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Autoimmune encephalitis (AIE) is a rare, severe, and rapidly progressive encephalopathy, and its diagnosis is challenging, especially in adolescent populations when the presentation is mainly psychiatric. Currently, cerebral $^{18}$-fluorodeoxyglucose positron emission tomography ($^{18}$F-FDG-PET) imaging is not included in the diagnostic algorithm. We describe a 16-year-old patient with probable seronegative encephalitis with catatonia for which several cerebral PET scans were relevant and helpful for diagnosis, treatment decision making, and follow-up monitoring. The patient recovered after 2 years of treatment with etiologic treatment of AIE and treatment of catatonia. This case suggests a more systematic assessment of the clinical relevance of $^{18}$F-FDG-PET imaging in probable seronegative AIE.

Keywords: adolescence, catatonia, cerebral PET/CT, encephalitis, abnormal movement

Introduction

Autoimmune conditions associated with psychosis and catatonia include systemic autoimmune disorders that can target the central nervous system (e.g., systemic lupus erythematosus) and autoimmune encephalitis (AIE) (1, 2). Autoimmune encephalitis (AIE) is a rare, severe, and rapidly progressive encephalopathy caused by antibody-mediated neuroinflammation (3). AIE is a form of encephalitis, which are diseases involving severe brain inflammation with different causes and a complex differential diagnosis (3). Diagnosing AIE is challenging because of the overlap in clinical presentations between AIE, other inflammatory brain diseases, brain infections, metabolic diseases, and psychiatric disorders (1). It is especially difficult in children because of the complexity of normal behavioral changes during childhood and the limited capacity of younger children to describe their symptoms (4). Moreover, compared to adults with AIE, children may manifest important differences in symptoms, paraclinical findings, comorbidities, treatment response, and prognosis (5, 6). They may present with a wide array of psychiatric symptoms, including psychosis, obsessive compulsive disorder, mania, hypomania, catatonia, autistic/cognitive regression, and other conditions (7).
Several antibodies have been described in children with AIE (5), and the three most commonly noted antibodies target the N-methyl-D-aspartate receptor (NMDAR), myelin oligodendrocyte glycoprotein (MOG), and glutamic acid decarboxylase 65 (GAD65) (6, 8–10). It has also been recognized that not all children with a clinical phenotype of AIE have a known autoantibody (4). A consensus statement paper proposed defining three diagnostic categories of “possible,” “probable,” and “definitive” AIE. The paper proposed specific diagnostic criteria mixing clinical and paraclinical signs (3). However, to date, cerebral 18-fluorodeoxyglucose positron emission tomography (18F-FDG-PET) is not included in the diagnostic algorithm of AIE, even though few articles over the past 10 years have suggested that 18F-FDG-PET may contribute to early diagnosis (11–13) or contribute when no antibodies targeting the central nervous system are found (14, 15). Here, we present a case report of a 16-year-old boy with probable seronegative AIE in which several 18F-FDG-PET images were relevant and helpful for diagnosis, treatment decision making, and follow-up monitoring.

CASE DESCRIPTION

Jason is a 16-year-old boy with no medical or psychiatric history except repeated ear infections as a child. The first symptoms appeared at the age of 14 with a slight psychomotor slowdown and a lack of motivation during the summer. Six months later, the psychomotor slowdown worsened, and several neuropsychiatric symptoms appeared: abnormal movements of the upper limbs, fingers, and head and obsessive compulsive disorder with the impossibility of swallowing his saliva (cf. Supplementary Video 1). Within a few months, the patient developed a catatonic syndrome with catalepsy, posturing, progressive mutism, negativism, and a refusal to eat, which caused a loss in body weight of 10 kg.

Jason was first hospitalized in a neuropsychiatric department where he underwent exhaustive biological evaluations, brain MRI, several EEG recordings, video EEG, and lumbar puncture, which included a search for brain-targeted antibodies. All exams were normal, with the exception of moderate elevations in anti-streptolysin O (ASLO) and streptodornase antibodies. In this department, he was treated with a combination of benzodiazepine (lorazepam 12 mg/d) and amoxicillin (3 g/d for 3 weeks) due to a suspicion of PANDAS (Pediatric Auto-immune Neuropsychiatric Disorders Associated with Streptococcus Infections), and this treatment led to a slight and very short improvement.

