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CASE REPORT

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Autoimmune encephalitis with coexisting antibodies to GABABR, GAD65, SOX1 and Ma2

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Abstract

Background Autoimmune encephalitis (AE) is a disease caused by an abnormal reaction between the body's autoimmunity and the central nervous system, in which the abnormal immune response targets antigenic components within or on the surface of neuronal cells. The main manifestations are mental and behavioural changes, cognitive impairment, impaired consciousness, seizures, movement disorders, etc. Most cell surface antibodies respond well to immunotherapy, intracellular antibodies, on the other hand, are usually associated with more tumours and are relatively difficult to treat with a poor prognosis. In recent years, autoimmune encephalitis that is positive for multiple anti-neuronal antibodies has been gradually recognized in the clinic, with complex and varied clinical manifestations, especially in combination with malignant tumours, which have worse treatment and prognosis. Current clinical studies on the coexistence of multiple anti-neuronal antibodies in patients with AE are mainly disseminated case reports. Patients with AE in which four anti-neuronal antibodies coexist are even rarer.

Case presentation We report a patient who initially presented with an irritating dry cough and hyponatraemia and a chest CT suspicious for malignancy, followed by progressive deterioration of persistent status epilepticus, consciousness and cognitive deficits, and psycho-behavioural abnormalities. Serum and cerebrospinal fluid antibodies against neuronal surface or intracellular antigens were detected using a cell-based assay (CBA) method. Serum and cerebrospinal fluid were found to be positive for anti-GABABR, GAD65, SOX1 and Ma2 antibodies. And a definitive diagnosis of small cell lung cancer was made by immunohistochemistry. He eventually received gammaglobulin, steroid pulsed therapy and tumour chemotherapy.

Conclusions The coexistence or overlap of multiple anti-neuronal surface antibodies with anti-neuronal intracellular antibodies is rare and increases the likelihood of underlying malignancy. Elucidating the impact of individualized immunotherapy and coexisting antibodies on the clinical presentation of patients has the potential to improve long-term prognosis.

Keywords Autoimmune encephalitis, paraneoplastic limbic encephalitis, intractable epilepsy, small cell lung cancer, hyponatraemia

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Background

Autoimmune encephalitis (AE) refers to a heterogeneous group of CNS autoimmune diseases characterized by the production of different anti-neuronal surface antigen antibodies and anti-neuronal intracellular antigen antibodies [1]. The main manifestations are mental and behavioural changes, cognitive impairment, impaired consciousness, seizures, movement disorders. The etiology of AE is not fully understood, with tumours and infections being the most common causes, while genetic factors and the use of immune checkpoint inhibitors (ICIs) have also received attention in recent years [2, 3]. Neuropathology often with lymphocyte-based inflammatory cells infiltrate the brain gray matter, white matter and cerebrovascular vessels can also be involved, and this type of encephalitis accounts for about 10–20% of all cases of encephalitis [4]. Most cell surface antibodies respond well to immunotherapy, but some patients with severe disease or tumour combination have a poor prognosis, with refractory epilepsy and varying degrees of cognitive impairment. While intracellular antibodies usually have a neoplastic background, which attack CNS cells by cytotoxic T cells [5], leading to neural cell death and usually have a poor prognosis.

