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Review Article

Imaging Characteristics of Autoimmune Encephalitis

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Abstract

Autoimmune encephalitis encompasses a group of inflammatory disorders that are mediated by autoimmune mechanisms and can lead to severe disability and even death. Early diagnosis and treatment are essential for improving clinical outcomes. However, the diagnosis of autoimmune encephalitis in the clinical setting presents some challenges because of the diversity of clinical presentations and the delay in obtaining antibody panel results. Conventional imaging techniques, including magnetic resonance imaging (MRI) and positron-emission tomography (PET), may facilitate early diagnosis. This article reviews in detail the changes observed on brain MRI and PET in patients with autoimmune encephalitis.

Keywords: Magnetic Resonance Imaging; Positron-Emission Tomography; Autoimmune Encephalitis

Introduction

Autoimmune encephalitis encompasses a group of autoimmune-mediated inflammatory disorders, which are being increasingly recognized in clinical practice [1,2]. Autoimmune encephalitis is histopathologically characterized by the perivascular aggregation and infiltration of inflammatory cells, mainly lymphocytes, in many brain regions. Although the underlying pathogenesis is unclear, T-cells, B-cells, and complement are thought to be involved [3-6]. Autoimmune encephalitis is generally classified into two categories: (i) classic paraneoplastic limbic encephalitis associated with the so-called well-characterized onconeural autoantibodies against intracellular neuronal antigens (e.g. Hu and Ma2), and (ii) newer types of autoimmune encephalitis associated with autoantibodies to the neuronal surface or synaptic antigens [7]. An intermediate form between these two categories also exists. Anti-N-methyl-D-aspartate receptor (NMDAR) encephalitis is the most common form among the newer types of autoimmune encephalitis, accounting for 79.7% of all cases of autoimmune encephalitis, followed by anti-leucine-rich glioma-inactivated 1 (LGI1) receptor encephalitis [8].

In recent years, the number of patients admitted to the intensive care unit to be treated for autoimmune encephalitis has been increasing [9]. These disorders place a higher financial burden on

patients than do other types of encephalitis (e.g. herpes simplex encephalitis) [10]. Autoimmune encephalitis may cause severe disability and even death [11]. Many researchers have investigated various methods for the accurate diagnosis and timely treatment of patients with autoimmune encephalitis [12-14]. It has been demonstrated that the early initiation of immunosuppressive therapy may improve clinical outcomes [15-19]. Because early diagnosis is the basis of early treatment, the development of more accurate diagnostic examinations is imperative. The diagnostic criteria for autoimmune encephalitis include clinical features, laboratory results, and auxiliary examination findings [20,21]. The clinical presentation of autoimmune encephalitis includes seizures, psychiatric disorders, hallucinations, catatonia, paranoid thoughts, and behavioral and mood disorders. These symptoms are heterogeneous and nonspecific. Only about 50% of patients who undergo cerebrospinal fluid analysis show mild-to-moderate lymphocytic pleocytosis and increased protein concentration at the time of symptom onset [20]. Antibody tests are confirmatory but may be negative in some patients [22]. Furthermore, these tests are only available at specialized centers, and the results are obtained after several days. The limited availability of antibody tests and the lengthy waiting period for the results often delay diagnosis and complicate the treatment of autoimmune encephalitis [23,24]. Abnormal neuroimaging findings can provide clues to the central nervous system pathology, prompting further diagnostic work up and treatment. In this review, we focus on the neuroimaging characteristics of autoimmune encephalitis.

Magnetic resonance imaging

Magnetic resonance imaging (MRI) is a relatively economical and convenient auxiliary examination that is widely used in the diagnosis and treatment of nervous system diseases. MRI abnormality is one of the diagnostic criteria for autoimmune encephalitis [20]. Brain MRI is not only an auxiliary diagnostic tool for autoimmune encephalitis but also plays a role in follow-up, monitoring, and prognostic evaluation.

Autoimmune encephalitis is a type of limbic encephalitis mediated by autoantibodies. However, it is now known that extra-limbic structures can also be affected. The imaging findings characteristic of various types of autoimmune encephalitis are distinct. Kamble., *et al*. [25] retrospectively analyzed the MRI results of 15 patients with autoimmune neuronal synaptic encephalitis, including 9 patients with anti-NMDA antibodies, 4 patients with anti-TPO antibodies, and 2 patients with anti-VGKC antibodies. Both patients with anti-VGKC antibodies had abnormal imaging findings, while only 60% of the patients with anti-NMDA antibodies had abnormal imaging findings. Among the four patients with anti-TPO antibodies, one presented normal MRI findings, while the other three patients exhibited diffuse brain atrophy. This suggests that the incidence of MRI abnormalities differs among the various types of autoimmune encephalitis.

