# Plasma exchange in neurological disease

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ABSTRACT

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To cite: Osman C, Jennings R, El-Ghariani K, et al. Pract Neurol Epub ahead of print: [please include Day Month Year]. doi:10.1136/ practneurol-2019-002336 Plasma exchange is a highly efficient technique to remove circulating autoantibodies and other humoral factors rapidly from the vascular compartment. It was the first effective acute treatment for peripheral disorders such as Guillain-Barré syndrome and myasthenia gravis before intravenous immunoglobulin became available. The recent recognition of rapidly progressive severe antibody-mediated central nervous system disorders, such as neuromyelitis optica spectrum disorders and anti-N-methyl-D-aspartate-receptor encephalitis, has renewed interest in using plasma exchange for their acute treatment also. In this review we explain the principles and technical aspects of plasma exchange, review its current indications, and discuss the implications for its provision in the UK.

## INTRODUCTION

Plasma exchange was first described in 1914.<sup>1</sup> Blood components are removed from the body and separated, allowing the plasma component alone to be extracted. The plasma is replaced with an appropriate fluid, commonly human albumin solution. Plasma exchange is effective at removing immunoglobulins and other humoral components from the plasma fraction.

Several neurological disorders are mediated by pathological antibodies against cell surface antigens, including neuromuscular disorders, such as myasthenia gravis, and central nervous system (CNS) disorders, such as anti-N-methyl-D-aspartate (NMDA) receptor encephalitis. The mechanism of action of plasma exchange appears more complex than simply removing circulating pathogenic antibody from the circulation. It probably has additional immunomodulatory effects including removal of immune complexes and cytokines as well as changing the numbers of immune cells and the function of regulatory T cells  $(T_{reg})$  and natural killer cells.<sup>2</sup>

The technique was first introduced as a possible treatment for Guillain-Barré syndrome in 1978<sup>3</sup> and randomised trials published between 1985 and 1987 showed its significant benefit.<sup>4 5</sup> In 1976 Newsom-Davis and colleagues<sup>6</sup> showed plasma exchange was also an effective treatment for myasthenia gravis, confirmed by subsequent cases.<sup>7 8</sup>

By the end of the 1980s, plasma exchange was widely used in regional neurological centres and intensive care units as first-line treatment for acute Guillain-Barré syndrome and myasthenic crisis. However, the training required for staff to operate the complex machinery, and the need for central venous access prevented its more widespread use smaller hospitals.

Intravenous immunoglobulin is also a well-established treatment for a range of antibody-mediated autoimmune disorders. It was first reported to be effective in treating children with immune thrombocytopenic purpura in 1981,<sup>9</sup> and was subsequently found to be <u>as effective</u> as plasma exchange in treating myasthenia gravis<sup>10–12</sup> and Guillain-Barré syndrome.<sup>13 14</sup>

immunoglobulin Intravenous has complex mechanisms of action. As with plasma exchange, it accelerates removal of pathogenic autoantibodies from the circulation by saturating the neonatal Fc receptor, thereby preventing recycling of endogenous immunoglobulin. Intravenous immunoglobulin has many practical advantages over plasma exchange, particularly because it does not require highly specialist staff training or insertion of a central venous catheter. It can therefore be given in local hospitals, without needing to transfer patients to neurological centres. Also, critically unwell patients can receive intravenous immunoglobulin, with less risk than with plasma exchange of haemodynamic instability and immune compromise

from removal of immunoglobulin. The use of intravenous immunoglobulin in the 1990s as an effective treatment for Guillain-Barré syndrome and myasthenia gravis led to significantly fewer neurological patients needing plasma exchange, and subsequent loss of skill and expertise in neurological units to deliver this treatment.<sup>15</sup>

