Haematological manifestations of lupus

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ABSTRACT

Our purpose was to compile information on the haematological manifestations of systemic lupus erythematosus (SLE), namely leucopenia, lymphopenia, thrombocytopenia, autoimmune haemolytic anaemia (AIHA), thrombotic thrombocytopenic purpura (TTP) and myelofibrosis. During our search of the English-language MEDLINE sources, we did not place a date-of-publication constraint. Hence, we have reviewed previous as well as most recent studies with the subject heading SLE in combination with each manifestation. Neutropenia can lead to morbidity and mortality from increased susceptibility to infection. Severe neutropenia can be successfully treated with granulocyte colony-stimulating factor. While related to disease activity, there is no specific therapy for lymphopenia. Severe lymphopenia may require the use of prophylactic therapy to prevent opportunistic infections. Isolated idiopathic thrombocytopenic purpura maybe the first manifestation of SLE by months or even years. Some manifestations of lupus occur more frequently in association with low platelet count in these patients, for example, neuropsychiatric manifestation, haemolytic anaemia, the antiphospholipid syndrome and renal disease. Thrombocytopenia can be regarded as an important prognostic indicator of survival in patients with SLE. Medical, surgical and biological treatment modalities are reviewed for this manifestation. First-line therapy remains glucocorticoids. Through our review, we conclude glucocorticoids do produce a response in majority of patients initially, but sustained response to therapy is unlikely. Glucocorticoids are used as first-line therapy in patients with SLE with AIHA, but there is no conclusive evidence to guide second-line therapy. Rituximab is promising in refractory and non-responding AIHA. TTP is not recognised as a criteria for classification of SLE, but there is a considerable overlap between the presenting features of TTP and SLE, and a few patients with SLE have concurrent TTP. Myelofibrosis is an uncommon yet well-documented manifestation of SLE. We have compiled the cases that were reported in MEDLINE sources.

INTRODUCTION

Systemic lupus erythematosus (SLE) is a prototypic systemic autoimmune disease with variable multisystem involvement and heterogeneous clinical features, ranging from mild to life threatening. There is no gold standard test to diagnose SLE, hence the determination of the presence of this disease, in addition to being a diagnosis of exclusion, ultimately rests with the judgement of a clinician.

The first classification criteria for SLE were developed by the American Rheumatism Association (predecessor of the American College of Rheumatology (ACR)) in 1971. Immunological tests were incorporated into the criteria and revised SLE classification criteria were published in 1982. The criteria, in 1997, underwent another revision and included advancing knowledge about the association of antiphospholipid (aPL) antibodies with SLE. Although the criteria are widely accepted and used, only a few potential manifestations of SLE are represented. The Systemic Lupus International Collaborating Clinics (SLICC) SLE classification criteria comprise 11 clinical and 6 immunological criteria. In contrast to the ACR criteria, the SLICC criteria require at least one clinical and one immunological criteria for the classification of SLE.

Autoimmune haemolytic anaemia (AIHA), leucopenia and thrombocytopenia are part of both ACR and SLICC criteria.

Haematological abnormalities are common findings in patients with SLE. Sometimes, haematological abnormalities can be caused by the pathophysiology of SLE itself, but at other times they can be found in patients with SLE but not be a manifestation of SLE. Neither set of criteria, however, specify how leucopenia and lymphopenia in these patients can be differentiated from decreased white cell count caused by immunosuppressive therapy or other causes. Thus, it is important to distinguish haematological abnormalities as either manifestations of SLE, consequence of SLE treatment or as part of another blood cell dyscrasia.

LEUCOPENIA

Introduction

According to the ACR and SLICC criteria for classification of SLE, leucopenia is defined as...
Granulocytopenia, or neutropenia, will be the focus of this section, while the next section will discuss lymphopenia, which is the most common WBC abnormality among patients with SLE. Neutropenia is usually defined as an absolute neutrophil count <1000 cells/mm³. Although leucopenia occurs in 50–60% of patients with SLE, only 17% have a WBC count <1000/mm³. The definition of a low total white count or low neutrophil count is complicated by the presence of benign ethnic neutropenia in many (25–50%) persons of sub-Saharan African heritage. In individuals with this condition, an abnormally low neutrophil count is not easily definable.

