channel 43 (MEG_{min} = −234 fT/cm, MEG_{max} = 203 fT/cm; channel 8 (MEG_{min} = −213 fT/cm, MEG_{max} = 46 fT/cm); channel 92 (MEG_{min} = −422 fT/cm, MEG_{max} = 609 fT/cm). The vertical scale for MEG was (MEG_{min} = −697 fT/cm, MEG_{max} = 697 fT/cm).

4. Discussion

There are only a few reports in the literature concerning the use of MEG in hydrocephalus and most of them refer to children and young adults. Mäkelä & Hari [9] studied a patient with a communicating hydrocephalus using a whole-head neuromagnetometer. Auditory evoked fields were elicited with 600 ms tones, 0.25, 0.5, 1, 2, and 4 kHz in frequency. Despite apparent decrease of white matter, the patient's thalamocortical connections seemed to be able to maintain normal evoked and spontaneous cortical activity. Morisako *et al.* [10] reported a case of enlarged perivascular spaces (EPVS) in the mesencephalothalamic region associated with hydrocephalus. A 56-year old woman with EPVS-associated hydrocephalus underwent third ventriculostomy and biopsy. They compared pre- and postoperative MEG and tractography data to evaluate the effects of EPVS. Castillo *et al.* [11] studied the relation between cortical oscillatory rhythms and the structural integrity of the corpus callosum in 21 children with spina bifida and hydrocephalus (SBH). Children with SBH showed reduced values of spectral power in the posterior and temporal regions in the theta, alpha, and beta bands when compared with age-matched controls. Simos *et al.* [12] explored features of brain organization in children with spina bifida meningomyelocele and shunted hydrocephalus. The authors concluded that in these children a complex pattern of changes in cortical morphology and activation may serve as evidence for functional and structural brain reorganization ensuring preservation of language and decoding abilities. Malekpour *et al.* [13] investigated the impact of the posterior callosal anomalies associated with SBH on interhemispheric cortical connectivity. It was found that in children with SBH, posterior effective and functional connectivity between hemispheres, as well as posterior cortical power, are generally reduced.

There are two types of hydrocephalus that mainly affect adults: NPH and hydrocephalus exo-vaco. Hydrocephalus exo-vaco develops following brain damage by a stroke or when the brain has suffered a traumatic injury. NPH can develop at any age, although it is most common in older people. A variety of problems can cause NPH (e.g. head trauma, tumors, infection, subarachnoid hemorrhage). The most common treatment applied in hydrocephalus patients is the surgical insertion of a VP shunt. This treatment most often restores