Recently, several antibody-mediated CNS disorders have been identified, including neuromyelitis optica spectrum disorders (NMOSD), <u>acute disseminated</u> <u>encephalomyelitis (ADEM)<sup>16-19</sup> and autoimmune</u> encephalitis.<sup>20</sup> Collectively, these newly recognised CNS autoimmune disorders pose significant clinical challenges to neurologists due to their rapid progression and the risk of permanent neurological disability if not treated early and aggressively. Although there is little evidence from randomised clinical trials, experience from published case series suggests that early multimodal immunotherapy is important to improve prognosis. Typical acute treatment regimens include plasma exchange or intravenous immunoglobulins—to reduce circulating autoantibodies quickly—together with intravenous corticosteroids. National Health Service (NHS) England has now also approved rituximab as a second-line treatment for neuromyelitis optica and anti-NMDA receptor (NMDAR) encephalitis.<sup>21</sup>

It is timely to review the role of plasma exchange in neurological disorders given important recent developments. First, its technology has advanced significantly in the last 20 years, now allowing treatment via peripheral venous access in local hospitals as well as regional centres. Second, the rapid global increase in intravenous immunoglobulin use has significantly increased costs and constrained the UK supply, with around 15% less intravenous immunoglobulin available than required for current demand. Third, the recent recognition of devastating rapidly progressive antibody-mediated CNS diseases, such as NMOSD and autoimmune encephalitis secondary to antibodies to LGI1/CASPR2 and NMDA, has led to renewed interest in plasma exchange as an effective treatment to reduce the concentration of circulating autoantibodies rapidly.

In this article, we review the recent advances in plasma exchange technology, and the evidence for using it to treat neurological disorders with reference to the recently published guidelines from the American Association of Neurologists (AAN) and the American Society for Apheresis (ASFA). We provide practical information to guide neurologists in the choice of plasma exchange variables, such as the volume of plasma to be exchanged and the frequency and total number of exchanges. Finally, we review current provision of plasma exchange in the UK and highlight how we might improve access to these services for neuroimmunology patients.

## Technical considerations

Apheresis equipment separates blood components using centrifugation or filtration; either can be used for plasma exchange. Filtration technology separates blood components based on their particle size. Plasma is the easiest to filter, then platelets, red cells, lymphocytes and lastly granulocytes in this order. Filtration occurs across a flat-plate membrane or more commonly in a hollow-fibre system in which blood is pumped into a bundle of hollow fibres with side pores contained within a cylinder. During the exchange, the patient's plasma leaves the fibres through the side pores, then diverted and replaced by an appropriate replacement fluid. Such a system requires maintaining an appropriate transmembrane pressure to ensure smooth flow of plasma without plugging the pores with cellular components. Centrifugation technology separates blood components on the basis of their specific gravity. Whole blood is pumped into a separation chamber, for example, a rotating bowel or a beltshaped channel, where the dense red cells are pushed to the periphery, followed by white cells, platelets and then plasma. The machine applies an appropriate g force and uses sensors to detect a state of equilibrium during which the desirable separation of components has been reached with identifiable interface between components. During the exchange, the patient's plasma is diverted into a collection bag and replaced with a replacement fluid while other components are returned to the patient.<sup>22</sup>

Although earlier comparison found both techniques had similar safety and efficiency, they are not used equally across medical specialities, with centrifugal machines more commonly used in apheresis services in the UK and North America. Filtration, being conceptually related to dialysis, is mainly used in renal units. Filtration machines are smaller and use lower extra-corporeal volume making them easier to use for smaller patients; they are also more efficient in removing cellular debris. The technique is quicker and can exchange more plasma volume in shorter periods of time than centrifugal machines. However, filtration uses heparin to anticoagulate the extra corporeal circuit. This also anticoagulates the patient's blood and may increase the risk of bleeding in patients with thrombocytopenia or a recent biopsy. The blood–filter interactions previously caused allergic reactions, but newer technologies have improved on this. However, such an interaction may activate the kallikrein-kinin system, creating high serum concentration of bradykinin that can cause an anaphylactoid response in patients using angiotensin-converting-enzyme inhibitors. Plasma exchange via membrane filtration invariably requires placement of a central venous catheter for the procedure.