The nature of the MRI changes associated with various types of autoimmune encephalitis has previously been investigated. Newey., *et al*. [26] evaluated six patients with anti-VGKC receptor autoimmune encephalitis, all of whom had abnormal MRI findings. Most of these patients had mesial temporal lobe hyperintensity on T2-weighted/fluid-attenuated inversion recovery (FLAIR) images. Anti-VGKC receptor autoimmune encephalitis may also manifest on MRI as restricted diffusion in the hippocampus, anterior cingulate gyrus, and insular cortex [25]. A study of patients with anti-NMDAR encephalitis found that 50% of the patients had no abnormal MRI findings and that the other half showed only nonspecific changes in the grey and white matter [27]. Bacchi., *et al*. [28] analyzed the MRI abnormalities described in 41 studies of anti-NMDAR encephalitis. They found that the most common abnormalities were hyperintensity in the temporal lobe, usually in the medial region, on T2-weighted/FLAIR images. The incidence of gray-matter changes in the cerebral cortex was approximately equal to that of subcortical white-matter changes. High signal changes were also seen in the frontal lobe, hippocampus, periventricular region, and cerebellum (Figure 1). Other affected structures included the basal ganglia, insula, brainstem, and thalamus. Brain atrophy was seen on diffusion-weighted MRI in two patients with temporal lobe atrophy and one patient with hippocampal atrophy (Figure 2). Leptomeningeal enhancement was the most common manifestation on enhanced scans, followed by cortical enhancement. Pediatric patients with definite autoimmune encephalitis also showed MRI abnormalities within the limbic structures, especially the anteromedial temporal lobe (56%) [29]. The deep white matter of the brain, rather than the limbic system, was found to be most prone to MRI abnormalities in patients with autoimmune encephalitis of non-neoplastic etiology, especially those with anti-GABABR encephalitis [30]. Extra-limbic involvement has also been reported in patients with anti-GAD antibody-associated autoimmune encephalitis [31]. T2-weighted/FLAIR images revealed hyperintense mass-like lesions in the left anterior superior frontal gyrus and the right temporal

lobe. Involvement of the right internal and external capsules was also detected. The lesions did not exhibit gadolinium enhancement. Furthermore, an association between clinical manifestations and MRI lesions was found during the treatment process. MRI revealed enlargement of the lesions when the disease worsened and new non-enhancing hyperintense lesions appeared on T2-weighted/FLAIR images when the disease recurred [31].

