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Case Report

Functional magnetic resonance imaging under anaesthesia of a patient with severe chronic disorders of consciousness

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ABSTRACT

Clinical case: We report on a 19-year old male patient who is recovering from near-drowning. The patient was admitted for re-evaluation in a Minimally Conscious State.

Method: A regular functional Magnetic Resonance Imaging was not possible due to complex motor tics of the patient with sudden flexion and extension movements of arms and legs as well as opisthotonic retroflexion of the head and trunk. Thus, the patient was anaesthetised and functional Magnetic Resonance Imaging was performed under general anaesthesia which was introduced and maintained with Sevoflorane and Fentanyl provided analgesia. Four functional runs were performed and the patient's responses were recorded. During each one of these runs one extremity (dorsum manus or pedis) was stimulated with a brush with an operator-paced frequency of about 2 Hz.

Results and conclusion: Clear responses were found in the somatosensory cortex contra lateral within the post central gyrus during stimulation of the left hand. Considering the other three extremities no significant responses were found. Nevertheless, we conclude that a functional Magnetic Resonance Imaging under anaesthesia is possible for patients with severe chronic disorders of consciousness and brain areas responding to stimuli can be detected.

1. Introduction

In the last decades emergency treatment and intensive care improved which resulted in more people surviving severe brain injuries. Though, several of those patients do not recover totally but stay with severe chronic disorders of consciousness (scDOC). The diagnosis of the different stages of scDOC as well as the prognosis is challenging and has an impact on legal as well as ethical questions. In the last years neuroimaging tools, especially functional Magnet Resonance Imaging (fMRI), gained importance for the diagnosis and prognosis of scDOC because there are patients who do not show any sign of consciousness when behavioural tested but indeed show responses and signs of consciousness when examined using imaging techniques [1].

However, focusing on the clinic practice one will find that it is not easy to perform an fMRI of patients with scDOC. Some of them develop movement disorders, such as parkinsonism, dystonia, chorea, rigidity, myoclonus, or seizures and status epilepticus which overlay and contaminate the clinical examination and make high quality fMRI investigations impossible due to movement artefacts. Up to now there are no studies focusing on fMRI examinations of patients with scDOC under anaesthesia. Huang et al. showed that signal synchronisation and temporal variability of spontaneous brain activity are similarly changed in subjects under anaesthesia and patients with scDOC [2]. Nevertheless, they did not anaesthetise patients with scDOC. Hence it is not fully known in which way narcotics affect the blood oxygenation level dependant (BOLD) activity in patients with scDOC and whether it is possible to detect BOLD activity in such patients under anaesthesia.

In the following we present a case study on a patient in Minimally Conscious State (MCS) [3]. Our patient had complex sudden tonic flexion and extension movements of arms and legs as well as sudden

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tonic opisthotonic retroflexion of the head and trunk, which relaxed again after some seconds. Thus, fMRI seemed impossible. The only way such an examination was manageable was to anaesthetise the patient.

2. Case report

2.1. Clinical case

A 16-year-old boy was admitted after accidental near- drowning and cardiopulmonary resuscitation in September 2012. He suffered from hypoxic encephalopathy. After some remission stages he fulfilled the criteria of a MCS according to Giacinio et al. [3]. In November 2015 he was admitted to our centre for re-evaluation. He was able to perform gaze fixation and gaze following. Moreover, he had a partial preservation of conscious awareness that demonstrated cognitively mediated behaviour, which occurred inconsistently but reproducible and sustained long enough to be differentiated from reflexive behaviour. Considering simple commands and appropriate environmental stimuli a finger movement or a blink occurred that was not merely a coincidental behaviour. Further he showed signs of self and environmental awareness. Gestural or verbal yes/no responses or intelligible verbalisation were not possible. The patient was also able to smile and cry appropriately but showed no vocalisations or gestures that occur in direct response to linguistic content of questions. Besides, the patient could reach for objects and a clear relationship between object location and direction of reach was observable. He also showed pursuit eye movement and sustained fixation that occurred in direct response to moving or salient stimuli. Because of a cross sectional injury of the medulla, the patient showed a spastic tetra paresis with long tract signs and a positive Babinski sign on both sides. Muscle reflexes in all levels were hyper reflexive. Furthermore, there was a directed reaction to painful stimuli on all extremities. The patient appeared in a decerebrate posture with flexion of the upper and extension of the lower extremities. Moreover, he had bilateral spastic contractures in the wrist and ankle. Besides, the patient showed choreatiform and athetotic paroxysmal ballistic movements of both arms and legs and even of the trunk. The patient was provided with a urine catheter, a tracheostomy and percutaneous transdermal gastric probe. Furthermore, the patient had a myelopathy C4 to T1 with transverse spinal cord syndrome after burst fracture of C6 and C7 with spinal fusion C4 to T2. He also suffered from symptomatic epilepsy with complex focal and secondary generalized seizures.

