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MAPPING OF CORTICAL ACTIVITY ASSOCIATED WITH PELVIC FLOOR CONTRACTIONS AND FILLING OF URINARY BLADDER USING FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI)

Hypothesis / aims of study

The neural regulation of lower urinary tract (LUT) is dependent on a complex control system residing at various levels in brain, spinal cord and peripheral nervous structures. A diagnostic modalities especially a positron emission tomography (PET) and a functional magnetic resonance imaging (fMRI) in recent years led to significant discoveries identifying structures and mechanisms at the level of central nervous system (CNS).

The goal of this study is to bring new knowledge regarding the cerebral control of pelvic floor muscles and to evaluate brain cortical activity associated with filling phase of urinary bladder using functional magnetic resonance imaging (fMRI) performed synchronously with filling cystometry.

Study design, materials and methods

All functional magnetic resonance imaging (fMRI) examinations were performed on 3T MR scanner (Siemens Trio) using gradient-echo EPI sequence with parameters: TE=30ms, TR=3s, voxel=2x2x2mm. The entire measurement was covered by 120 dynamics (volumes of 44 slices) and divided into 10 rest periods (10 dynamics each, 30s) and 10 stimulations (2 dynamics, 6s) when the subject was instructed to contract pelvic floor with the frequency of 1 Hz for 6 seconds.

Evaluation of the fMRI data was done in SPM5 using standard general linear model. ndividual statistical maps used the threshold of a corrected p=0.05 (FWE correction). Group level statistical analysis was performed using t-test and the threshold of p=0.05, with FDR correction.

Pelvic floor contractions: 17 female volunteers were included in the study (age 20-68 years). Women with a significant pelvic organs prolaps were not included in the study. Further exclusive criteria for enrolment were systemic neurological diseases, dementia, serious dysfunction of the lower urinary tract, infections of the urinary tract, presence of bladder stones and previous irradiation of the pelvis.

The patients were examined in the supine position. We used perineometer to verify the contractions during examination. The patient was asked to perform 3-4 pelvic floor contractions lasting about six seconds, followed by a resting phase of 30 seconds. This procedure was repeated ten times, the whole fMRI examination was covered by 120 dynamics.

We expected to localize the cortex centre of the lower extremities in a close proximity of the centre responsible for the control of the pelvic floor, and we asked the patient to perform a flexion of toes according to the following scheme: flexion of right toes, repeatedly for the period of 15 seconds, followed by 15-second rest phase, flexion of left toes, repeatedly for the period of 15 seconds, followed by 15-second rest phase. This block was repeated five times and was covered by 100 dynamics.

Filling phase of urinary bladder: 14 female volunteers (20-68yrs) were enrolled. Evaluation started with filling cystometry. Standard cystometry protocol was extended to strengthen the afferent sensory signal. The sensory activation was enabled by cyclic phases of filling and emptying. Synchronously with extended cystometry we evaluated cortical activity using fMRI.

Statistical evaluation using general linear model compared 1) empty/full bladder and 2) cyclic phases of filling and emptying. Individual statistic maps used Family Wise Error on p=0,05. Group statistic (t-test) for both comparisons level of significance p=0,001 uncorrected. Topographical mapping was done according to standard MNI-152 template.

Results

Pelvic floor contractions: Reproducible results were obtained in nine of the patients. Other patients were not able to perform the isolated pelvic floor contraction without using the gluteal or abdominal muscles at the given conditions. Main clusters of activation associated with the contractions we detected are as follows: gyrus precentralis bilaterally [+-4,-12,70], supplementary motor area bilaterally [+-2,0,46]. Other, less significant clusters of activation were observed in the left gyrus precentralis [-34,-14,74], on the left side of gyrus frontalis medius [-38,36,32], on the right side of gyrus frontalis medius [42,36,32] and in the right gyrus temporalis superior [62,-34,22].

Filling phase of urinary bladder: 10 from 14 fMRI measurements were representative and included into a group statistics.

We detected cortical activity in following areas with MNI-125 coordinates: [-5,20,-10] middle and inferior frontal gyrus, [-25,-60,52] parietal gyrus, [-5,-35,60] angular gyrus, [7,-10,-10] posterior and anterior cingulate gyrus and [10,-15,0] subcortical grey nuclei. Results are documented in figure 1 and 2.

Interpretation of results

With regards to pelvic floor contractions our study was the first one from the so far published works, which monitored the effectiveness of pelvic floor muscles contraction with perineometer during the fMRI examinations.