After this first-line treatment, he was transferred to our child and adolescent psychiatry department. A multidisciplinary team meeting including psychiatrists, neurologists, and internists led to the diagnosis of probable seronegative encephalitis. He was treated with six plasma exchanges (PE), an intravenous immunoglobulin (IVIG) cure, and five IV boluses of methylprednisolone. In a few weeks, this treatment resulted in a dramatic improvement in his mental and general condition, with the recovery of eating and talking. One year after the first symptoms had appeared, he was able to go back home and school. Only mild OCD symptoms (handwashing) remained. Shortly after this second-line treatment, he underwent an initial brain 18F-FDG-PET examination (2 MBq/kg, 10-min acquisition started 30 min post injection) which was the first abnormal paraclinical exam showing moderate mediofrontal and thalamic hypometabolism (Figure 1A).

One month later, his clinical state worsened, and the catatonic syndrome with abnormal movement reappeared, leading to a second hospitalization. A third-line treatment with an IVIG cure followed by 5 PE briefly improved the symptoms. After a 2-month relapse, rituximab (600 mg × 2), an immunosuppressant treatment, was administered along with a third cure of 10 PE that did not improve the clinical condition of the patient. A second brain 18F-FDG-PET examination was performed and showed the appearance of a metabolic decrease in the parietotemporal associative cortex and a high metabolic increase in the striatum (Figure 1B). In addition, the whole-body imaging that was performed to screen for occult malignancy was negative.

On brain 18F-FDG-PET performed 1 month later, the hypometabolism decrease worsened in the posterior areas and extended to the occipital cortex, including the primary visual cortex (Figure 1C). Once again, the 18F-FDG-PET findings were correlated with the patient’s condition (Figure 2). During this hospitalization, a gastrostomy was performed because of refusal to eat and denutrition in the context of a very severe catatonic syndrome.

A few months later, a slow but important improvement of his clinical state appeared with the effective treatment of catatonia by lorazepam (20 mg) and ECT (6 sessions). It is likely that the late response to rituximab contributed to this improvement. A few weeks later, a second-line immunosuppressant (azathioprine) was introduced. He also received levodopa (187.5 mg/d) based on the hypothesis of impairments in the cerebral motivated behavioral system (basal ganglia, orbital cortex). Another 18F-FDG-PET performed to monitor the treatment response revealed a partial improvement in posterior associative metabolism, with the emergence of moderate mesiotemporal and mediofrontal hypometabolism (Figure 1D).

After 3 months, the improvement led to the recovery of eating, talking, catatonia (Figure 2) and Jason showed normal general behavior, although a slight frontal syndrome (lack of initiative and emotion, perseverance) and mild anosognosia persisted (cf. Supplementary Video 2). In agreement with the clinical course, brain metabolism returned to normal in the posterior areas and striatum with mild, residual hypometabolism in the mediofrontal cortex and hippocampus (cf. Figure 1E). Two months later, in August, a final cerebral 18F-FDG-PET scan was unchanged, with normal posterior associative cortex and mild medioprefrontal and mesiotemporal hypometabolism (Figure 1F).

During the writing of this case report, we had a follow-up with Jason and his family. He had a new relapse at the end of September with the recurrence of severe catatonic syndrome. No treatment improved his condition with the exception of the administration of the immunosuppressant rituximab that was promptly decided upon given Jason’s history. In a few weeks, Jason was able to go back to school, although he sometimes had a brief psychomotor slowdown.
DISCUSSION

The diagnosis of AIE in children and adolescents is challenging for several reasons: (a) numerous differential diagnoses; (b) low incidence; and (c) changes in mood, behavior, and personality, possibly coinciding with puberty (3). Over one-third of patients with AIE present abnormal movements, such as ataxia, chorea, dystonia, myoclonus, or tremor (5, 16–18), and over 50% of patients present multifocal neuropsychiatric symptoms rather than isolated clinical syndromes (19). However, many present with psychiatric symptoms at an early stage.