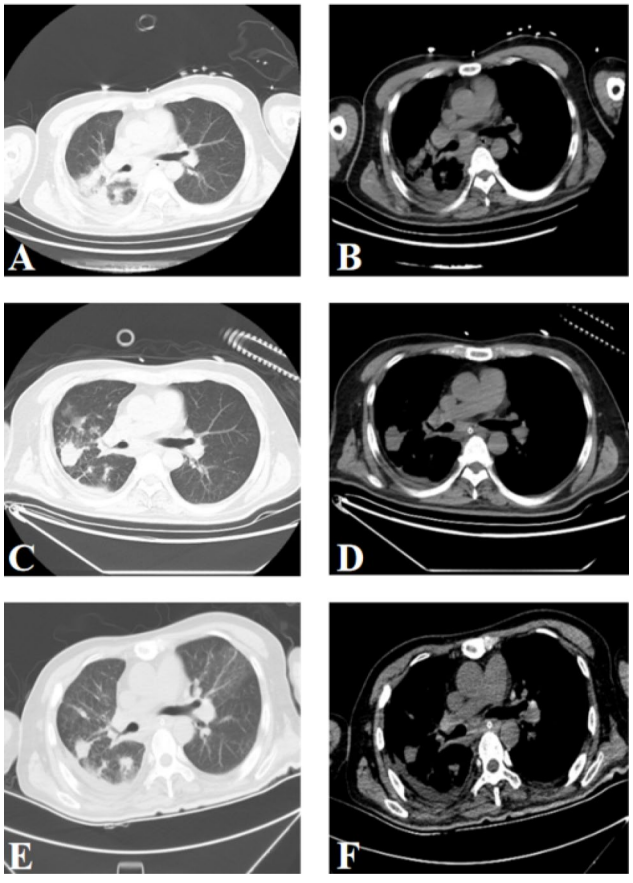

Fig. 1 Chest CT image showing the occupation of the right hilar and right middle and lower lobes of the lungs (**A**, **B**). After one cycle of chemotherapy, the absorbed of lung lesions became small and aggregated (**C**, **D**). After two cycles of chemotherapy, the lung space is reabsorbed to a smaller extent. (**E**, **F**)

Case presentation

The 45-year-old male patient had a history of heavy smoking and drinking: approximately 20 years of drinking, an average of 1 bottle of white wine per day; approximately 20 years of smoking, an average of 1 packet per day. In March 2021, he developed an irritating dry cough, and chest CT revealed a localized area on the right lung hilum, which was suspicious of a malignant tumor; the patient then intermittently presented with a loss of consciousness, epileptic seizures, psychiatric behavioral abnormalities, and cognitive impairment. The laboratory test results were as follows: Na+116.4 mmol/L (normal value 137.0-147.0 mmol/L); inflammatory indicators: C-reactive protein: CRP 31.6 mg/L (normal value<10.0 mg/L); calcitoninogen: PCT>10 ng/ml (normal value<0.5 ng/ml); and sputum culture indicating *Streptococcus pyogenes* infection. After anti-infection treatment, tracheotomy and ventilator-assisted ventilation were performed. On 7 April 2021, chest CT (Fig. 1A and B) revealed right central lung cancer and metastasis to large lymph nodes in the mediastinum and bilateral hilar lymph nodes.

After 2 weeks of hospitalization, the results of lumbar puncture revealed a cerebrospinal fluid pressure of 210 mmH20 (1 mmH20=0.0098 kPa); cerebrospinal fluid cytology revealed 750/mm^3 erythrocytes, 12/mm^3 leukocytes, 77% lymphocytes, 22% monocytes, and 1% neutrophils; Penn's test was negative; cerebrospinal fluid biochemistry revealed 0.55 g/ L TP-CSF (normal value 0.12–0.60 g/L), 3.2 mmol/L GLU (normal value 2.20–3.90 mmol/L), 117 mmol/L Cl (normal value 120–132 mmol/L). Twenty-four hour dynamic EEG suggested moderately abnormal dynamic EEG monitoring, with bilateral frontal zone spike and spike slow wave issuance in the sleep period. Cranial magnetic resonance enhancement suggested deep patchy high signal foci in the left temporal lobe on T1-weighted images (Fig. 2A); T1-weighted-FLAIR images (Fig. 2B); T2-weighted images (Fig. 2C); Diffusion-weighted images (Fig. 2D). Lung puncture biopsy in May 2021 revealed markedly extruded and deformed cells in fibrous tissue and inflammatory necrotic material (Fig. 3), consistent with small cell carcinoma. Immunohistochemistry (IHC) revealed TTF1 (+), NapsinA (-), P40 (-), P63 (-), CD56 (+), Syn (+), CgA (+), CD117 (+), and Ki67 (approximately 80%) in cancer cells. The diagnosis of SCLC was confirmed, and the 1st cycle of chemotherapy with etoposide+carboplatin regimen was started on May 8 (specific regimen: etoposide 100 mg IV d1-3, carboplatin 300 mg IV d1, 21 days for 1 cycle).