An MRI scan was also performed under anaesthesia. This scan showed a severe hypoxic encephalopathy with pronounced inner and outer cerebral atrophy. Moreover, extensive post hypoxic gliosis could be seen, cortically and sub cortically, especially frontally and parieto-temporo-occipitally in both hemispheres with a preponderance on the left hemisphere. Post hypoxic signal changes were found on both sides in the basal ganglia and in the corpus callosum. Furthermore, the scan showed signs of a Wallerian degradation in the brainstem. No signs of diapedesis of the liquor. In comparison to the MRI scan of October 2012 deterioration of the findings was seen i.e. increase of the inner and outer brain atrophy as well as an increase of the post hypoxic signal changes in both hemispheres (Fig. 1).

2.2. FMRI

In order to re-evaluate the state of the patient an fMRI was performed with a 12-channel head coil on a 3 T Siemens Magnetom Trio Tim scanner (Siemens Erlangen, Germany). Four functional runs were performed. Stimulation of the extremities with expected response in the somatosensory cortex was chosen because of its stability and robustness [4]. Stability and robustness of the stimulus were important in order to evaluate whether an examination under anaesthesia of patients in scDOC was possible. A well-trained operator stimulated all four extremities with a brush with a self-paced frequency of about 2 Hz – one extremity per functional run – onto the dorsa manuum and pedum. The experiment was as follows. In the beginning 6 dummy scans were performed, after that 89 whole brain images were obtained with a T2*-weighted single-shot echo-planar sequence with repetition time TR 2200 ms, echo time TE 30 ms, flip angle FA 70°, field of view FOV 210 × 210 mm and matrix 64 × 64. During the first 9 images no stimulation was performed, followed by four blocks of each 10 images long lasting stimulation and 10 images long lasting rest. Moreover a high resolution anatomical image using 3D Magnetization Prepared Rapid Gradient Echo T1-weighted sequence (TR 2300 ms; TE 2.91 ms; time of inversion TI 900 ms; FA 9°; 160 slices; slice thickness 1.20 mm; in-plane resolution 1.0 mm × 1.0 mm; GRAPPA = 2) was acquired.

2.3. Anaesthesia

Anaesthesia was started by inhalation of Sevoflurane until an end-tidal concentration of 4% was reached. Analgesia was provided by Fentanyl 0.15 mg intravenously. The patient was ventilated to end-tidal 36 mmHg CO_2. Based on Marcar's findings anaesthesia was maintained with Sevoflurane MAC 0.75 throughout the entire examination [5]. The patient recovered uneventfully from anaesthesia.