In Jason’s case, the first point that caught our attention was the diagnostic challenge. If we refer to the Graus et al. (3) consensus statement that proposed three diagnostic categories of “possible,” “probable,” and “definitive” AIE, the diagnosis of possible AIE was made in the beginning. Indeed, for this patient, we only had a limited number of atypical neurological symptoms associated with a psychiatric presentation: abnormal movements that appeared at the beginning of the illness were not specific to any neurological or psychiatric disease (cf. Supplementary Video 3). Because AIE can resemble acute psychosis and schizophrenia, children, and adolescents are sometimes referred to psychiatric services, causing concern about misdiagnosis of young patients with acute psychosis and not diagnosing underlying organic conditions (1, 20).

In Jason’s case, during multidisciplinary meetings to discuss the case, several psychiatric diagnoses were considered, such as melancholia and conversion disorder, which resulted in back and forth between the neurology department and psychiatric department, impacting the time until different treatments were administered. Currently, we know that the early diagnosis of pediatric AIE is crucial because delays in treatment worsen the prognosis and increase the risk of permanent neurocognitive deficits (21, 22).

To date, $^{18}$F-FDG-PET imaging is not included in the Graus et al. (3) criteria, although its contribution to limbic encephalitis is mentioned by the authors as a footnote in panel 2. However, we used the causality algorithm described by Ferrafiat et al. in 2018 to guide diagnosis and treatment
for our patient. The CAUS score was 7/10, which was an argument for an autoimmune condition (threshold > 5) (15). In addition, if we consider Jason’s brain metabolism abnormalities that correlated with clinical severity as relevant, then the diagnosis of probable AIE would be made. This is the hypothesis we had that justified aggressive immunomodulatory and immunosuppressive treatment resulting in significant clinical improvement (Figure 2). In a relevant number of patients described in the literature, 18F-FDG-PET imaging has shown limbic and extralimbic abnormalities, even in MRI-negative or inconclusive cases (12). Probasco et al. (13) demonstrated that in 61 adults with AIE, brain 18F-FDG-PET was more often abnormal (85% of the cases) than EEG, MRI, or routine CSF analysis. Brain hypometabolism was the most observed pattern. Solnes et al. demonstrated that brain 18F-FDG-PET had a better sensitivity than MRI in 23 (21 adults and 2 youths) seropositive patients with AIE. In these papers, the imaging pattern was more often a decrease than an increase in regional metabolism (12). These PET findings were also more strongly associated with the clinical picture and active disease status than MRI. The literature regarding PET and AIE is very limited in the pediatric population and is limited to case reports [e.g., (14, 15)]. The largest report is a retrospective study of 34 children showing that quantitative PET was abnormal in 94.1% of patients with acute AIE vs. 41.2% for MRI and 6.9% for CT (23).

We believe that the current case adds to this literature that suggests PET as a relevant exam for possible AIE. Throughout the period of support for this patient in our department, several 18F-FDG-PET scans were performed and helped us for several reasons: (a) the abnormalities in 18F-FDG-PET were an argument for an ongoing neurological impairment, even if it was not included in the diagnostic algorithm; (b) the improvement in brain metabolism matched patient improvement, and this correlation led us to be very determined in the use of aggressive immunomodulatory and immunosuppressive treatment. All consecutive 18F-FDG-PET examinations were performed in a single center with high experience in neuroimaging, and the images were interpreted in a double-blind manner by a second colleague to check interrater validity. In addition, as shown in Figure 1, we used a control group of 23 individuals aged <40 years with no neurologic or psychiatric symptoms to compare Jason’s PET scans with the Z-scored method provided by Scenium software (Siemens Healthineers, Erlangen, Germany). Significant differences in metabolism were found in the brain regions interpreted as abnormal by nuclear medicine practitioners (see Figures 1G–I).
REFERENCES


DATA AVAILABILITY STATEMENT
The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT
Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants’ legal guardian/next of kin. Written informed consent was obtained from the patient and his parents for publication of the case report and the attached figures, PET images and videos.

DISCLOSURE
During the last 2 years, DC reported past consultation for or the receipt of honoraria from Otsuka, Lundbeck, and Jansen.

AUTHOR CONTRIBUTIONS
MG, MR, and AC: wrote the first draft. AK: supervised the TEP logistic and produced Figure 1. AK, MS, and MB: evaluation of TEP and recruitment of TEP controls. AA, AO, and MR: were in charge of the psychiatric treatment. DP and YA: gave neurologic and internal medicine expertise and treatment respectively. DC and AC: supervised the whole case report and revised the MS. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL
The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyt.2021.685711/full#supplementary-material
26. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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