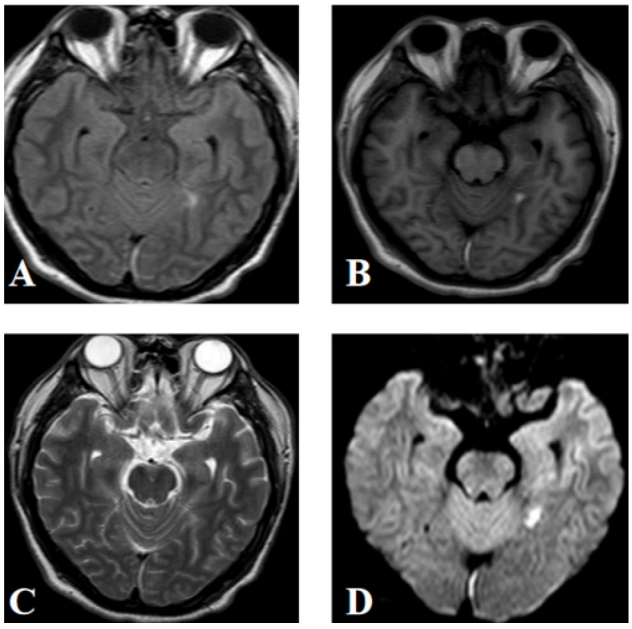

Fig. 2 MRI scan showing deep patchy high-signal foci in the left temporal lobe. **A** T1-weighted images; **B** T1-weighted FLAIR images; **C** T2-weighted images; **D** diffusion-weighted images

The anti-neuronal antibodies were detected by a third-party medical diagnostic company (Goldcorp Medical). On 7 May 2021, serum and cerebrospinal fluid anti-neuronal surface or anti-neuronal intracellular antibodies were detected using a cell-based assay (CBA). The results of 11 paraneoplastic syndrome antibody tests (serum) revealed the following: anti-GAD65 antibody was IgG positive (+), anti-SOX1 antibody was IgG positive (+), anti-Ma2 antibody was IgG positive (+), and the rest of the anti-Zic4, anti-Tr (DNER), anti-Ma1, anti-amphiphysin, anti-CV2, anti-Ri, anti-Yo, and anti-Hu antibodies were negative. The results of 11 paraneoplastic syndrome antibody tests (cerebrospinal fluid) revealed the following: anti-GAD65 antibody was IgG positive (+), anti-SOX1 antibody was IgG positive (+), anti-Ma2 antibody was IgG positive (+), and the rest of the anti-Zic4, anti-Tr (DNER), anti-Ma1, anti-amphiphysin, anti-CV2, anti-Ri, anti-Yo, and anti-Hu antibodies were negative. Autoimmune encephalitis-associated antibodies 6 items (serum) revealed the following: anti-γ-aminobutyric acid receptor (GABABR) antibody IgG positive (+) 1:100; and the rest of the anti-NMDAR, anti-AMPA1, anti-AMPA2, anti-LGI1, and anti-CASPR2 antibodies were negative. Autoimmune encephalitis-associated antibodies 6 items (cerebrospinal fluid) revealed the following: anti-γ-aminobutyric acid receptor (GABABR) antibody IgG positive (+) 1:100; and the rest of the anti-NMDAR, anti-AMPA1, anti-AMPA2, anti-LGI1, and anti-CASPR2 antibodies were negative (Fig. 4A and B). pulsed therapy with immunoglobulin (IVIg 0.4 g/kg*d for 5 days) was started, and dexamethasone (10 mg once per day) was given as an anti-inflammatory therapy.

On 28 May 2021, sputum culture was performed, and the results suggested *Acinetobacter baumannii*. The patient was given a combination of cefoperazone sodium sulbactam sodium, minocycline, and cotrimoxazole, and the infection was controlled. The patient experienced repeated episodes of hyponatremia and electrolytes on June 4, suggesting that a blood sodium concentration of 104 mmol / L, should be used for symptomatic treatment.