Based upon our experience, we consider the monitoring of exact performance of the pelvic floor muscles contractions to be very important. Large percentage of the patients, even if thoroughly instructed regarding the way of contraction, was not able to perform it during examination. Having been asked to perform the pelvic floor contraction, the patients had a tendency to contract auxiliary muscles (gluteal muscles and muscles of the abdominal wall), rather than the muscles of the pelvic floor. These patients had to be excluded from the final analysis.

In our study, the examination was performed with an empty urinary bladder. Other authors examined the cortex activation during the contraction of pelvic floor muscles with a full bladder. However, described activation presents more likely a correlate to the increased sensory input at the filling of the bladder.(3) At present, there are numerous studies being performed aimed at the activity of cerebral structures during the filling phase of the micturition cycle. We know that an increased filling of the bladder leads to a reflexive activation of the pelvic floor. In order to be able to distinguish between the activation of cerebral structures caused by afferent stimulation from the bladder and the cerebral activity caused by the activation of pelvic floor muscles, an exact mapping of the projections of the pelvic floor contractions is necessary.

Regarding filling phase of urinary bladder using our methodology we acquired reproducible data and detected CNS activity associated with filling of urinary bladder. These results are comparable with fMRI results described by other authors [4,5] and correlate also with methodology using PET.[6]
Urodynamic record documented a detrusor activity and allowed for evaluation of associated CNS activity which was not detected. We came to a conclusion that detrusor overactivity is a process limited to an autonomic reflex without any CNS regulatory input.