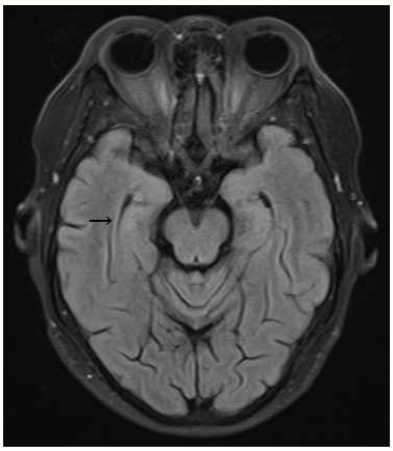

Figure 1

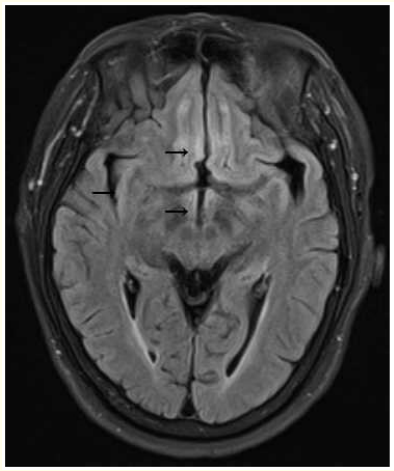

Figure 2

At present, the etiology and pathophysiology of AIE remain unclear. Finke., *et al*. [32] conducted a case-control study of 24 patients with an established diagnosis of anti-NMDAR encephalitis and age- and gender-matched controls. They found significantly reduced functional connectivity of the left and right hippocampus in the patients with anti-NMDAR encephalitis as compared with controls. In addition, diffusion tensor imaging revealed extensive white-matter changes, which were most prominent in the cingulum and were correlated with disease severity. However, they observed no significant differences between patients and controls in T1/T2-weighted structural imaging or gray-matter morphology. Peer., *et al*. [33] observed alterations in functional connectivity, including impaired hippocampal functional connectivity, decoupling of the medial temporal and default-mode networks, and overall impairment of frontotemporal connections, in patients with autoimmune encephalitis. These alterations were associated with memory impairment and schizophrenia-like symptoms. Szots., *et al*. [34] examined structural and metabolic brain abnormalities in patients with LGI1 encephalitis by using various MRI techniques, including automated volumetry, diffusion tensor imaging, and magnetic resonance spectroscopy (MRS). The results showed that the pathological changes affected not only the temporomesial structures but also the frontal lobes and the cerebellum. Global brain atrophy and disintegration of the white-matter tracts were associated with poor clinical outcomes among patients with LGI1 encephalitis. MRS revealed lower levels of glutamine/glutamate in the white matter in patients with LGI1 encephalitis than in controls. Notably, alterations in functional connectivity may not only impair connectivity but also increase connectivity [35].

Few studies have assessed the association between various MRI features and disease prognosis. In a study of patients with anti-NMDAR encephalitis, Iizuka., *et al*. [36] reported that cerebellar atrophy was progressive, irreversible, and associated with poor long-term outcomes. However, diffuse cerebral atrophy without cerebellar atrophy was reversible and not associated with poor outcomes. Another study on patients with relapsing anti-NMDAR encephalitis found that the incidence of relapse was not correlated with the incidence of MRI abnormalities [37]. Further research is needed to characterize the correlation between MRI changes and clinical outcomes.

In studies of autoimmune encephalitis, the proportion of normal MRI scans varies widely [38,39]. Therefore, negative MRI findings cannot be used as evidence to exclude a diagnosis of autoimmune encephalitis. Some studies have reported that the incidence of positive MRI findings decreases after the acute phase of the

disease [25,36]. However, other studies have described conflicting results, i.e. the proportion of MRI abnormalities increases with disease progression [40,41]. Thus, it is necessary to continue to study the MRI manifestations of various types of autoimmune encephalitis in different stages.

Positron-emission tomography

Positron-emission tomography (PET) functional neuroimaging may help overcome the diagnostic limitations of MRI [42,43] by improving the diagnostic sensitivity in autoimmune encephalitis [44]. ^{18}F-Fluorodeoxy-glucose PET (^{18}F-FDG PET) is currently the functional imaging method used most commonly in clinical practice for evaluating brain metabolism and this method is able to detect abnormalities with greater sensitivity than MRI [26]. Solnes., *et al*. [45] retrospectively reviewed 23 cases of antibody-positive autoimmune encephalitis to determine the rate of positive MRI and ^{18}F-FDG PET abnormalities. They found that abnormalities were more often observed on ^{18}F-FDG PET than on MRI. The most common abnormality on brain ^{18}F-FDG PET imaging was lobar hypometabolism, which was most frequently observed in the parietal lobe, followed by the occipital lobe. Although ^{18}F-FDG PET is more sensitive than MRI, not all autoimmune encephalitis patients have positive PET scans. In one study, only 85% of patients were found to have abnormalities on FDG-PET: hypometabolism in 69% of patients, hypermetabolism in 3% of patients, and both hyper- and hypometabolism in 13% of patients [46]. Thus, the most common abnormality of brain metabolism in patients with antibody-positive autoimmune encephalitis is hypometabolism.

Various metabolic abnormalities have been detected in patients with autoimmune encephalitis. For example, patients with anti-GAD receptor encephalitis have anomalies of brain metabolism ranging from hypermetabolism in the basal ganglia and brainstem, to bilateral hypermetabolism in the basal ganglia and mesial temporal lobe with hypometabolism in the parieto-temporal lobe, to cerebellar hypometabolism alone [18]. However, patients with anti-NMDAR encephalitis have a common pattern of brain metabolic changes: glucose hypermetabolism in the frontal and temporal lobes and hypometabolism in the occipital lobes [47]. Furthermore, the abnormal metabolic pattern is related to disease severity [48]. Novy., *et al*. [49] confirmed an anteroposterior metabolic gradient and found a significant increase in FDG uptake in the caudate nuclei in patients with anti-NMDAR encephalitis. Yuan., *et al*. [50] reviewed the PET scans of patients at various stages of anti-NMDAR encephalitis. They observed changes in anteroposterior metabolic gradient and found that these changes in brain metabolism were related to the clinical course and antibody level. In the acute and subacute phases, severe hypometabolism was observed bilaterally in the occipital lobes, with relatively mild hypermetabolism in the parietal and frontal lobes, as well as the basal ganglia. Antibody levels were also high during these phases. Extensive cortical hypometabolism and low antibody levels were observed during the early recovery phase. During the recovery phase, PET images were almost within the normal range, and all antibody tests yielded negative results. The relapsing phase was characterized by heterogeneous abnormalities of brain metabolism.