Throughout the course of the disease, the patient's memory impairment and mental abnormalities persisted without improvement; at the end of cycle 1 of chemotherapy, the exudative foci in the lungs were absorbed compared with the previous ones (Fig. 1C and D), and respiratory function improved compared with the previous ones before stopping the ventilator-assisted ventilation and administering methylprednisolone sodium succinate 500 mg once per day high-dose pulsed treatment for 3 days. After the 2nd cycle of chemotherapy, the

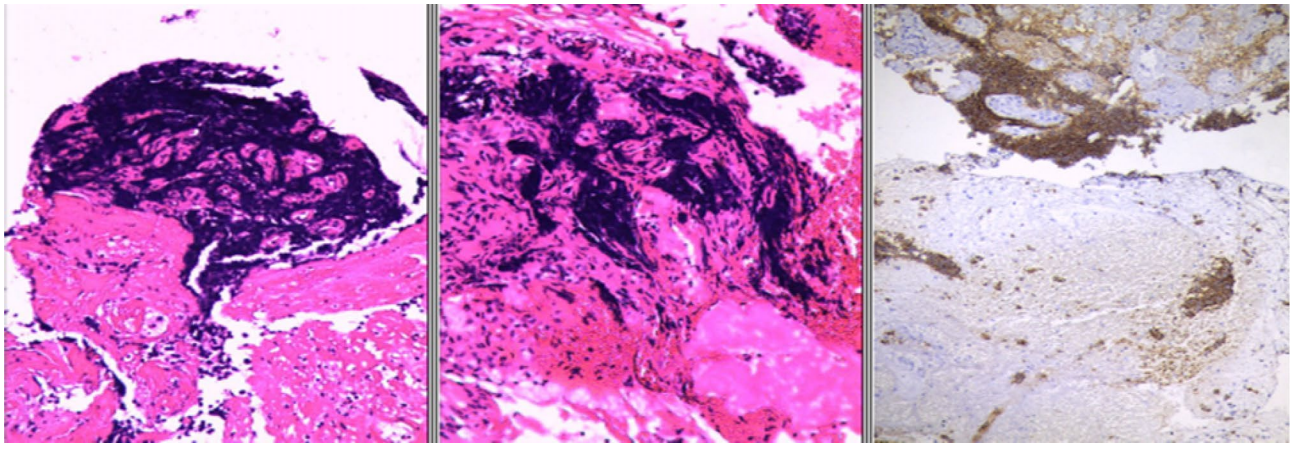

Fig. 3 Bronchoscopic lung aspiration biopsy cytology showing cancer cells (Giemsa staining,40×)

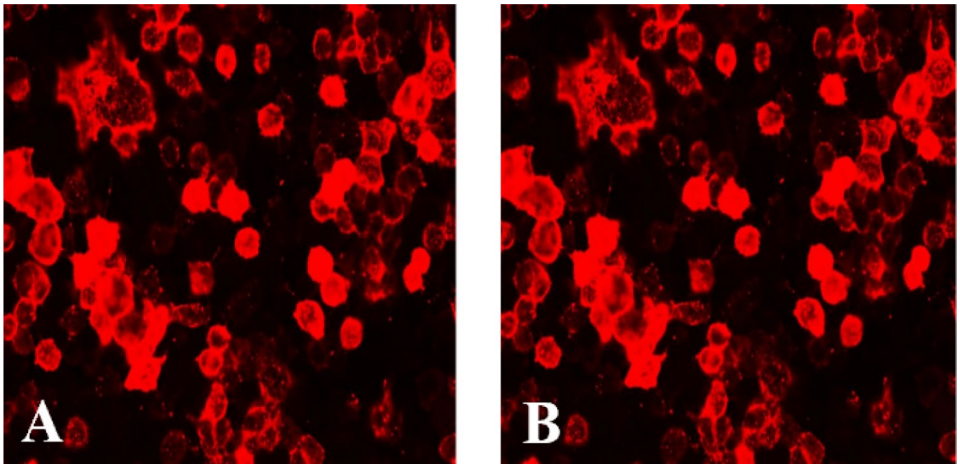

Fig. 4 A Serum and B CSF anti - γ - aminobutyrate B receptor (GABAB) antibody IgG (+) 1:100

lung lesions were further controlled (Fig. 1E and F), but some exudative lesions still existed. The patient was later discharged from the hospital on 8 July 2021 for financial reasons, as his mental acuity improved, and he regained consciousness. After discharge, the patient still experienced intermittent episodes of convulsive symptoms, the patient's hyponatraemia persisted unrelieved, his symptoms gradually worsened, he continued to be maintained on oral medication, he terminated chemotherapy for lung cancer for financial reasons, and he died within 2 months of discharge during telephone follow-up.