Centrifugal equipment uses citrate to anticoagulate the extracorporeal circuit, with no anticoagulant effects for patients. More importantly, <u>centrifugal</u>

Table 1 Comparison of plasma exchange techniques				
	Membrane <mark>filtration</mark>	Centrifugal separation		
Access	<mark>Central</mark>	Peripheral+Central		
Anticoagulation	Heparin	Citrate		
Plasma extraction	30%	70%		
Blood flow rate	High	Low		
Alternative indications	Haemofiltration for renal failure	Stem cell harvest for autologous bone marrow transplant		

machines are more versatile and haematology departments commonly use them to separate, collect and manage cellular components from the patient, allowing efficient stem cell collection, red cell exchange and so on.<sup>22</sup> Existing filtration techniques do not commonly separate different cell types. Moreover, there are theoretical concerns that filtration may retain some pathological large proteins that cannot be removed because of their size or electrical charges. Although there are no trial data to support these concerns, haematologists only use centrifugal techniques to treat thrombotic thrombocytopenic purpura. Centrifugal machines are slower because of the limitation in the volume of citrate that can be safely returned to patients without causing significant hypocalcaemia and because of the time required to establish adequate interface between different components of blood. Importantly, plasma exchange via the centrifugal system can be delivered through peripheral venous access as well as central venous access. Typically, plasma exchange procedure via centrifugation can be completed in adults in about 90 min (table 1).

For safe and effective plasma exchange, the neurologist must decide on three important factors.

The first decision is the plasma volume to be exchanged. This is typically one plasma volume but higher volumes of 1.3–1.5 can be used if necessary, for example, in patients with catastrophic presentation of NMOSD who need a higher clearance of circulating component.<sup>23</sup>

The second decision is the <u>frequency of procedures</u>. In our unit, we perform <u>alternate day</u> exchanges. However, <u>most</u> <u>units</u> <u>perform</u> <u>daily</u> <u>exchanges</u> <u>over 5 days</u>. It may be appropriate to perform daily exchanges, at least for the first three exchanges, followed by alternate days with the assumption that this will allow more pathological molecules including autoantibodies to return from the extravascular space to the circulation and hence be removed.

The third decision is the number of exchanges to complete a full cycle. Patients receiving plasma exchange for maintenance therapy may require fewer exchanges. In our own unit, we perform three exchanges of one plasma volume on alternate days every 6 weeks in patients with myasthenia gravis and stiff-person syndrome, with good outcomes.

Plasma exchange is relatively safe, with most significant side effects originating from the method of vascular access. Central venous access carries a significantly higher risk of complications than peripheral access, as noted in a retrospective study of plasma exchange in myasthenia gravis.<sup>24</sup> The anticoagulant used in extra-corporal circulation, mostly citrate, can cause toxicity in the form of sensory symptoms and occasionally cardiac arrhythmia. Reactions to the replacement fluids are very rare with human albumin solution. Plasma exchange must be completed with trained staff using validated and maintained equipment.<sup>25</sup>

#### Role of plasma exchange in antibody-mediated and metabolic neurological conditions Peripheral nervous system disorders

## Guillain-Barré syndrome

There is convincing evidence that Guillain-Barré syndrome is caused by <u>antibodies to gangliosides</u> and other neural antigens with complement fixation leading to <u>peripheral nerve damage.<sup>26</sup></u> Several validated large randomised-controlled trials have shown significant clinical improvement in those receiving plasma exchange.<sup>4 5 13 14</sup>

A recent Cochrane review in 2017 of adults with Guillain-Barré syndrome found moderate-quality evidence showing significantly more improvement with plasma exchange than with supportive care alone, without a significant increase in serious adverse events.<sup>27</sup> The AAN<sup>28</sup> and ASFA<sup>29</sup> guidelines support using plasma exchange in Guillain–Barré syndrome as an established and effective treatment with a strong level of evidence.