Changes in brain metabolism have also been associated with the severity of the clinical manifestations of autoimmune encephalitis. Patients with mild catatonia had hypermetabolism in the frontotemporoparietal regions and bilaterally in the basal ganglia. However, patients with severe catatonia had more significant and widespread hypermetabolic changes in the thalamus and brainstem. The extent of the hypometabolic changes did not markedly differ among patients. This pattern suggests that the severity of catatonia may be associated with hypermetabolism rather than hypometabolism [51]. Upon recovery from autoimmune encephalitis, brain metabolism returned to normal [48,52]. One study on pediatric patients with anti-NMDAR encephalitis patients found that changes in cerebral metabolism were related to clinical severity and paralleled prognosis [43]. FDG-PET imaging has clinical applications in the follow-up evaluation and therapeutic monitoring of patients with autoimmune encephalitis [53]. However, few reports have evaluated prognostication based on FDG-PET in autoimmune encephalitis and the utility of this technique in predicting the prognosis of these patients remains to be determined [54].

Conclusion

In summary, autoimmune encephalitis may involve the limbic system as well as extra-limbic structures. The clinical manifestations of autoimmune encephalitis are nonspecific and heterogenous. Although the imaging features of different types of autoimmune encephalitis vary widely, some previous studies [36,44] suggest that neuroimaging helps in detecting abnormalities early, making an accurate diagnosis, determining disease severity, and predicting prognosis.

The existing studies on neuroimaging in autoimmune encephalitis are almost all retrospective studies with relatively small sample sizes. Additional large-scale studies will be necessary to systematically evaluate the value of neuroimaging in the early diagnosis and timely evaluation of therapeutic efficacy, as well as the prediction of prognosis, in patients with autoimmune encephalitis.

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Conflict of Interest

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Bibliography

1. Ramanathan S., *et al*. "Autoimmune encephalitis: recent updates and emerging challenges". *Journal of Clinical Neuroscience* 21.5 (2014): 722-730.

2. Zuliani L., *et al*. "Management of antibody-mediated autoimmune encephalitis in adults and children: literature review and consensus-based practical recommendations". *Neurological Sciences* 40 (2019): 2017-2030.

3. Hoftberger R and Lassmann H. "Immune-mediated disorders". *Handbook of Clinical Neurology* 145 (2017): 285-299.

4. Kelleher E., *et al*. "Autoantibodies and Psychosis". *Current Topics in Behavioral Neurosciences* 44 (2020): 85-123.

5. Selmi C., *et al*. "Current trends in autoimmunity and the nervous system". *Journal of Autoimmunity* 75 (2016): 20-29.

6. Varley J., *et al*. "Autoantibody-mediated diseases of the CNS: Structure, dysfunction and therapy". *Neuropharmacology* 132 (2018): 71-82.

7. Leypoldt F., *et al*. "Autoimmune encephalopathies". *Annals of the New York Academy of Sciences* 1338 (2015): 94-114.

8. Guan HZ., *et al*. "Autoimmune Encephalitis: An Expanding Frontier of Neuroimmunology". *Chinese Medical Journal* 129.9 (2016): 1122-1127.

9. Harutyunyan G., *et al*. "Autoimmune Encephalitis at the Neurological Intensive Care Unit: Etiologies, Reasons for Admission and Survival". *Neurocritical Care* 27.1 (2017): 82-89.

10. Cohen J., *et al*. "Autoimmune encephalitis: A costly condition". *Neurology* 92.9 (2019): e964-e972.

11. Broadley J., *et al*. "Prognosis in autoimmune encephalitis: Database". *Data in Brief* 21 (2018): 2694-2703.

12. Bien CG. "Diagnosing autoimmune encephalitis based on clinical features and autoantibody findings". *Expert Review of Clinical Immunology* 15.5 (2019): 511-527.

13. Blaabjerg M., *et al*. "Editorial: Emerging Challenges in the Diagnosis and Treatment of Autoimmune Encephalitis". *Frontiers in Neurology* 10 (2019): 146.

