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Precuneal epilepsy: Clinical features and surgical outcome☆

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ABSTRACT

Objective: The precuneus is a complex and highly connected structure located in the medial portion of the superior parietal lobule. The clinical presentation of precuneal epilepsy is poorly characterized, mostly because these patients have seldom been distinguished from those with other types of parietal lobe epilepsy. The present study aims to improve the understanding of precuneal epilepsy by detailing its clinical features and surgical outcomes.
Methods: Six previously unreported cases of drug-resistant precuneal epilepsy investigated between 2002 and 2014 were retrospectively studied. Seizure focus was confirmed by presence of a lesion, intracranial monitoring, or post-operative seizure control when applicable.
Results: Seizures arising from the precuneus have heterogeneous presentations, including body movement sensation, visual auras, eye movements, vestibular manifestations, and complex motor behaviors. Two patients with an anterior precuneus lesion described body movement sensations whereas two others with a posterior precuneus lesion experienced visual symptoms. Two of the five patients who underwent epilepsy surgery achieved good seizure control (Engel IA). One patient underwent gamma knife surgery with an Engel IV outcome. Surgical complications included contralateral visual field impairment, limb hypoesthesia and hemispatial neglect. One patient developed late-onset epilepsia partialis continua from a Rolandic subdural grid-related contusion.
Significance: In absence of a clear precuneal epileptogenic lesion, recognition of a precuneal focus is challenging. Magnetoencephalography may sometimes localize the generator but invasive EEG remains in well-selected cases necessary to identify the seizure focus. Surgical failures may be explained by the widespread connectivity of the precuneus with distant and adjacent structures. Different ictal manifestations of precuneal epilepsy in this series provide a clinical correlate to the described functional subdivisions of the precuneus.

1. Introduction

The precuneus is a complex structure located in the medial portion of the superior parietal lobule and hidden in the medial longitudinal fissure. It is bounded anteriorly by the marginal branch of the cingulate sulcus (primary somatosensory cortex), posteriorly by the parieto-occipital fissure (cuneus), and inferiorly by the subparietal sulcus (posterior cingulate gyrus). The precuneus corresponds mainly to the medial portion of Brodmann area (BA) 7, with some authors also including the superior portion of BA31. It has widespread connexions with other cortical and subcortical regions, especially with higher association structures. Major connexions include the posterior cingulate and retrosplenial cortices, other parietal areas (e.g., inferior and superior parietal lobules, parietal operculum), the frontal lobe (including dorsolateral prefrontal cortex, dorsal premotor area, supplementary motor area, and anterior cingulate cortex), the parieto-occipital visual area and the temporo-parieto-occipital area, the thalamus, and the claustrum [1,2].

The precuneus remains a poorly understood region of the brain. This is explained by its deep anatomical location, which makes this structure difficult to access to any type of investigation, and by the rare occurrence of focal precuneal damage following strokes or other brain injuries. Electrical stimulations of this region have been associated with tactile sensations, body displacement perceptions including sensations of falling, vertigo, eyeball/eyelid movements or sensations, and visual illusion/hallucinations [3–8]. Data from functional neuroimaging studies suggest that it is involved in visuospatial imagery, episodic

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memory retrieval and self-processing operations [1,9,10]. Resting-state studies suggest that it plays a central role in the default mode network [11,12]. Finally, damage to the right precuneus is associated with left spatial neglect [13], and a smaller right precuneus volume is related to poor egocentric memory [14].

Precuneal epilepsy is not well characterized, in part because patients with epileptic seizures arising from the precuneus have generally not been distinguished from other patients with parietal lobe epilepsy [15–18]. In addition, electrical stimulations of the precuneus and case reports of seizures arising from that area report much more variable clinical manifestations. A recent study on a small series of four subjects described a specific electroclinical phenotype for seizures arising from the medial parietal lobe, consisting in asymmetric tonic posturing associated with diffuse low voltage activity on EEG [19]. However, the study included patients with a widespread epileptogenic zone extending beyond the precuneus, to the postcentral gyrus or occipital lobe. Hence, there is a need for a better characterization of precuneal epilepsy. Furthermore, the localization value of EEG and the resolution of neuroimaging methods in detecting a precuneus generator or lesion remains poorly documented, as are the neuropsychological impairments and surgical outcomes following precuneus resection.

The present study reviews the clinical features and surgical outcomes of six previously unreported cases of drug-refractory precuneal epilepsy in an attempt to improve our understanding of this relatively unknown subtype of parietal lobe epilepsy.

2. Material and methods

We retrospectively identified all consecutive patients with precuneal epilepsy who had been investigated between 2002 and 2014 at Notre-Dame Hospital and at the Montreal Neurological Institute, in Montreal, Canada. Institutional review board approval was obtained from both institutions involved. A precuneal epileptogenic focus was assumed in the presence of a) an epileptogenic precuneal lesion; b) confirmation by intracranial EEG; or c) presence of a tight magnetoencephalographic (MEG) cluster in the precuneus. In patients who underwent epilepsy surgery, a precuneal focus was definitively confirmed in cases achieving seizure freedom.