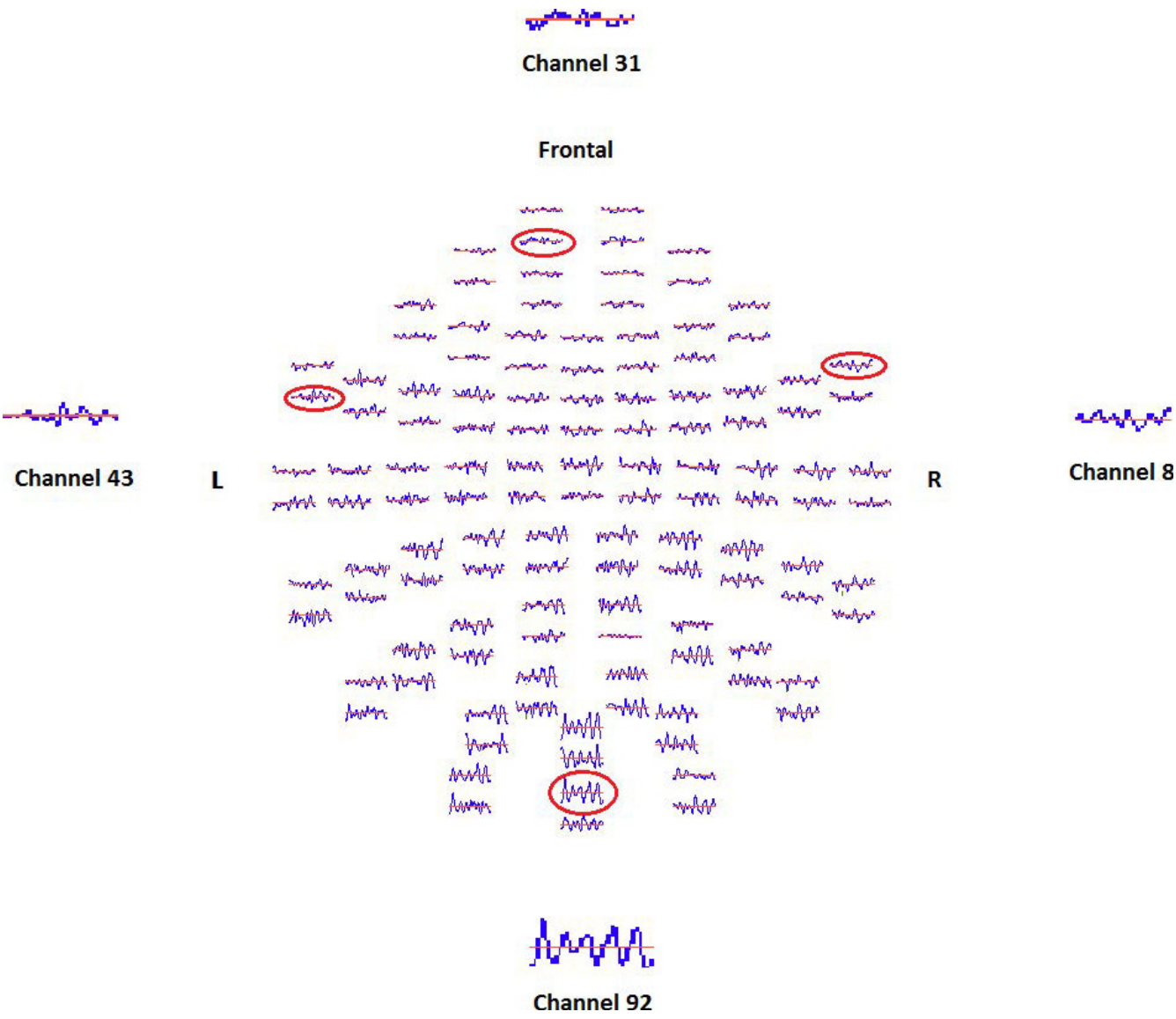

Fig. 2. MEG data derived from a short segment of continuous, spontaneous MEG recordings. The vertical scale for MEG ranges from a minimum of - 697 fT/cm to a maximum of 697 fT/cm. Encircled recordings have been magnified. L: left, R: right.

CSF drainage to normal levels. However, complications may occur and regular monitoring is required for the patients' entire life.

Phase-contrast cine MR imaging has long been used to quantitatively measure the flow characteristics of CSF in the aqueduct of patients with NPH [14, 15]. The CSF flow study using MRI is considered to be useful not only to differentiate NPH from brain atrophy, but also to provide quantitative predictors of a positive shunt outcome [16]. Nevertheless, a recent report by Halperin *et al.* [2] concluded that there is not enough evidence to judge the efficacy of aqueductal flow MR measurement as predictor of response to shunting in idiopathic NPH. Recently, morphological and anatomical MR imaging features have also been proposed as suitable radiological markers that could aid in the selection of candidates for shunt surgery [17, 18]. However, it may be difficult to predict the effectiveness of shunting even when the imaging and clinical features are characteristic of NPH.

The current study hypothesizes that MEG could possibly play a role as a non-invasive, non-imaging tool capable of differentiating between NPH and brain atrophy and potentially contribute to the identification of good responders to VP shunting. NPH patients mainly exhibit ventricular enlargement, as opposed to brain atrophy patients in which the increase in CSF volume is mostly related to dilated cortical sulci and cisterns [19]. Fig. 3 exhibits MEG recordings from a 67-year old male patient with brain atrophy and memory loss. It seems that brain atrophy is associated with a more generalized decrease in MEG signals, indicating the high sensitivity of MEG to activity originating in sulci, which appears more prominent in central and posterior regions. Contrarily, data from the NPH patient presented in Fig. 2 revealed a significant signal drop in frontal and frontotemporal regions. It is worth noting that the frontal horns of the lateral ventricles mostly affected in NPH (Fig. 1) are located superficially and, thus, frontal recordings are expectedly decreased,