Pathogenesis
The pathogenesis of neutropenia in SLE is not entirely understood. Both humoral and cellular immune mechanisms may be involved. Three potential mechanisms of neutropenia in SLE are (1) increased peripheral destruction of granulocytes; (2) changes in marginal and splenic pool, or increased margination; and (3) decreased marrow production. Yamasaki et al. studied the pathogenesis of granulopoietic failure in SLE. A decreased number of colony-forming units (CFU) in the bone marrow was demonstrated in 16 women with SLE, and this number was found to correlate with the peripheral granulocyte/monocyte count. This work also found peripheral blood T lymphocytes from three patients with SLE tended to suppress the CFU growth from allogenic normal bone marrow. T lymphocytes from patients with SLE on glucocorticoid therapy did not suppress the CFU growth from allogenic normal bone marrow. According to this study, suppression by T lymphocytes contributed to the decreased marrow CFU, which may play a role in the pathogenesis of granulopoietic failure in SLE.

Peripheral destruction of neutrophils is mainly due to circulating antineutrophil antibodies. Starkebaum et al. documented neutrophil kinetic studies showing a shortened intravascular survival with an increased marrow neutrophil production. These investigators collected normal control sera from healthy laboratory workers and hospital staff as well as serial serum samples from a patient with SLE over a 2-year course. The IgG neutrophil-binding activity of the patient’s serum was elevated in serial samples obtained over the timeframe. Fractions of patient’s serum that contained immune complexes failed to opsonise normal neutrophils for ingestion by other normal granulocytes. Enhanced opsonising ability was only displayed by monomeric IgG fraction of the patient’s serum. There were no conclusions drawn on the nature of antigen recognition of neutrophils by the antibodies in this SLE serum. The results of their study, however, suggested an autoimmune mechanism for neutropenia in patients with SLE.

Rustagi et al. in a study of 18 patients with SLE, suggested complement-activating antineutrophil IgG autoantibodies existed in SLE and their presence correlated with neutropenia. The neutrophil-binding IgG was 2–3 times higher than normal in patients with SLE, yet there was no significant difference in IgG levels between non-neutropenic and neutropenic patients. Complement-induced injury is responsible for some other SLE lesions. So, postulating that neutrophils are affected by complement fixation, with resultant neutrophil depletion, is reasonable. The overall results of this study suggest that the existence of complement-activating antineutrophil IgG autoantibodies correlates with the occurrence of neutropenia. As shown in immune haemolytic anaemia and immune thrombocytopenia, complement fixation by binding of antigranulocyte antibody to the cell surface mediates injury in SLE neutropenia.

Association of anti-Ro (or Sjögren’s syndrome-related antigen A (SSA)) antibodies with neutropenia was studied by Kurien et al. among 72 patients with SLE attending an academic rheumatology clinic. Patients with SLE with anti-Ro autoantibodies were found to have significantly lower neutrophil counts than patients with SLE without anti-Ro. Furthermore, the data indicate that anti-Ro are cross-reactive with a 64 kD protein on neutrophil cell surfaces and may facilitate neutropenia in patients with SLE. If this antigen or another antigen being bound on the neutrophil surface is also present on bone marrow precursors, then there may be a dramatic decrease in peripheral granulocyte levels. Harmon postulated that the mere presence of IgG antibody against peripheral neutrophils may not suffice to cause neutropenia if the bone marrow is able to compensate with healthy production. However, if these antibodies that bind peripheral granulocytes also target marrow precursors, then a more severe neutropenia may ensue by both peripheral destruction and decreased marrow production.

