Functional Imaging of Brainstem Structures Involved in Voiding Control

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Introduction

The lower urinary tract serves to store urine and to induce its periodic expulsion. Both functions are controlled by central pathways and organized as simple on-off switching circuits. There are several clinical and animal studies describing micturition controlled by the central nervous system. Recent functional imaging studies have proven that certain brainstem and forebrain areas are involved in voluntary and involuntary voiding. During filling and emptying of the bladder, the pontine micturition centre and periaqueductal grey play a crucial role in co-ordination, whereas hypothalamus, cingulate gyrus, prefrontal cortex and basal ganglia are responsible for micturition timing.

Despite the increasing number of fMRI studies its application concerning central micturition control is rare. The goal of the present study was to identify the components of the central micturition control network using fMRI and furthermore, to assess the involvement of brainstem areas in healthy women with the main emphasis on pelvic floor control.

Methods

Subjects: 11 female adults (mean age ± SD: 30.0 ± 6.9, age range: 20 – 44 years) with no history of neurological or psychiatry disease participated in the study which was approved by the Ethical Committee of the University of Göttingen. Written informed consent was obtained from all subjects.

MR Imaging: MR Imaging was performed at 3 Tesla (Siemens Trio, Erlangen, Germany) using the standard 8 channel phased-array head coil. Functional imaging was performed using a T2*-sensitive gradient-echo EPI technique with an in-plane resolution of 2 x 2 mm² (TR: 2000 ms, TE: 36 ms, flip angle: 70°, acquisition matrix: 84 x 128). 22 sections of 4 mm thickness angulated in an axial-to-coronal orientation, covering the whole brain and brainstem structures including the pons at high quality, were acquired.

Paradigm: All subjects sensed an urgent desire to void due to a filled bladder. During the functional experiments, the subjects were instructed to either (RELAX) release pelvic floor muscles to mimic voiding or (TENSE) contract pelvic floor muscles to mimic the interruption of voiding. In an event-related manner the instructions RELAX and TENSE were given (2 s each), separated by control conditions (18 s) during which the subjects were had to lie relaxed and wait for the next instruction. Each instruction was given 15 times resulting in a total time of 620 s for the fMRI experiment.

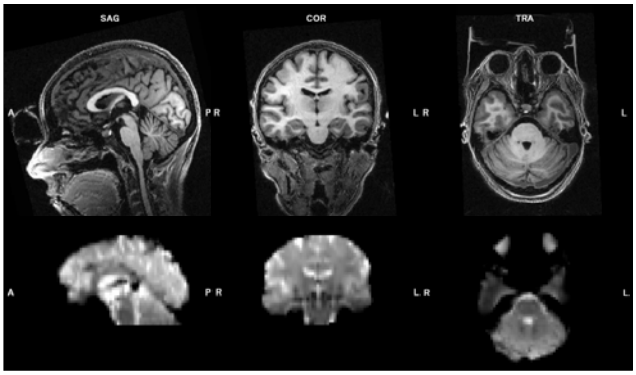

Figure 1: Comparison of the 3D anatomical dataset (top) and the corresponding co-registered T2*-weighted functional raw dataset (bottom) of a single subject. T2*-weighted images reveal a high quality even in the brainstem including the pons, known to be particularly vulnerable to susceptibility and flow artifacts.

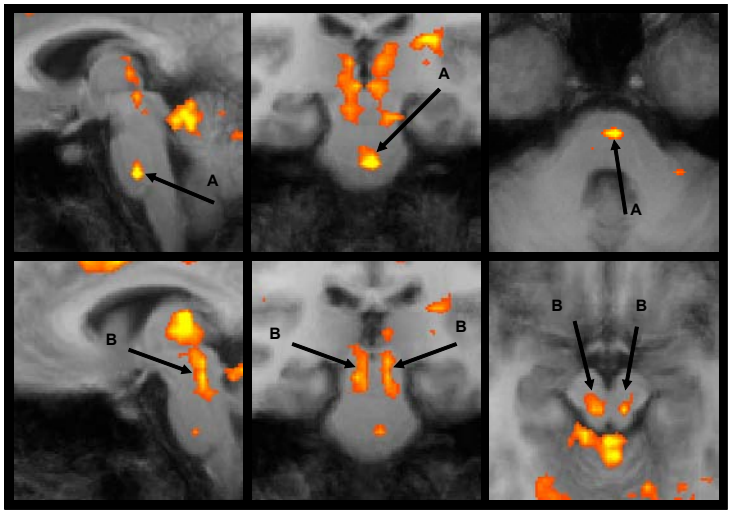

Figure 2: Pontine Micturition Centre (A) and Periaqueductal Grey (B)

Results

None of the subjects were able to start voiding during the experiment. This is presumably due to subconscious restraint resulting from the inconvenient situation. Nevertheless, both events (RELAX and TENSE) induced strong and similar BOLD activation patterns including frontal cortex, sensori-motor cortex, cerebellum, and basal ganglia in all subjects. The most striking results were well-localized activations in the region of periaqueductal grey and the pontine micturition centre (Figure 2). To our knowledge this is the first study using fMRI and demonstrating activations in the brainstem related to micturition. Comparing the conditions RELAX and TENSE revealed regions in the sensori-motor cortex, the putamen, and the cerebellum where condition TENSE induced a stronger BOLD response than condition RELAX. Otherwise, condition RELAX induced stronger responses in the anterior cingulate, the pre-sma, and the inferior insular cortex.

Discussion

The presented data show that brainstem regions as well as more rostral regions are involved in voluntary micturition control. All areas of activity described in recent functional imaging studies have also been observed during the examination of female volunteers. In contrast to a few of these studies however, we did not find a hemispheric predominance.

In future studies our experimental approach will be applied to patients with neurological diseases causing voiding dysfunction. Thus, fMRI studies may be of significance to elucidate and confirm brain systems involved in the pathophysiology of micturition disorders caused by certain neurological diseases.

References

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