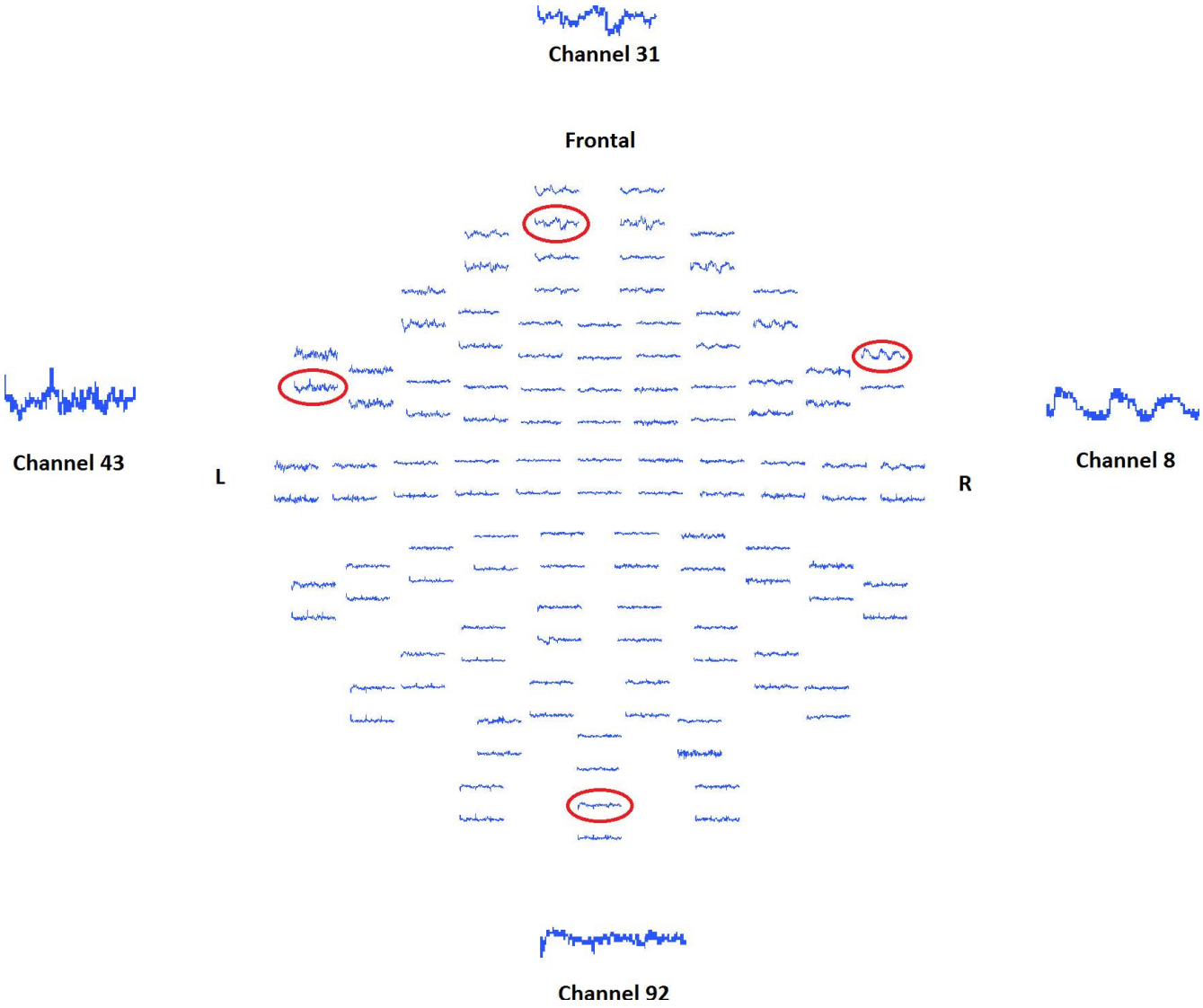

Fig. 3. MEG recordings from a 67 year old male with brain atrophy. To facilitate comparison, the vertical scale is the same as in Fig. 2 (min = - 697 fT/cm, max = 697 fT/cm) and magnified recordings from the same channels are shown. L: left, R: right.

also reflecting the fact that MEG is more sensitive to superficial cortical activity.

5. Conclusion

Current results suggest that MEG might have a potential role in the diagnosis and characterization of NPH due to low magnetic fields associated with frontal and temporal areas. Results of this work warrant a thorough investigation with regard to the MEG usefulness in differentiating between NPH and brain atrophy and in the selection of candidates for shunt surgery. Further research in a larger sample of hydrocephalus patients is required before firm conclusions can be drawn.

Acknowledgments

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Conflict of Interest

All authors declare no conflict of interest.

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