14. Hermetter C., *et al*. "Systematic Review: Syndromes, Early Diagnosis, and Treatment in Autoimmune Encephalitis". *Frontiers in Neurology* 9 (2018): 706.

15. Titulaer MJ., *et al*. "Treatment and prognostic factors for long-term outcome in patients with anti-NMDA receptor encephalitis: an observational cohort study". *Lancet Neurology* 12.2 (2013): 157-165.

16. Byrne S., *et al*. "Earlier treatment of NMDAR antibody encephalitis in children results in a better outcome". *Neurology: Neuroimmunology and NeuroInflammation* 2.4 (2015): e130.

17. Irani SR., *et al*. "N-methyl-D-aspartate antibody encephalitis: temporal progression of clinical and paraclinical observations in a predominantly non-paraneoplastic disorder of both sexes". *Brain* 133.6 (2010): 1655-1667.

18. Tripathi M., *et al*. "Metabolic topography of autoimmune non-paraneoplastic encephalitis". *Neuroradiology* 60.2 (2018): 189-198.

19. Vollmer TL and McCarthy M. "Autoimmune encephalitis: A more treatable tragedy if diagnosed early". *Neurology* 86.18 (2016): 1655-1656.

20. Graus F., *et al*. "A clinical approach to diagnosis of autoimmune encephalitis". *The Lancet Neurology* 15.4 (2016): 391-404.

21. Neurology Branch of Chinese Medical Association. Chinese expert consensus on the diagnosis and management of autoimmune encephalitis". *Chinese Journal of Neurology* 50.2 (2017): 91-98.

22. Lee SK and Lee ST. "The Laboratory Diagnosis of Autoimmune Encephalitis". *Journal of Epilepsy Research* 6.2 (2016): 45-50.

23. Antoine JC. "Autoimmune encephalitis: paving the way for early diagnosis". *Lancet Neurology* 15.4 (2016): 349-350.

24. Dubey D., *et al*. "Characteristics of Autoimmune Encephalitis at Two Teaching Hospitals". *AAN Enterprises* (2015): 4.

25. Kamble N., *et al*. "Clinical and imaging characteristics of 16 patients with autoimmune neuronal synaptic encephalitis". *Neurology India* 63.5 (2015): 687-696.

26. Newey CR., *et al*. "[(18)F]-Fluoro-Deoxy-Glucose Positron Emission Tomography Scan Should Be Obtained Early in Cases of Autoimmune Encephalitis". *Autoimmune Diseases* (2016): 9450452.

27. Dalmau J., *et al*. "Clinical experience and laboratory investigations in patients with anti-NMDAR encephalitis". *Lancet Neurology* 10.1 (2011): 63-74.

28. Bacchi S., *et al*. "Magnetic resonance imaging and positron emission tomography in anti-NMDA receptor encephalitis: A systematic review". *Journal of Clinical Neuroscience* 52 (2018): 54-59.

29. Albert DV., *et al*. "Utility of Neurodiagnostic Studies in the Diagnosis of Autoimmune Encephalitis in Children". *Pediatric Neurology* 55 (2016): 37-45.

30. Vallabhaneni D., *et al*. "Perfusion Imaging in Autoimmune Encephalitis". *Radiology Case Reports* (2018): 3538645.

31. Kojima G., *et al*. "PET-positive extralimbic presentation of anti-glutamic acid decarboxylase antibody-associated encephalitis". *Epileptic Disorders* 16.3 (2014): 358-361.

32. Finke C., *et al*. "Functional and structural brain changes in anti-N-methyl-D-aspartate receptor encephalitis". *Annals of Neurology* 74.2 (2013): 284-296.

33. Peer M., *et al*. "Functional connectivity of large-scale brain networks in patients with anti-NMDA receptor encephalitis: an observational study". *Lancet Psychiatry* 4.10 (2017): 768-774.

34. Szots M., *et al*. "Global brain atrophy and metabolic dysfunction in LGI1 encephalitis: A prospective multimodal MRI study". *Journal of the Neurological Sciences* 376 (2017): 159-165.

35. Heine J., *et al*. "Beyond the limbic system: disruption and functional compensation of large-scale brain networks in patients with anti-LGI1 encephalitis". *Journal of Neurology, Neurosurgery, and Psychiatry* 89.11 (2018): 1191-1199.