The concept of progenitor cell growth suppression is not new. There is evidence of T cell-mediated or monocyte-mediated suppression of central bone marrow granulocytopoiesis in SLE. Experimental results of Duckham show that whole serum from patients with SLE is associated with bone marrow colony growth retardation in 43% of patients. Whether this suppression is due primarily to colony retardation or colony stimulation factor inactivation is not clear. Yamasaki et al. studied a population of patients with SLE that exhibited suppression of granulocyte/monocyte colony formation by T cells in vitro. This is another mechanism by which neutropenia may be mediated. Fortunately, suppression of granulocytopoiesis rarely results in severe neutropenia.
Matsuyama et al.\textsuperscript{16} carried out a study to evaluate the involvement of tumour necrosis factor (TNF)-related apoptosis-inducing ligand (TRAIL) in the pathogenesis of neutropenia in SLE. This study found serum TRAIL levels to be higher in patients with SLE and neutropenia in comparison to the patients with SLE without neutropenia as well as healthy volunteers. Twenty-eight patients with SLE and eight healthy volunteers participated in the study. None of the patients were on immunomodulatory drugs when blood samples were collected. Duplicate measurement of TRAIL and granulocyte colony-stimulating factor (G-CSF) was carried out by ELISA. Expression of TRAIL receptors on peripheral blood polymorphonuclear leucocytes was obtained by flow cytometry analysis. In total, 15 of 28 patients had neutropenia and serum TRAIL level in patients with SLE with neutropenia was conclusively found to be higher.\textsuperscript{16}

**Clinical presentation**

Neutropenia can be one of the contributing factors towards the infectious comorbidity in SLE. Recurrent infections are the only known significant consequence of neutropenia. Local signs and symptoms of infection—rubor, tumour, calor and dolor as originally described by Celsius in the first-century CE—may be attenuated in patients with SLE due to immunosuppression. Constitutional signs and symptoms of infection, such as fever, may also be absent in the immunocompromised patient. Hence, high vigilance is required.

Martinez-Banos et al.\textsuperscript{17} carried out a prospective study that included 126 patients with SLE. Of these patients, 5\% had moderate to severe neutropenia (<1000 or <500 neutrophils, respectively).\textsuperscript{17} The main aim of their study was to evaluate predisposing factors, clinical outcomes and related prognostic implications of neutropenia in patients with SLE. Among the 33 patients that developed neutropenia, the use of immunosuppressive medication was an independent risk factor for neutropenia as part of drug toxicity-induced myeloid hypoplasia.\textsuperscript{17}

Sugimoto et al.\textsuperscript{18} encountered a patient with low neutrophil count in the early morning that increased in late morning. This 35-year-old woman, with a 3-year history of SLE, had fever and skin rash on the trunk. Her peripheral neutrophil count was decreased to 280/\mu L, but a blood sample obtained later the very same day showed a neutrophil count of 1400/\mu L. The same pattern was maintained on the third and sixth day of her hospital stay. Her clinical condition, however, improved markedly. Prednisone, 15 mg/day, was being administered at 8:00, and the second blood sample, with the improved count, obtained at 10:00. The authors concluded these diurnal changes were related to the dosing and granulocyte kinetic effects of glucocorticoids on neutrophils.\textsuperscript{18}

**Treatment**

As neutropenia in SLE is common and usually mild, there are no current guidelines for therapy and expectant management is the rule. Treatment is required in severe and life-threatening neutropenia, yet there are no randomised controlled studies to delineate treatment. As with treatment for thrombocytopenia, retrospective case studies may guide current therapy.

Kondo et al.\textsuperscript{19} reported one patient with SLE with agranulocytosis and septic shock who presented with a WBC count of 400/\mu L with no neutrophils. A bone marrow aspirate demonstrated hypocellularity, maturation arrest and an immature myeloid series of 33.8\% prior to treatment. A treatment regimen of recombinant human granulocyte (rhG)-CSF and methylprednisolone saw a rapid and sustained resolution of the neutropenia. She was treated with rhG-CSF (100 \mu g/day for 5 days) and methylprednisolone pulse therapy (1 g/day for 3 days). Seven days after initiation of treatment, the WBC count was increased to 17 200/\mu L with myeloid series 89.5\%. The patient showed significant improvement. Thus, similar to other significant haematological abnormalities in SLE, neutropenia is suppressed by glucocorticoids. But, in this patient, uncertainty exists as to which therapy was responsible for recovery. There may be a synergistic action between methylprednisolone and rhG-CSF.\textsuperscript{19}

Euler et al.\textsuperscript{20} investigated the effect of rhG-CSF on neutrophil count, unaccompanied by immunosuppressive effects of methylprednisolone. In this study, the authors treated three patients with SLE with four cycles of daily subcutaneous filgrastim. In all four treatment cycles, filgrastim resulted in a rapid rise in neutrophil count within 48 h. These investigators concluded that use of rhG-CSF was viable therapy in patients with lupus neutropenia with normal or increased granulopoiesis.\textsuperscript{20} The authors of the present paper have treated a patient with SLE with persistently severely low granulocyte count (<500/mm\textsuperscript{3} typically) with continuous rhG-CSF for >3 years. A bone marrow examination showed hypercellularity of the myeloid line. She had complete resolution of neutropenic fever episodes, which were occurring several times a year, and she was able to taper glucocorticoid therapy.