#### Chronic inflammatory demyelinating polyneuropathy

Chronic inflammatory demyelinating polyneuropathy (CIDP) is a chronic autoimmune demyelinating disease of the peripheral nervous system presenting with progressive relapsing weakness and sensory loss in limbs.<sup>30</sup> The clinical effectiveness of plasma exchange in CIDP was demonstrated in a randomised double-blind placebo controlled trial that showed improvement in neurological disability score versus the placebo arm.<sup>31</sup> A further randomised double-blind placebo controlled study confirmed the previous study findings of clinical benefit but noted a waning of clinical effect after 2 weeks.<sup>32</sup>

A Cochrane review concluded that there is moderateto-high quality evidence from two small trials showing that plasma exchange gave short-term improvement in disability and nerve function. However, plasma exchange may be followed by rapid deterioration, with two-thirds of participants suffering a relapse requiring maintenance plasma exchange.<sup>33</sup>

The AAN<sup>28</sup> and ASFA<sup>29</sup> conclude that plasma exchange is effective in CIDP and can be offered as a first line agent, where indicated, with strong level of evidence.

## <mark>Myasthenia gravis</mark>

Myasthenia gravis is an autoimmune disorder in which antibodies against either the <u>skeletal muscle nicotinic</u> acetylcholine receptor or other antigens at the neuromuscular junction (eg, muscle-specific kinase) impair neuromuscular transmission, causing <u>fatigable weak-</u> <u>ness.</u> Between 1977 and 2000, there were multiple case reports and series from a total 379 patients with myasthenia gravis reporting benefit from plasma exchange.<sup>34 35</sup>

Although plasma exchange and intravenous immunoglobulin have been found to be equally effective in myasthenia gravis,<sup>11</sup> in our experience the clinical response to <u>plasma exchange is often more rapid than</u> with intravenous immunoglobulin.

Further case reports and series have shown excellent response to plasma exchange with improvement in respiratory failure.<sup>7</sup><sup>8 36</sup> A retrospective class II study compared 19 patients treated with single session of plasma exchange before thymectomy versus 32 treated with thymectomy alone. Patients treated with plasma exchange had fewer crises in the following month and year with a greater postoperative remission at 5–7 years.<sup>37</sup>

We need further research comparing plasma exchange with alternative short-term treatments for myasthenic crisis and to determine the value of longterm plasma exchange for treating myasthenia gravis.<sup>38</sup>

The AAN<sup>28</sup> and ASFA<sup>29</sup> conclude that in the last few year randomised studies have proven the clinical effectiveness of plasma exchange in moderate-to-severe myasthenia gravis and for prethymectomy patients.

#### Paraproteinemic polyneuropathies

Paraproteinemic polyneuropathies are progressive neuropathies involving the peripheral nerves in association with a monoclonal gammopathy of IgA. IgG or IgM. About half of IgM paraproteins associated with peripheral polyneuropathy have specificity for myelin-associated glycoprotein.<sup>39</sup> A double-blind trial of 39 patients with neuropathies associated with IgG, IgA or IgM monoclonal gammopathies of unknown significance (MGUS) randomised patients into placebo plasma exchange or true plasma exchange two times per week for 3 weeks. The IgG and IgA MGUS-associated polyneuropathy group obtained clinical benefit from plasma exchange but not the patients with IgM paraprotein.<sup>40</sup>

The AAN<sup>28</sup> and ASFA<sup>29</sup> guidelines conclude that plasma exchange can be considered in polyneuropathy associated with IgA or IgG MGUS, but not IgM, with strong level of evidence.

## Stiff-person syndrome

Stiff-person syndrome is a rare chronic disorder characterised with fluctuating muscle rigidity in trunk and limbs and hypersensitivity to noise/touch and emotional distress resulting in muscle spasms. Up to 90% of patients have serum GAD-65 antibodies.<sup>41</sup> A systematic literature review identified a total of 26 patients diagnosed with anti-GAD65 positive stiffperson syndrome and found that 42% of patients showed significant symptomatic improvement after plasma exchange.<sup>42</sup>

A retrospective analysis of 10 patients with anti-GAD65 positive stiff-person syndrome found that plasma exchange may help these patients, both for acute exacerbations and long-term maintenance.<sup>43</sup>

The ASFA<sup>29</sup> conclude that plasma exchange may be effective in patients with stiff-person syndrome who have not responded to first-line therapy, but with only low-quality evidence available.