Discussion and conclusions

In this report, we describe the clinical presentation, treatment and prognosis of a patient with four-autoantibody AE in combination with small-cell lung cancer, with the aim of providing protocols for the early identification and treatment of multiple-antibody AE.

It is uncommon for AE patients to have multiple neuronal antibodies, especially more than two. In 2019, a retrospective analysis of 189 AE patients in southwestern China revealed that dual antibodies were present in only eight patients [6]. In 2022, from a study of 276 patients with AE from different clinical centers, we found that two or more antibodies were present in 22 patients, and three or more antibodies were present in three of them [7]. As the spectrum of anti-neurological antibodies continues to expand and become more commonly used, the phenomenon of overlapping antibodies and overlapping clinical phenotypes is increasing. The main symptoms of patients with multiple anti-neuronal antibodies are closely related to cerebrospinal fluid-positive autoantibodies [8]. Although AE is considered a paraneoplastic syndrome associated with cancer, it is important to recognize that the strength of this association may vary depending on the particular antibody, leading to a different relationship with paraneoplastic syndromes [9]. In 2017, a patient with paraneoplastic limbic encephalitis and small cell lung cancer with anti-SOX1, anti-Hu and anti-aphid antibodies was diagnosed for the first time in India, and after immunotherapy with intravenous steroids and immunoglobulins, plasmapheresis and cyclophosphamide, as well as oncological chemotherapy, there was no improvement in clinical symptoms, and the patient progressed to pulmonary sepsis and died [10]. In 2019, Ryan Kammeyer reported for the first time the case of a patient with multiple autoantibodies coexisting in cerebrospinal fluid (anti-NMDAR, anti-Ma1/Ma2) and serum (anti-GAD65) and a suspected lung tumor, which improved with treatment with intravenous steroids, plasmapheresis and rituximab [11]. In 2022, Xue-wu Liu presented a patient with AE coexisting with anti-NMDAR, GAD65 and SOX1 antibodies and concomitant small cell lung cancer who improved after immunotherapy and tumor chemotherapy [12]. In 2023, Maryam Alhamer reported an elderly female patient with AE with serum anti-Ri, anti-CENP-A/B, anti-LGI1, and anti-AMPAR2 antibodies who exhibited acute changes in mental status (persecutory delusions and audiovisual hallucinations) [9]. Our case reports a patient with AE with co-existing anti-GABABR, GAD65, SOX1 and Ma2 antibodies in both serum and cerebrospinal fluid with severe hyponatraemia and small cell lung cancer, who improved and had further reduction of lung lesions after steroids, immunotherapy and oncological chemotherapy; Unfortunately, the patient had an inadequate course of tumour chemotherapy and sustained electrolyte disorders, resulting in a poor prognosis.

GABABR antibody are considered to be pathogenic autoantibodies, with a possible pathogenesis that involves altering the quantity or function of target antigens to play a direct pathogenic role [13]. It has been hypothesised that blockade by GABABR antibody during the initial stages of the disease promotes synchronization