**Summary**

Mild neutropenia is a common finding in SLE that requires no specific therapy. Whether or not this leads to immune suppression is not known. However, a small percentage of patients with SLE develop severe, even life-threatening, neutropenia, which may be caused by a variety of mechanisms, both T cell and B cell mediated. The patient with severe neutropenia with opportunistic infection or the risk of such infection can be successfully treated with G-CSF.

**LYMPHOPENIA**

**Introduction**

Lymphopenia is defined as <1.5×10\textsuperscript{9} lymphocytes/L on two or more occasions according to the ACR and SLICC...
Low lymphocyte counts commonly occur in SLE with a prevalence ranging from 20% to 93% and are observed frequently in patients with active or severe disease. Moreover, lymphocyte levels may fluctuate during the clinical course, irrespective of treatment. However, glucocorticoids and immunosuppressive drugs may contribute to the lymphopenia in severe disease. The degree of lymphopenia can be quite striking with values <0.5×10⁹/L observed in 10% of patients. Lymphopenia occurs independently of neutropenia but may also contribute to the leukopenia seen in these patients.

Both T and B lymphocyte subpopulations may be affected, whereas the null lymphocyte subpopulation is frequently spared. In particular, the CD4+ subset of T cells is more profoundly affected, although the CD4/CD8 ratio is usually unchanged. This surprising observation may be explained by the deficiency of the CD4 epitope that reacts with monoclonal antibody used for the detection of this subset, leading to a technical artefact. The naive B lymphocyte subset (CD19+/CD27−) is more affected than the memory B lymphocyte subset (CD19 +/CD27+) in patients with active SLE.

Pathogenesis

The pathogenesis of lymphopenia is still unclear. Anti-lymphocyte antibodies have long been held responsible for the decline in lymphocyte numbers and in lymphocyte function. The number of autoantibody types responsible for these activities has expanded in the last several decades. Recent studies suggest that defects in apoptosis may also play a role.

Antilymphocyte antibodies are a heterogenous group of autoantibodies. Titres vary with disease activity, and presence of antilymphocyte activity is associated with lymphopenia. Historically, these antibodies have been identified in vitro by their ability to lyse lymphocytes. More recently, these antibodies have been identified by their binding to the surface of lymphocytes or plasma membrane components. Other autoantibodies, for example, anti-Ro, are associated with lymphopenia.

Circulating lymphotoxic antibodies are commonly identified in SLE, and levels correlate with lymphopenia. Such antibodies are identified by their ability to mediate complement-mediated lymphocyte toxicity at 37°C. The prototypic antibodies are cold-reactive IgM antibodies. Some targets have been defined and include CD45 and peptides of the T cell receptor, among others. IgG antilymphocyte antibody has also been described. These antibodies have the potential to deplete lymphocytes by antibody-dependent cellular toxicity. Their molecular targets include but are not limited to human leucocyte antigen class II antigens, interleukin (IL)-2 receptors, soluble products of activated T cells, glycosphospholipids and the ribosomal P protein.

Lymphocyte apoptosis may also contribute to lymphopenia in patients with SLE. Accelerated in vitro apoptosis of lymphocytes and increased amounts of circulating apoptotic bodies have been demonstrated. Upregulation of fas antigen on naive peripheral T cells may contribute to increased apoptosis. In contrast, this subpopulation of T cells is relatively devoid of fas antigen in normal individuals and those with rheumatoid arthritis. These T cells may be highly susceptible to fas-mediated apoptotic cell death. Silva et al also observed increased apoptosis in SLE lymphocytes compared with healthy controls. Neglect apoptosis, which is independent of fas–fas ligand binding and occurs with the loss of survival stimuli, was responsible for this finding. Lymphocytes from patients with neuropsychiatric lupus were particularly susceptible to this form of apoptosis, especially in the presence of autologous sera containing aPL or anti-Ro antibodies.