#### **Refsum's disease**

Refsum's disease is an autosomal recessive disorder of phytanic acid metabolism. Patients present with retinitis pigmentosa, peripheral neuropathy, cerebellar ataxia, sensorineural deafness and anosmia.<sup>44</sup> Acute clinical deterioration in Refsum's disease is associated with high plasma phytanic acid concentrations and can be treated with plasma exchange. Several published small case series of patients with Refsum's disease have shown significant and rapid clinical improvement in patients in whom plasma exchange has lowered the plasma phytanic acid concentration.<sup>45–47</sup>

Plasma exchange is indicated in Refsum's disease when there is worsening clinical condition or failure of dietary control to reduce the high plasma phytanic acid levels. The ASFA<sup>29</sup> concluded that it is possibly effective based on the individual case series and reports.

#### **CNS disorders**

## Acute disseminated encephalomyelitis

<u>ADEM</u> is a CNS acute inflammatory demyelinating disease that often has a monophasic course but can relapse and can be difficult to distinguish from multiple sclerosis. Recent evidence suggests that up to half of patients with ADEM have serum antibodies to myelin-oligodendrocyte glycoprotein (MOG), suggesting the disorder may be antibody-mediated in many people. Patients can present with altered mental status, encephalopathy, ataxia, hemiparesis, and may progress to coma.<sup>48</sup> Most are initially treated with intravenous corticosteroids.<sup>49</sup>

In a small case series, four out of 10 ADEM patients who had not responded to corticosteroids significantly improved with plasma exchange.<sup>50</sup> Many of the reported case series include patients with several different demyelinating syndromes (eg, acute transverse myelitis, ADEM and multiple sclerosis), making it difficult to evaluate how effective plasma exchange is in specific CNS demyelinating diseases.<sup>51–53</sup>

The AAN and ASFA conclude that plasma exchange may be effective treating ADEM particularly in those unresponsive to corticosteroids.<sup>29</sup>

#### Neuromyelitis optica spectrum disorders

NMOSD comprise a group of inflammatory disorders characterised by antibody-mediated inflammation involving the optic nerve and spinal cord. A significant proportion of patients have serum antibodies to aquaporin four and MOG.<sup>17–19</sup> First line is pulsed intravenous methylprednisolone 1000 mg.<sup>54</sup> In severe NMOSD cases, expert neurologists generally recommend starting plasma exchange as well, to remove circulating autoantibody and complement rapidly in the hope that this will improve prognosis.<sup>55</sup>

In a retrospective review of 59 consecutive patients with acute severe CNS demyelination who received plasma exchange at the Mayo Clinic between 1984 and 2000, six out of 10 NMOSD patients responded, typically within days.<sup>50</sup> The timing of plasma exchange to treat acute severe NMOSD is important. Of 60 patients with acute attacks of NMOSD treated in this way, the probability of complete recovery reduced from 50% if plasma exchange was given at day 0, to 1%–5% if it was delayed to day 20.<sup>23</sup> Plasma exchange improves the short-term prognosis of NMOSD relapses if given early and is has proven effectiveness regardless of NMOSD-IgG status.<sup>55</sup>

A large retrospective analysis of 185 patients with relapsing NMOSD found that first-line therapy with plasma exchange may be superior to high-dose corticosteroid pulse therapy in achieving complete remission in transverse myelitis but not in optic neuritis. Escalation therapy with plasma exchange increases remission rates and should be offered in appropriate cases.<sup>56</sup>

The AAN<sup>28</sup> and ASFA<sup>29</sup> conclude that plasma exchange is probably effective in corticosteroid-refractory acute attacks but probably ineffective as a maintenance therapy.