of large numbers of neurons, thereby inducing seizures. Antibody titres in serum and cerebrospinal fluid correlate with initial disease severity, and cerebrospinal fluid antibody titres also reflect short-term prognosis of the disease. Approximately 50% of patients with anti-GABAB receptor antibodies develop an underlying tumor, most commonly small cell lung cancer [14]. Anti-GABABR antibodies combined with paraneoplastic-associated antibodies had the highest prevalence and may be associated with tumour-induced anti-GABABR antibodies [15]. With consistency in our report, anti-GABABR antibodies with antibody titres of 1:100 in both serum and cerebrospinal fluid may cause severe and refractory seizures in patients with small-cell lung cancer and further stimulate hyponatraemia. SOX1 belongs to the family of DNA-binding transcription factors and is an autoantibody that specifically binds to the nucleus of the Bergmann astrocyte in the Purkinje cell layer of the cerebellum. The production of antibodies to SOX1 is due to an enhanced autoimmune response to cell membrane ion channels. Studies have shown that anti-SOX1 antibodies are a potential risk factor for SCLC, SOX1 antibodies alone do not indicate the presence of cancer, but when coexisting with VGCC antibodies it causes LEMS, which predicts the presence of SCLC and is a specific serological marker for SCLC, but is not associated with patient survival [16]. The risk of cancer increases with age, male sex, and the presence of coexisting neuronal cell surface antibodies [17]. Anti-GAD antibody encephalitis is an autoimmune encephalitis mediated by anti-glutamic acid decarboxylase antibody, which belongs to the intracellular antibody and is manifested as stiff person syndrome, cerebellar ataxia, limbic encephalitis, seizures, etc., and is often combined with a variety of autoimmune disorders, and is very seldom accompanied by tumours. Anti-GAD65 antibody is the main type of anti-GAD antibody. GAD65 antibody reacts with GAD65 only during membrane permeabilization without internalization in live neurons [18]. The neurological syndromes associated with GAD are poorly treated by the immune response, and there is no significant correlation between the antibody titre and the severity of the disease; moreover, the pathogenicity of these conditions remains to be confirmed by further studies. However, autoimmune mechanisms play a key role in the pathogenesis of the disease. Josep Dalmau et al. [19] found that patients with anti-Ma2 antibody-associated encephalitis presented with symptoms of limbic, mesencephalic, or brainstem dysfunction with MRI abnormalities. Greater than >50% of these patients usually have testicular germ cell tumours, and neurological deficits improve or stabilize after cancer treatment and immunosuppression [19]. In addition, hyponatraemia is a common paraneoplastic syndrome caused by ectopic secretion of small cell lung cancer [20]. Tomonobu Koizumi et al. [21] reported that about approximately 9%~15% of patients with small cell lung cancer had combined hyponatremia, which is usually closely related to the ectopic secretion of antidiuretic hormone by paraneoplastic tumours. Recalcitrant hyponatremia secondary to abnormal secretion of antidiuretic hormone (SIADH) is an independent risk factor for poor prognosis in patients with malignant tumours [21, 22], and timely sodium supplementation therapy can significantly improve the survival prognosis of patients.

This article describes a patient with AE with anti-GABAB, SOX1, Ma2, GAD65 antibodies and with refractory status epilepticus, severe hyponatraemia and small cell lung cancer. The patient initially presented with pulmonary symptoms, seizures and electrolyte disturbances, followed by gradual deterioration of consciousness and cognition, and psychiatric abnormalities. After the diagnosis was made, the patient received gammaglobulin, steroid pulse therapy, and chemotherapy for small-cell lung cancer, which resulted in improvement of the patient's consciousness and psychiatric symptoms, as well as further reduction of the lung lesions, but persistent hyponatremia, which made it difficult to correct, and the patient was discharged from the hospital due to financial reasons, and the above symptoms recurred. The patient died within two months, and it was considered that it might be related to the insufficient course of chemotherapy for the tumour. The co-existence or overlap of multiple anti-neuronal surface antibodies with anti-neuronal intracellular antibodies is currently rare. When anti-neuronal cell surface protein antibodies are superimposed on classical paraneoplastic anti-neuronal antibodies, the former may be pathogenic, whereas the latter are suggestive of an underlying malignancy. The superposition of antibodies may also cause the superposition of clinical syndromes, so it is often necessary to analyze the specific antibody types and clinical manifestations, and to elucidate the effects of individualized immunotherapy and co-existing antibodies on the clinical manifestations of patients, the clinical significance and mechanisms of which still need to be thoroughly investigated.