The past decade has put forward more studies correlating leucopenia with specific antibodies targeting nuclear antigens. Blood samples of 82 patients seen between 1998 and 2001 were included in a study by Wenzel et al. Leucocyte subsets were measured using flow cytometry, with autoantibodies detected by indirect immunofluorescence and ELISA. A number of peripheral leucocyte subsets were lower in autoantibody-positive patients in comparison with patients without these antibodies. Hence, this study showed a possible interaction between these antibodies and lymphocyte subpopulation in vivo.

Clinical presentation

Presence of lymphopenia may be clinically silent or associated with increased risk of infections and/or active SLE. Data on the increased risk of infection are controversial and are complicated by the use of immunosuppressive therapies. Ethnicity may also play a role in explaining the conflicting results.

Life-table analysis of patients in the Netherlands from 1991 showed no effect of lymphopenia on patient survival. In contrast, marked T cell depletion was associated with serious and often multiple infections in severely affected patients with SLE in India. However, high-dose glucocorticoids and cyclophosphamide use make these latter results difficult to interpret. One study found the combination of severe lymphopenia, values <0.35×10⁹/L, and immunosuppressive therapy increases risk of Pneumocystis jiroveci pneumonia. Nonetheless, Ginzler’s summary of the literature supports the premise that SLE is associated with increased infections even in the absence of immunosuppressive drugs. Most studies have generally found that increased disease activity associates with increased risk of infections. Uraemia and immunological dysfunction are considered the major risk factors for infection. Lymphopenia, especially affecting T cells, likely contributes to this dysfunction.

Some authors, but not all, have shown that lymphopenia correlates with disease activity. Fever, polyarthritis, as well as central and peripheral nervous system disease, in particular, are associated with lymphopenia.
Development of lymphopenia during the course of disease is frequently associated with disease relapse. Mirzan et al, in their prospective study to characterise prognostic parameters for SLE disease flares, concluded lymphopenia to be one of the predictors of flares. The authors evaluated 120 patients every three months for 2 years. At every visit, clinical manifestation and laboratory parameters were assessed and systemic lupus erythematosus disease activity index (SLEDAI) was determined. All patients were in clinical remission at enrolment. The authors conclusively stated that flares in SLE could be predicted by lymphopenia. Lymphocyte counts also frequently rose with disease remission. Therefore, lymphopenia may have prognostic significance.

Treatment
There are no recommendations for treatment specifically for lymphopenia analogous to those for haemolytic anaemia or thrombocytopenia. However, treatment for other clinical aspects of disease activity can lead to improvement in lymphocyte counts. Use of prophylaxis against P. jiroveci should be considered in patients with lymphocyte counts ≤ 0.35×10⁹/L. Belimumab, a monoclonal antibody that impairs B lymphocyte survival by binding B lymphocyte stimulator (BlyS), is efficacious as add-on therapy in patients with SLE with uncontrolled disease activity. A recent analysis of the effect of this drug on organ-specific disease activity has been reported in which data from the two randomised, placebo-controlled trials were pooled. This study shows no improvement of lymphopenia at either dose of belimumab among patients with baseline haematological involvement (n=137).

Summary
Lymphopenia may occur by interplay of different mechanisms. Specific therapy for lymphopenia is not indicated in patients with SLE, but lymphopenia, and its degree, may be related to the disease activity. Severely low lymphocyte count may predispose patients to opportunistic infections such that prophylactic therapy should be considered, especially in those patients on immunosuppressive therapy.

THROMBOCYTOPENIA
Introduction
For the purpose of the ACR classification criteria for SLE and the new SLICC criteria, the definition of thrombocytopenia is a platelet count <100 000/mm³ (or 100×10⁹/L) without any other identifiable cause. Excluding thrombocytopenia as a result of pharmacological therapy may be especially difficult in patients with SLE. Pseudothrombocytopenia must be excluded by careful examination of the peripheral blood smear in order to determine whether platelet aggregation along with adherence to leucocytes has occurred.