## Multiple sclerosis

Multiple sclerosis is a relapsing progressive demyelinating disorder of the CNS white matter, thought to be an autoimmune disorder with genetic predisposition influenced by environmental factors.<sup>57</sup> Previous reviews have concluded that plasma exchange provides no therapeutic benefit in the chronic progressive forms of multiple sclerosis.<sup>58</sup> <sup>59</sup> However, there is evidence that those presenting with acute attacks, due to a humoral pattern of immunopathological demyelination, may respond best to plasma exchange. All 10 patients with acute CNS relapses associated with pattern II (humoral) demyelination achieved moderate to substantial functional neurological improvement following plasma exchange compared with no patients with pattern I or pattern III demyelination.<sup>60</sup> This reported case series from the Mayo Clinic predates the identification of antibodies to MOG in patients with ADEM and NMOSD. It is possible therefore that the group of atypical MS patients with acute fulminating disease that responded to plasma exchange in this case series included patients with antibodies to MOG.

The AAN<sup>28</sup> and AFSA<sup>29</sup> conclude that plasma exchange is probably effective as an adjuvant treatment for severe relapsing forms of multiple sclerosis and in corticosteroid-unresponsive fulminant forms with a strong level of evidence; however, it is unlikely to be effective in progressive forms.

## Autoimmune encephalitis

The autoimmune encephalitides comprise a group of uncommon and frequently devastating neurological disorders that typically present with a combination of seizures, altered mental status, cognitive impairment and memory loss, together with movement disorders. The incidence and prevalence of autoimmune encephalitis is probably equal to that of the infective encephalitides.<sup>61</sup>

In recent years, autoantibodies targeting cell surface proteins associated with ligand and voltage-gated ion channels have been identified in a high proportion of patients with autoimmune encephalitis, greatly increasing our understanding of the pathogenesis of these disorders. Two of the the most common autoimmune encephalitis syndromes include encephalitis associated with antibodies to the NMDAR<sup>20</sup> and limbic encephalitis due to antibodies that target LGI1 and CASPR2 as part of the voltage-gated potassium channel complex.<sup>62</sup>

## LGI1 and CASPR2 associated encephalitis

In a retrospective analysis of patients with LGI1 and CASPR2 autoimmune encephalitis, four out of seven patients treated with plasma exchange in conjunction with corticosteroids and intravenous immunoglobulins had complete resolution of symptoms and two out of seven had mild improvement. Giving corticosteroids early led to a faster decrease in autoantibody titres.<sup>63</sup>

In an open-label prospective study of patients with LGI1 and CASPR2 autoimmune encephalitis treated with combination immunotherapy comprising plasma exchange, intravenous immunoglobulin and intravenous methylprednisolone, seizures and hyponatraemia remitted within 1 week and cognitive function improved in all patients within 3 months.<sup>64</sup>

The ASFA<sup>29</sup> conclude that plasma exchange is probably effective in autoimmune encephalitis from observational studies and case series that have shown that LGI1 and CASPR2 autoantibodies decrease with plasma exchange and this is associated with clinical improvement.

## Anti-NMDAR encephalitis

Encephalitis associated with antibodies to NMDAR typically presents in children and young adults with a characteristic syndrome of abnormal behaviour, dyskinesias and dystonia, memory deficits, autonomic instability and decreased level of consciousness. There is a female predominance, particularly in young adults under 45 years, with an associated ovarian teratoma in up to half of female adults. Current treatment protocols highlight the importance of surgery for ovarian teratoma together with intensive immunotherapy including intravenous corticosteroids, plasma exchange, intravenous immunoglobulins and, in severe cases, rituximab.<sup>20 21</sup>

A recent systematic review of plasma exchange in paediatric anti-NMDAR encephalitis identified 71 papers reporting on a total of 242 patients.<sup>65</sup> The median time to first treatment was 21 days. In most patients, plasma exchange was combined with corticosteroids and intravenous immunoglobulins. The data confirmed a trend towards better outcome when plasma exchange was performed early and when given with corticosteroids.

The ASFA<sup>29</sup> conclude that plasma exchange is probably effective when given in combination with either corticosteroids or intravenous immunoglobulins and can be considered as part of the first line therapy.