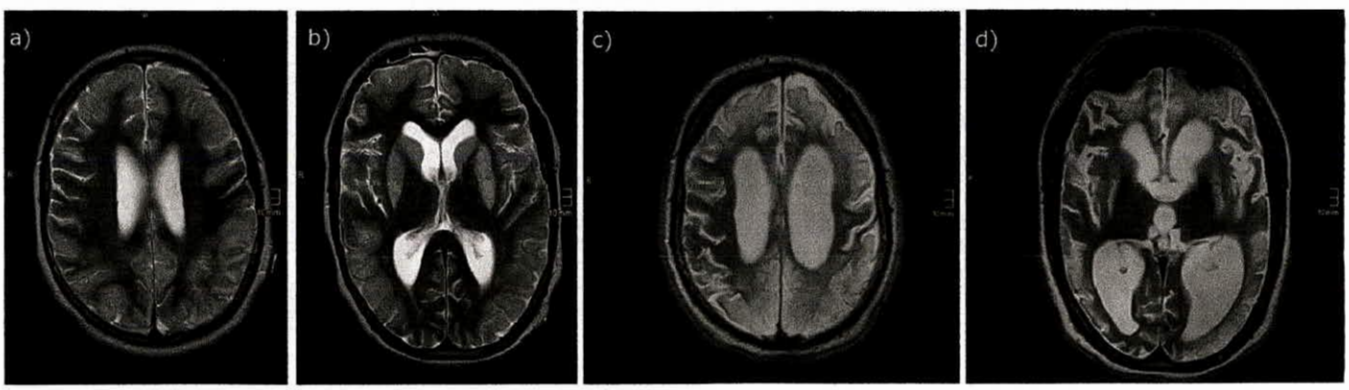

Fig. 1. Shown in radiological convention: a) MRI at onset: axial T2-weighted image showing global cortical hyperintense signal changes in both hemispheres due to hypoxic brain damage leading also to cortical laminar necrosis. At the time of onset, no brain atrophy can be detected. b) MRI at onset: axial T2-weighted image showing subcortical hyperintense signal changes within the basal ganglia of both hemispheres due to hypoxic brain damage. Again, no brain atrophy can be detected within the MRI image. c) MRI at time point two (three and a half years later): axial T2-weighted image showing global cortical and subcortical white matter hyperintense signal changes in both hemispheres due to hypoxic brain damage. Three and a half years post onset extensive brain atrophy can be detected within the MRI image. d) MRI at time point two (three and a half years later): axial T2-weighted image showing global cortical and subcortical basal ganglia white matter hyperintense signal changes in both hemispheres due to hypoxic brain damage. Again, extensive brain atrophy can be detected within the MRI image with extensive enlargement of both lateral ventricles and the third ventricle.

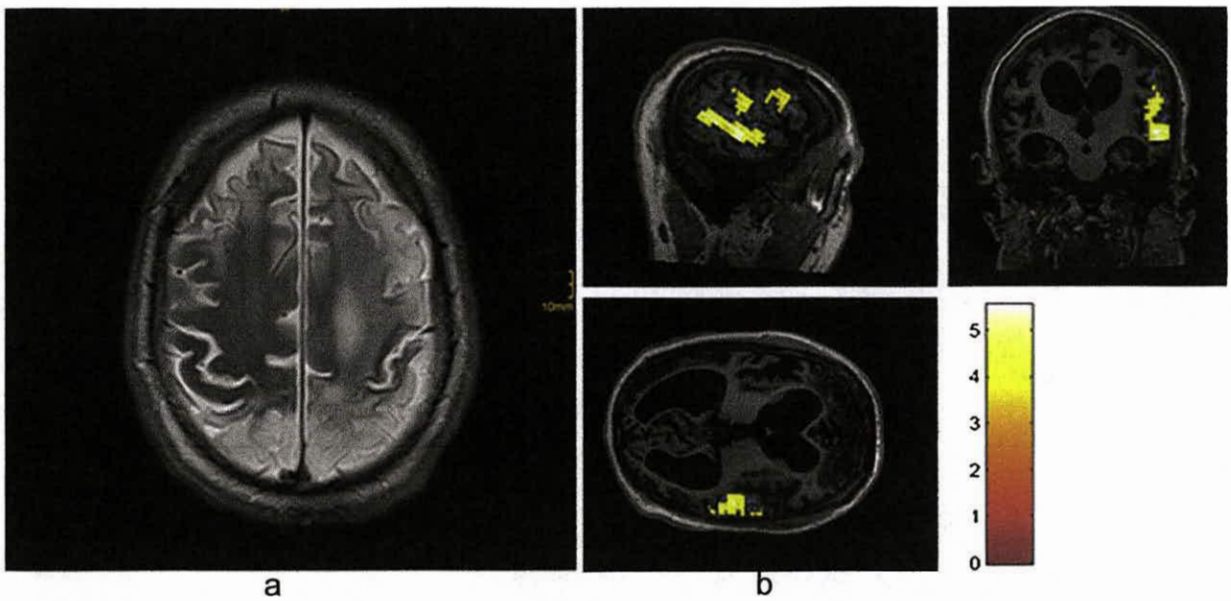

Fig. 2. a) Axial T2-weighted MRI shows extensive post hypoxic cortical gliosis, especially frontally and parieto-temporo-occipitally in both hemispheres with a preponderance on the left hemisphere. (Image shown in radiological convention.) b) fMRI of the patient during brushing with a frequency of about 2 Hz onto the dorsum of the left hand- overlaid on an T1 image for visualisation. A clear activation of the right motor cortex was found. Colour bar indicates t-statistics (Image shown in neurological convention.).