Charts, neurophysiological and neuroimaging data were thoroughly reviewed to retrieve relevant information such as demographic data, seizure risk factors, age of onset, semiology, frequency, and medical and surgical interventions including findings from non-invasive and invasive presurgical tests. The presurgical evaluation included a standard neuropsychological evaluation, video-EEG recording of seizures (Stellate Harmony, Natus), and high-resolution cerebral magnetic resonance imaging (MRI; epilepsy protocol, Siemens 1.5T Avanto, Germany or Phillips 3T Achieva, Netherlands) in all six subjects, ictal single-photon emission computed tomography (SPECT) in four, ^{18}Fluoro-deoxyglucose positron emission tomography (PET) in three, and a MEG study (CTF 275-sensor system, Canada) in three. Four patients underwent an invasive EEG study, and structures explored by intracranial electrodes were based on findings from the presurgical evaluation and as agreed upon during an epilepsy surgery multidisciplinary conference. The study was approved by our institutional ethics committees.

3. Results

We identified six patients (3M; mean age at intervention 31.7 years, ranges 17–59) with precuneal epilepsy based on our inclusion criteria. Table 1 summarizes their clinical, paraclinical and surgical data.

3.1. Patients and seizure characteristics

Patients had no risk factors except for one patient who experienced febrile seizures in infancy. Onset of spontaneous seizures occurred at a mean age of 11.2 years old (range 4–16). Earliest ictal symptoms were visual in three patients (50%), consisting of visual distortion, flashes or eyeball movement, vestibular in two (33%), a falling or movement sensation, and complex motor behavior preceded by a cephalic sensation in the remaining patient. Overall, five of the six patients presented vestibular symptoms during their seizures, either at onset or sometime during the ictal phase. Interestingly, two of the three patients with early visual manifestations had a visible lesion in the posterior precuneus, bordering the parieto-occipital sulcus; the third patient was nonlesional. Conversely, both patients with early vestibular manifestations had a lesion involving the anterior precuneus, bordering the paracentral lobule (Fig. 1).

Most seizures in two patients were associated with altered consciousness (Pts 4 and 6). Seizure frequency varied from daily to monthly, and all together, patients were drug-resistant, having failed a median of eight antiepileptic medications. Five patients underwent resective surgery and one was treated with gamma-knife surgery (Pt 4). One patient (Pt 3) had four previous unsuccessful epilepsy surgeries in the frontal lobe and cingulate gyrus.

3.2. Neurophysiology, imaging and pathology findings

Scalp interictal and ictal EEG findings indicated together a posterior quadrant generator in four patients while in the remaining two (Pts 4 and 5), they were either diffuse or pointing to a more anterior temporal focus. One subject had no interictal epileptiform discharges, two had anterior fronto-temporal spikes and three bilateral posterior quadrant activity. Ictal EEG recordings suggested a parieto-occipital or centroparietal regional onset in three subjects while in the remainder, a temporal or diffuse seizure onset pattern was observed. Three patients underwent a MEG analysis of interictal discharges using the equivalent current dipole model (Pts 1–3): a cluster of sources was found in the suspected precuneus in two (both were non-lesional cases), and in the patient with a left precuneal DNET and fronto-temporal spikes on surface EEG (Pt 1), MEG identified sources clustering in the left temporal neocortex.

MRI disclosed a left precuneal dysembryoplastic neuroepithelial tumor (DNET) in two patients (Pts 1 and 5), and a cavernoma at the bottom of a sulcus (Pt 4), and focal transmantle dysplasia (Pt 6) in the right precuneus. The remaining two subjects (Pts 2 and 3) had no evidence of an epileptogenic lesion despite several MRIs.

PET was obtained in three of six patients and showed a concordant parieto-occipital hypometabolism in one patient (Pt 2), was non-concordant in one lesional case (Pt 4), and in the other patient (Pt 6) it was first considered normal but retrospectively a discrete hypometabolism was noticed at the site of dysplasia. Ictal SPECT, obtained in four patients, adequately localized the precuneal focus in only one (Pt 2).

Three patients underwent invasive intracranial EEG (icEEEG) recordings (Pts 3, 5 and 6). In nonlesional patient 3, three prior intracranial studies, without precuneal sampling, led to resections that had no impact on seizures. Focus localization in the precuneus was confirmed in a fourth invasive study. In two lesional patients, icEEG allowed a better delineation or confirmed the seizure onset zone and guided the extent of the surgery.

3.3. Neuropsychological assessment

All patients underwent a standard neuropsychological assessment prior to neurosurgery. Results are summarized in Table 2. Three patients had borderline intelligence functioning, whereas the other three had normal intelligence. Discrepancies between the verbal and non-verbal intelligence scales were found in all patients, although these were not good predictors of seizure focus lateralization: patient 5 (left focus) and patient 6 (right focus) had higher verbal IQ, while the other four patients had higher non-verbal IQ (two with a left focus, and two with a right focus). Five patients had mild attentional impairments, four,