#### Other paraneoplastic neurological syndromes

The paraneoplastic neurological syndromes comprise a diverse group of neurological disorders associated with onconeural antibodies. It is a rare syndrome occurring in 0.1%–1% of oncology patients. Classical paraneoplastic syndromes include cerebellar degeneration, limbic encephalitis, opsoclonus– myoclonus syndrome, subacute sensory ganglionopathy, Lambert-Eaton myasthenic syndrome and dermatomyositis.<sup>66</sup>

Plasma exchange reduces serum concentrations of antibodies and cytokines in paraneoplastic neurological syndromes.<sup>67</sup> There are only individual case reports of clinical improvement following plasma exchange in treating cerebellar degeneration related to ovarian carcinoma<sup>68</sup> <sup>69</sup> and Hodgkin's disease.<sup>70</sup> Plasma exchange also helped in cases of paraneoplastic encephalitis with thymoma,<sup>71</sup> opsoclonus–myoclonus<sup>72</sup> and in a case of paraneoplastic sensorimotor neuropathy.<sup>73</sup>

Note, however, that the antibodies detected in most paraneoplastic CNS conditions target intracellular antigens and are not proven to be pathogenic. Thus, reducing the concentration of circulating autoantibodies, either via plasma exchange or intravenous immunoglobulins, will probably not ordinarily lead to clinical improvement.



Figure 1 Spectra Optia centrifuge machine (picture from https://abdominalkey.com/plasma-exchange/).

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Disease	Grade	Conclusion
Guillain-Barré syndrome	1A	Established effective
CIDP	1B	Established effective
ADEM	2C	Probably effective in corticosteroid refractory cases
Multiple Sclerosis		
Relapses	1B	Probably effective as adjuvant
Fulminant	2B	Probably effective in corticosteroid refractory
Progressive	2B	Probably ineffective
Myasthenia gravis		
Moderate to severe	1B	Established effective
Prethymectomy	1C	Established effective
NMOSD		
Acute	1B	Established effective in corticosteroid refractory
Maintenance	2C	Probably ineffective
Stiff-person syndrome	2C	Possibly effective in corticosteroid refractory cases
Paraproteinemic polyneuropathies		
lgA/lgG	1B	Probably effective
IgM	1C	Probably ineffective
LGI1/CASPR2 encephalitis	2C	Probably effective
NMDAR encephalitis	1C	Probably effective
Paraneoplastic	2C	Possibly effective

Sydenham's chorea2BPossibly effectiveAAN, American Association of Neurologists; ADEM, acute disseminated<br/>encephalomyelitis; ASFA, American Society for Apheresis; CIDP, chronic<br/>inflammatory demyelinating polyneuropathy; NMDAR, anti-N-methyl-<br/>D-aspartate receptor; NMOSD, neuromyelitis optica spectrum disorders;<br/>PANDAS, paediatric autoimmune neuropsychiatric disorders associated<br/>with streptococcal infection.

Probably effective

Probably effective

2C

1B

The ASFA<sup>29</sup> conclude that plasma exchange is possibly effective in paraneoplastic neurological syndromes based on individual case reports and should only be considered as a third-line agent.

#### Other paediatric CNS disorders

neurological syndromes

Refsum's disease

PANDAS

Paediatric autoimmune neuropsychiatric disorders associated with streptococcal infection

Paediatric autoimmune neuropsychiatric disorders associated with streptococcal infection (PANDAS) typically present with abrupt onset of tic behaviour and obsessive-compulsive behaviour in prepubertal children, triggered by group A  $\beta$ -haemolytic streptococcal infection.<sup>74</sup> In a randomised placebo-controlled trial of plasma exchange and intravenous immunoglobulin in 29 children with PANDAS, both treatments produced striking improvements in obsessive-compulsive disorder at 1 month after treatment, with a greater improvement in the plasma exchange group than in the intravenous immunoglobulin group.<sup>75</sup> In addition, a recent retrospective series 35 patients with PANDAS also found significant improvement in symptoms of obsessive-compulsive disorder, tics and anxiety following plasma exchange.<sup>76</sup>

The ASFA<sup>29</sup> conclude that plasma exchange is probably effective based on case series and clinical trials.