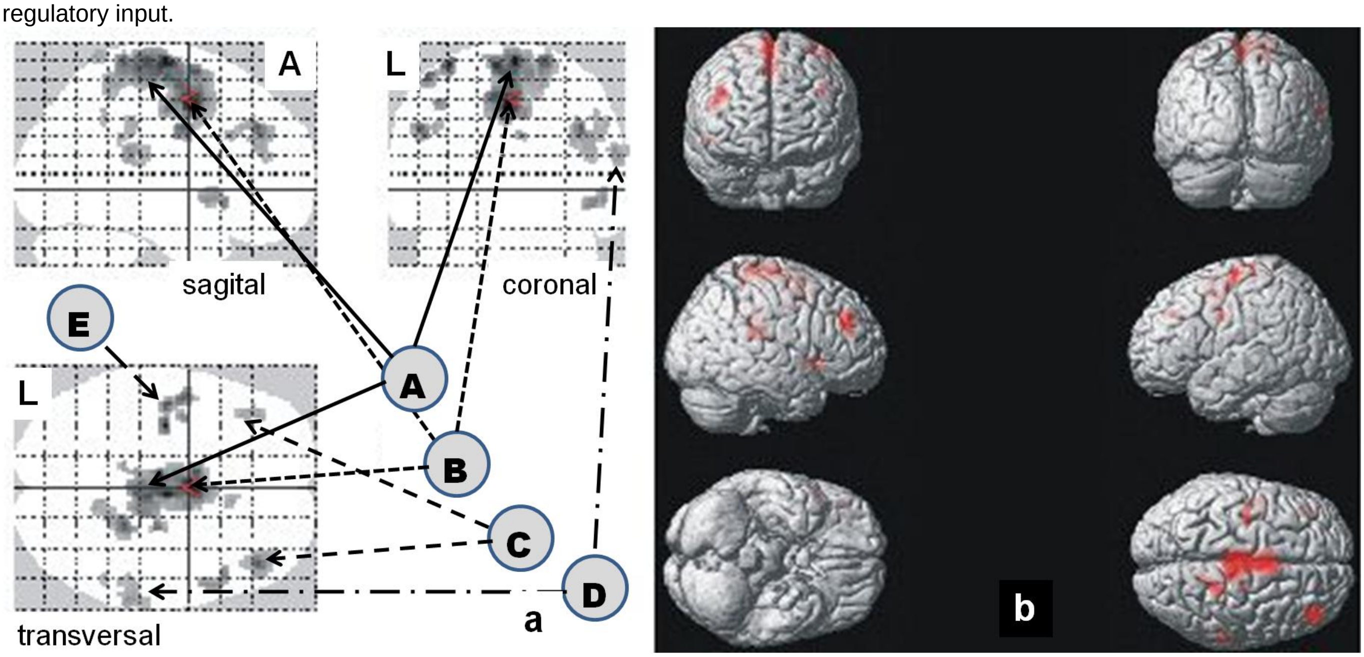
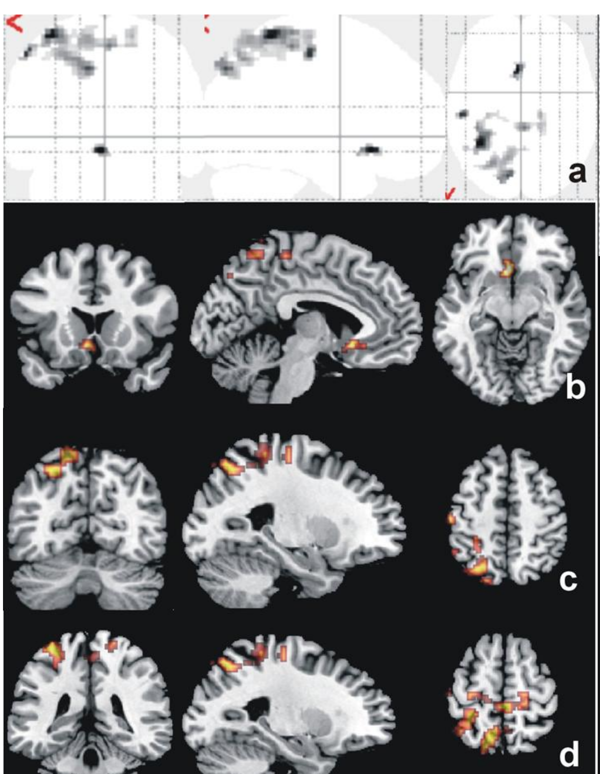
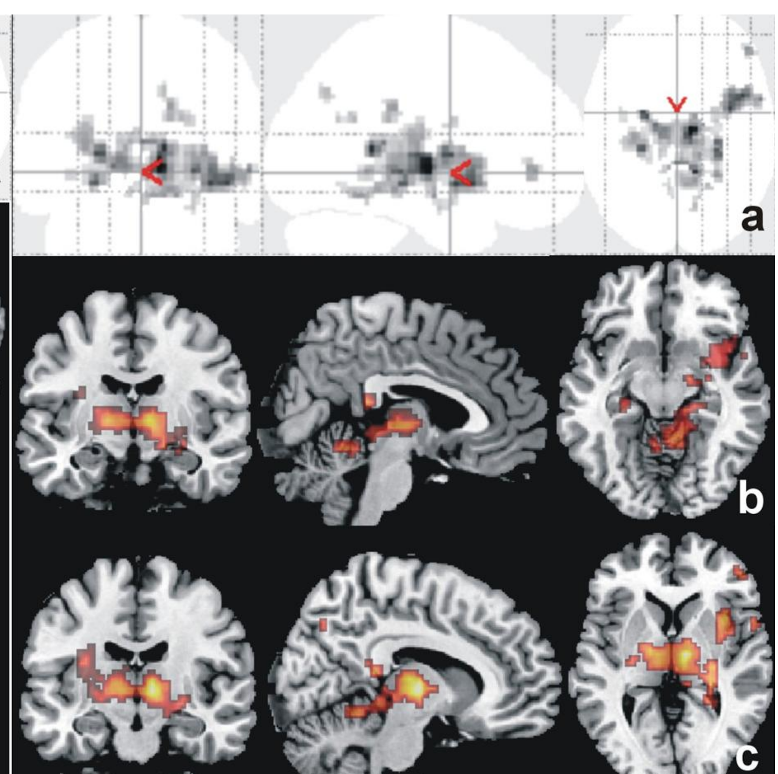


Figure 1: Brain activation during pelvic floor contraction shown on a) sagital, coronal and transversal projections and on b) 3D brain surface reconstruction: A) bilateral M1 for pelvic floor – medial part of gyrus frontalis, B) supplementary motor area bilaterally, C) gyrus frontalis medius bilateraly and D) in the right gyrus temporalis superior. Some activation was also observed in the left gyrus precentralis E).





1) Activity comparing empty/full bladder

2) Activity comparing cyclic phases of filling and emptying

Concluding message

Our work presents an exact topization of the cerebral activity during contraction of the pelvic floor muscles. Contraction of the pelvic floor muscles is associated with a massive activation in the supplementary motor area; apart from that we also observed activity in the area of gyrus frontalis medius and left gyrus precentralis.

Synchronous fMRI evaluation with urodynamic examination is a novel and feasible method that facilitates and precise interpretation of fMRI data acquired. Taking advantage of time dependence of fMRI signal and (synchronous) cystometry record, following cortical activity was detected during filling phase of urinary bladder: middle and inferior frontal gyrus, angular gyrus, posterior and anterior cingulate gyrus and subcortical grey nuclei.

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Disclosures

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