2.4. Data analysis

The software used for data analysis was SPM8 (http://www.fil.ion.ucl.ac.uk/spm/). The functional data were pre-processed i.e. realigned, unwarped and co-registered to the structural image. These parameters were then applied to the functional data, which were smoothed with an 8 mm full width at half maximum Gaussian kernel. After pre-processing was finished the data were analysed using a General Linear Model. The blocks of stimulation were convolved with a synthetic haemodynamic response function. Moreover, the six parameters of the realignment process were included as covariates to correct for head motion. A high-pass filter of 128 s was used. Each run was analysed by using a one-sample t-contrast to find voxel clusters (threshold for voxel clusters > 50 voxel) with higher signal change during stimulation via the brush than during rest. The threshold of the p-value for each analysis was $p < 0.001$, uncorrected.

3. Discussion

The strongest and widest activation was found when stimulating the left hand (see Fig. 2b). The pattern shows activation in the somatosensory cortex contra lateral to the left hand i.e. the right motor cortex within the post central gyrus. It was also the left hand which the patient used to move for goal directed activities of daily life, which strongly suggested that the right motor cortex was intact. Other than the right motor cortex the left one seems to be totally damaged which can be seen in the anatomical image (Fig. 2a). The results of the other three extremities did not give any conclusive findings, which often happens when trying to analyse fMRI of patients with scDOC. The fact that in one of the four extremities activation was found makes us conclude that the not finding in the other three is not directly correlated to the anaesthesia.

4. Conclusion

FMRI will gain more importance in the evaluation of brain function of scDOC patients. A regular fMRI examination is difficult in several of these patients because of movement, spastic contractures, autonomic decompensation or an intolerable stress burden. Hence, it is reasonable that an investigation under anaesthesia will be favoured in the future. According to our results presented, we conclude that an fMRI examination of patients with scDOC under anaesthesia is possible and a clear somatosensory perception can be detected. However, further investigations must clarify whether other fMRI paradigms can give a robust BOLD response in scDOC patients under anaesthesia as well.

Declaration of interests

None.

Ethical approval

According to the local law no ethical approval was needed for such an investigation.

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References

[1] O. Gosseries, N.D. Zasler, S. Laureys, Recent advances in disorders of consciousness: focus on the diagnosis, Brain Inj. 28 (2014) 1141–1150, http://dx.doi.org/10.3109/02699052.2014.920522.

[2] Z. Huang, J. Zhang, J. Wu, P. Qin, X. Wu, Z. Wang, R. Dai, Y. Li, W. Liang, Y. Mao, Z. Yang, J. Zhang, A. Wolff, G. Northoff, Decoupled temporal variability and signal synchronization of spontaneous brain activity in loss of consciousness: an fMRI study in anesthesia, NeuroImage 124 (2016) 693–703, http://dx.doi.org/10.1016/j.neuroimage.2015.08.062.

[3] J.T. Giacino, S. Ashwal, N. Childs, R. Cranford, B. Jennett, D.I. Katz, J.P. Kelly, J.H. Rosenberg, J. Whyte, R.D. Zafonte, N.D. Zasler, The minimally conscious state: definition and diagnostic criteria, Neurology 58 (2002) 349–353.

[4] J. Rath, M. Wurnig, F. Fischmeister, N. Klinger, I. Höllinger, A. Geißler, M. Aichhorn, T. Foki, M. Kronbichler, J. Nickel, C. Siedentopf, W. Staffen, M. Verius, S. Golaszewski, F. Koppelstaetter, E. Auff, S. Felber, R.J. Seitz, R. Beisteiner, Between- and within-site variability of fMRI localizations, Hum. Brain Mapp. 37 (2016) 2151–2160, http://dx.doi.org/10.1002/hbm.23162.

[5] V.L. Marcar, U. Schwarz, E. Martin, T. Loenneker, How depth of anesthesia influences the blood oxygenation level-dependent signal from the visual cortex of children, AJNR: Am. J. Neuroradiol. 27 (2006) 799–805.