#### Sydenham's chorea

Sydenham's chorea is a paediatric autoimmune post-infective neuropsychiatric disorder caused by antibodies directed against group A  $\beta$ -haemolytic streptococci that cross-react with neuronal antigens in basal ganglia, thereby altering cell signal transduction.<sup>77</sup> In a randomised unblinded, controlled study of 18 children with Sydenham's chorea receiving plasma exchange, intravenous immunoglobulin or prednisolone, all treatment groups responded with no significant difference between groups.<sup>78</sup> In addition, a single patient who had failed to respond to corticosteroids and other therapies showed a positive response to plasma exchange.<sup>79</sup>

The ASFA<sup>29</sup> conclude that plasma exchange is possibly effective in Sydenham's chorea based on controlled studies and case reports.

### Provision of plasma exchange in UK neurology centres

In the last 20 years, widespread prescription of intr venous immunoglobulin to treat antibody-mediate neurological disorders has led to a parallel declin in the use of (and therefore availability of) plasn exchange in centres across the UK. Most neurolo ical centres now rely on its provision by extern haematology and renal teams for both elective ar emergency patients. Renal units typically perfor plasma exchange by membrane filtration via centr venous catheters, which is suitable only for inp tients or outpatients who have apheresis lines. contrast, haematology units invariably perfor plasma exchange via centrifugation, which allow for treatment of outpatients via peripheral veno access as well as patients with difficult venous acce requiring placement of central venous catheter.

Recent difficulties in securing adequate supplies of intravenous immunoglobulin to treat an increasing range of antibody-mediated neurological disease make it necessary for neurologists to ensure access for plasma exchange at all neurological centres in the UK. NHS Blood and Transplant (NHSBT) has provided therapeutic plasma exchange to neurology patients in England for over 20 years. Specialist regional clinical teams based at eight sites across England (Liverpool, Manchester, Sheffield, Leeds, Birmingham, Bristol, Oxford and London) are able to provide access to plasma exchange at local neurology centres. NHSBT currently performs over a thousand procedures per year for neurology patients in England.

Larger neurology centres not co-located with NHSBT may choose to establish their own in-house plasma exchange service given the large savings achieved by reducing delays to treatment and the relatively low cost of the investment required in staff training and equipment. As an example, we have established a peripheral day case patient plasma exchange service in 2017 at the Wessex Neurological Centre in Southampton, UK, funded by cost savings over the previous service after purchasing a new Spectra Optia centrifuge machine for peripheral access plasma exchange (figure 1). A recent audit of our plasma exchange data after the first 18 months has shown significantly reduced delay to treatment with good patient outcomes and excellent safety profile.80

## CONCLUSION

Plasma exchange is an effective treatment for a range of antibody-mediated neurological diseases (table 2).<sup>81</sup> Its indications have widened from initial use in acute treatment of Guillain-Barré syndrome and myasthenia gravis to the management of devastating autoimmune CNS disorders, such as NMOSD and anti-NMDAR encephalitis, where rapid removal of autoantibodies and humoral factors is essential to improve prognosis. Centrifugal plasma exchange machines now enable patients to be treated via peripheral venous access thereby making this treatment available for day case patients. Given the concerns about availability of supply of intravenous immunoglobulins, it is important for neurologists to refamiliarise themselves with plasma exchange technology and to plan for provision of this essential service at neurological centres across the UK.

# Key points

- Plasma exchange is a highly efficient technique to remove circulating autoantibodies and other humoral factors rapidly from the vascular compartment.
- Plasma exchange is an effective treatment for a range of antibody-mediated neurological diseases.
- Centrifugal plasma exchange allows for day case treatment via peripheral venous access.
- Given the national UK shortage of intravenous immunoglobulin, neurologists need to re-familiarise themselves with plasma exchange treatment.

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