Abbreviations

AE	Autoimmune encephalitis
CBA	Cell-based assay
CNS	Central nervous system
GABABR	Gamma aminobutyric acid B receptor
SOX-1	Y-chromosome sex-determining region-associated high mobility superfamily 1
GAD65	Glutamic acid decarboxylase 65
CSF	Cerebrospinal fluid
EEG	Electroencephalogram
NMDAR	N-methyl-D-aspartate receptor
LGI1	Leucine-rich glioma-inactivated 1
SCLC	Small cell lung cancer
SIADH	Syndrome of abnormal secretion of antidiuretic hormone

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Author contributions
Authors' contributionsP.K.L: Conceptualization, Investigation, Methodology, Writing – original draft, Writing – review & editing. T.T.Y: Supervision, Validation, Writing – review & editing. Y.X.G: Supervision & Validation. J.Z: Supervision & Validation. Z.H.W: Funding acquisition, Resources, Writing – review & editing.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Consent for publication
Written informed consent was obtained from the patient for publication of this case report and any accompanying images.

Competing interests
The authors declare no competing interests.

Ethics statement
The studies involving humans were approved by the Medical Research Ethics Review Committee, General Hospital of Ningxia Medical University.

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 potential conflicts of interest.

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References

1. Seery N, Butzkueven H, O'Brien TJ, Monif M. <ArticleTitle Language="En">Rare antibody-mediated and seronegative autoimmune encephalitis: an update. Autoimmun Rev. 2022;21:103118. https://doi.org/10.1016/j.autrev.2022.103118.
2. Muniz-Castrillo S, Vogrig A, Honnorat J. Associations between HLA and autoimmune neurological diseases with autoantibodies. Auto Immun Highlights. 2020;11:2. https://doi.org/10.1186/s13317-019-0124-6.
3. Velasco R, Villagran M, Jove M, Simo M, Vilarino N, Alemany M, Palmero R, Martinez-Villacampa MM, Nadal E, Bruna J. Encephalitis Induced by Immune Checkpoint Inhibitors: A Systematic Review. JAMA Neurol. 2021;78:864–73. https://doi.org/10.1001/jamaneurol.2021.0249.
4. Masciocchi S, Businaro P, Scaranzin S, Morandi C, Franciotta D, Gastaldi M. General features, pathogenesis, and laboratory diagnostics of autoimmune encephalitis. Crit Rev Clin Lab Sci. 2024;61:45–69. https://doi.org/10.1080/10408363.2023.2247482.
5. Greenlee JE, Carlson NG, Abbatemarco JR, Herdlevaer I, Clardy SL, Vedeler CA. Paraneoplastic and Other Autoimmune Encephalitides: Antineuronal Antibodies, T Lymphocytes, and Questions of Pathogenesis. Front Neurol. 2021;12:744653. https://doi.org/10.3389/fneur.2021.744653.
6. Gu Y, Zhong M, He L, Li W, Huang Y, Liu J, Chen Y, Xiao Z. Epidemiology of Antibody-Positive Autoimmune Encephalitis in Southwest China: A Multicenter Study. Front Immunol. 2019;10:2611. https://doi.org/10.3389/fimmu.2019.02611.
7. Qiao S, Zhang SC, Wang ZH, Wang L, Zhang RR, Li HY, Jin Y, Liu LL, Wang ML, Wang AH, Liu XW. Coexistence of multiple anti-neuronal antibodies in autoimmune encephalitis in China: A multi-center study. Front Immunol. 2022;13:858766. https://doi.org/10.3389/fimmu.2022.858766.
8. Dalmau J, Geis C, Graus F. Autoantibodies to Synaptic Receptors and Neuronal Cell Surface Proteins in Autoimmune Diseases of the Central Nervous System. Physiol Rev. 2017;97:839–87. https://doi.org/10.1152/physrev.00010.2016.