36. Iizuka T., *et al*. "Association of Progressive Cerebellar Atrophy With Long-term Outcome in Patients With Anti-N-Methyl-d-Aspartate Receptor Encephalitis". *JAMA Neurology* 73.6 (2016): 706-713.

37. Gabilondo I., *et al*. "Analysis of relapses in anti-NMDAR encephalitis". *Neurology* 77.10 (2011): 996-999.

38. Dalmau J., *et al*. "Paraneoplastic anti-N-methyl-D-aspartate receptor encephalitis associated with ovarian teratoma". *Annals of Neurology* 61.1 (2007): 25-36.

39. Bigi S., *et al*. "The growing spectrum of antibody-associated inflammatory brain diseases in children". *Neurology: Neuroimmunology and NeuroInflammation* 2.3 (2015): e92.

40. Hacohen Y., *et al*. "Paediatric autoimmune encephalopathies: clinical features, laboratory investigations and outcomes in patients with or without antibodies to known central nervous system autoantigens". *Journal of Neurology, Neurosurgery, and Psychiatry* 84.7 (2013): 748-755.

41. Holzer FJ., *et al*. "Antibody-mediated status epilepticus: a retrospective multicenter survey". *European Neurology* 68.5 (2012): 310-317.

42. Heine J., *et al*. "Imaging of autoimmune encephalitis--Relevance for clinical practice and hippocampal function". *Neuroscience* 309 (2015): 68-83.

43. Lagarde S., *et al*. "Cerebral (18)FluoroDeoxy-Glucose Positron Emission Tomography in paediatric anti N-methyl-D-aspartate receptor encephalitis: A case series". *Brain and Development* 38.5 (2016): 461-470.

44. Turpin S., *et al*. "18F-Flurodeoxyglucose positron emission tomography with computed tomography (FDG PET/CT) findings in children with encephalitis and comparison to conventional imaging". *European Journal of Nuclear Medicine and Molecular Imaging* 46.6 (2019): 1309-1324.

45. Solnes LB., *et al*. "Diagnostic Value of (18)F-FDG PET/CT Versus MRI in the Setting of Antibody-Specific Autoimmune Encephalitis". *The Journal of Nuclear Medicine 58*.8 (2017): 1307-1313.

46. Probasco JC., *et al*. "Abnormal brain metabolism on FDG-PET/CT is a common early finding in autoimmune encephalitis". *Neurology: Neuroimmunology and NeuroInflammation* 4.4 (2017): e352.

47. Sethi NK., *et al*. "EEG and PET changes in anti-N-methyl-D-aspartic acid receptor encephalitis". *The American Journal of Psychiatry* 171.8 (2014): 889-890.

48. Leypoldt F., *et al*. "Fluorodeoxyglucose positron emission tomography in anti-N-methyl-D-aspartate receptor encephalitis: distinct pattern of disease". *Journal of Neurology, Neurosurgery, and Psychiatry* 83.7 (2012): 681-686.

49. Novy J., *et al*. "FDG-PET hyperactivity pattern in anti-NMDAr encephalitis". *Journal of Neuroimmunology* 297 (2016): 156-158.

50. Yuan J., *et al*. "Changing Brain Metabolism Patterns in Patients With ANMDARE: Serial 18F-FDG PET/CT Findings". *Clinical Nuclear Medicine* 41.5 (2016): 366-370.

51. Lee EM., *et al*. "18F-Fluorodeoxyglucose Positron-Emission Tomography Findings with Anti-N-Methyl-D-Aspartate Receptor Encephalitis that Showed Variable Degrees of Catatonia: Three Cases Report". *Journal of Epilepsy Research* 4.2 (2014): 69-73.

52. Chen B., *et al*. "Marked improvement of anti-N-methyl-D-aspartate receptor encephalitis by large-dose methylprednisolone and plasmapheresis therapy combined with (18) F-fluorodeoxyglucose positron emission tomography imaging: A case report". *Experimental and Therapeutic Medicine* 8.4 (2014): 1167-1169.

53. Trevino-Peinado C., *et al*. "Monitoring the Effect of Immunotherapy in Autoimmune Limbic Encephalitis Using 18F-FDG PET". *Clinical Nuclear Medicine* 40.9 (2015): e441-443.

54. Wegner F., *et al*. "Anti-leucine rich glioma inactivated 1 protein and anti-N-methyl-D-aspartate receptor encephalitis show distinct patterns of brain glucose metabolism in 18F-fluoro-2-deoxy-d-glucose positron emission tomography". *BMC Neurology* 14 (2014): 136.