9. Asbeutah S, Alhashime K, Alhamer M. A Case Report and Literature Review on Positivity for Multiple Antibodies: Autoimmune Encephalitis in Focus. Cureus. 2023;15:e50393. https://doi.org/10.7759/cureus.50393.
10. Fukuda TG, do Rosario MS, Branco RCC, Fukuda JS, de Souza ESRA, Oliveira-Filho J, de Jesus PAP. Multiple paraneoplastic antibodies (anti-SOX1, anti-Hu, and anti-Amphiphysin) detected in a patient with limbic encephalitis and small cell lung cancer. Neurol India. 2017;65:1127–8. https://doi.org/10.4103/neuroindia.NI_1256_15.
11. Kammeyer R, Piquet AL. Multiple co-existing antibodies in autoimmune encephalitis: A case and review of the literature. J Neuroimmunol. 2019;337:577084. https://doi.org/10.1016/j.jneuroim.2019.577084.
12. Qiao S, Zhou P, Wang ZH, Wu HK, Liu XW. Coexistence of NMDAR, GAD65, and SOX1 antibody-associated autoimmune encephalitis. Neurol Sci. 2022;43:6125–30. https://doi.org/10.1007/s10072-022-06220-7.
13. Terunuma M. Diversity of structure and function of GABA(B) receptors: a complexity of GABA(B)-mediated signaling. Proc Jpn Acad Ser B Phys Biol Sci. 2018;94:390–411. https://doi.org/10.2183/pjab.94.026.
14. Grativvol RS, Cavalcante WCP, Castro LHM, Nitrini R, Simabukuro MM. Updates in the Diagnosis and Treatment of Paraneoplastic Neurologic Syndromes. Curr Oncol Rep. 2018;20:92. https://doi.org/10.1007/s11912-018-0721-y.
15. Gong S, Han Y, He E, Liu M, Fu X, Deng F. Coexistence of anti-SOX1 and anti-GABAB receptor antibodies with paraneoplastic limbic encephalitis presenting with seizures and memory impairment in small cell lung cancer: A case report. Front Immunol. 2022;13:955170. https://doi.org/10.3389/fimmu.2022.955170.
16. Titulaer MJ, Klooster R, Potman M, Sabater L, Graus F, Hegeman IM, Thijssen PE, Wirtz PW, Twijnstra A, Smitt PA, et al. SOX antibodies in small-cell lung cancer and Lambert-Eaton myasthenic syndrome: frequency and relation with survival. J Clin Oncol. 2009;27:4260–7. https://doi.org/10.1200/JCO.2008.20.6169.
17. Arino H, Hoftberger R, Gresa-Arribas N, Martinez-Hernandez E, Armangue T, Kruer MC, Arpa J, Domingo J, Rojc B, Bataller L, et al. Paraneoplastic Neurological Syndromes and Glutamic Acid Decarboxylase Antibodies. JAMA Neurol. 2015;72:874–81. https://doi.org/10.1001/jamaneurol.2015.0749.
18. Gresa-Arribas N, Arino H, Martinez-Hernandez E, Petit-Pedrol M, Sabater L, Saiz A, Dalmau J, Graus F. Antibodies to inhibitory synaptic proteins in neurological syndromes associated with glutamic acid decarboxylase autoimmunity. PLoS ONE. 2015;10:e0121364. https://doi.org/10.1371/journal.pone.0121364.
19. Dalmau J, Graus F, Villarejo A, Posner JB, Blumenthal D, Thiessen B, Saiz A, Meneses P, Rosenfeld MR. Clinical analysis of anti-Ma2-associated encephalitis. Brain. 2004;127:1831–44. https://doi.org/10.1093/brain/awh203.
20. Adrogue HJ, Madias NE. The Syndrome of Inappropriate Antidiuresis. N Engl J Med. 2023;389:1499–509. https://doi.org/10.1056/NEJMcp2210411.
21. Koizumi T, Kobayashi T, Kanda S, Fukushima T, Muranaka F, Miura K, Asaka S. Syndrome of Inappropriate Antidiuretic Hormone Secretion as the Initial Presentation in a Patient with Stage I Small-cell Lung Cancer. Intern Med. 2022;61:709–13. https://doi.org/10.2169/internalmedicine.8223-21.
22. Takano K, Yatabe MS, Abe A, Suzuki Y, Sanada H, Watanabe T, Kimura J, Yatabe J. Characteristic expressions of GABA receptors and GABA producing/transporting molecules in rat kidney. PLoS ONE. 2014;9:e105835. https://doi.org/10.1371/journal.pone.0105835.

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