Pathogenesis
True thrombocytopenia can occur by three mechanisms: impaired production of platelets in the bone marrow, sequestration of platelets in the spleen or accelerated destruction of platelets in the peripheral circulation. The majority of patients with SLE with thrombocytopenia have increased peripheral destruction that is commonly mediated by antiplatelet antibodies, but the other two mechanisms play a role in some patients.

Autoantibodies
Antiplatelet antibodies and their antigenic targets have been extensively studied in both isolated idiopathic thrombocytopenic purpura (ITP) and SLE. Clear immunological differences between antiplatelet antibodies are found in the two illnesses. In addition, differences in the autoimmunity directed against platelets among subsets of patients with SLE, especially when stratified according to the presence of aPL antibodies, are described.

Similar to isolated ITP, both serum platelet-binding IgG and platelet-associated IgG are increased in patients with SLE with thrombocytopenia; however, these antibodies are also commonly present in the serum of patients with SLE without thrombocytopenia. In a group of 90 patients with SLE, of whom 29 had thrombocytopenia, there was no statistically significant correlation between the presence of antiplatelet antibodies and different disease manifestations except for thrombocytopenia. Nonetheless, in 25 patients without a history of thrombocytopenia, antiplatelet antibodies were associated with active disease.

As mentioned before, the targets of the immune response against platelets in patients with SLE differ from the targets seen in patients with isolated ITP. In ITP, patient antibodies bind platelet surface glycoproteins such as GP IIb/IIIa, Ib/IX and Ia/IIa. Meanwhile in patients with SLE, one study found almost no binding of platelet glycoproteins. Instead, immuno-blot studies of platelet eluate showed binding of a species migrating at 50–70 kD, the binding of which was inhibited by lysed platelets. Another study found binding to a similarly migrating species as well as one migrating at 80 kD. The specificity of aPL may vary according to the association with thrombocytopenia. In particular, antiprothrombin antibodies are commonly found in patients with aPL and thrombocytopenia. Whereas the proposed mechanism of thrombocytopenia in ITP is loss of immunological tolerance to specific platelet-associated antigens, thrombocytopenia in SLE may be caused in some instances by a more complex interaction between aPL antibodies and platelet-antigen antibodies.

As discussed above, thrombocytopenia in the setting of lupus is associated with aPL antibodies. A prospective, cohort study of 390 patients with SLE found that of 18 patients with thrombocytopenia 14 had anticardiolipin (aCL) antibodies, one of the many antiphospholipid
antibodies. In total, 47% of the entire group had these antibodies. Thus, the relative risk for thrombocytopenia in patients with aCL antibodies was greater than four.\textsuperscript{54} Another study assessed the fine specificity of antiphospholipid antibodies and found that aCL, antiphosphatidic, antiphosphoserine, antiphosphoinositol as well as the lupus anticoagulant were all associated with thrombocytopenia.\textsuperscript{55} In a series of 125 consecutive women with a lupus anticoagulant, 30 met criteria for SLE and 8 of these 30 patients had thrombocytopenia as a manifestation of SLE. Thus, there is a significant connection between the presence of the lupus anticoagulant and thrombocytopenia in patients with SLE.\textsuperscript{56} The known association of thrombocytopenia with the presence of aPL antibodies may,\textsuperscript{53–56} at least in some patients, be related to a common or a cross-reactive antigen since binding of some aCL antibodies can be inhibited by washed platelets.\textsuperscript{56}

**Genetics**

Genetic studies in SLE have been largely at the level of disease thus far, but a few have examined the genetics of severe disease and/or disease manifestations. We found\textsuperscript{57} and confirmed\textsuperscript{60} genetic linkage among American black families in which SLE is manifested by thrombocytopenia on chromosome 11p13.\textsuperscript{56} Of course, this ethnic group is well known to have not only an increased risk of SLE but also a more serious disease than any other ethnic groups studied so far. Fine genetic mapping of this genomic region using single-nucleotide polymorphisms shows genetic association near the CD44 gene.\textsuperscript{61} Unfortunately, a putative disease-causing allele has not been identified as yet. Other data also suggest that thrombocytopenia in SLE might have a genetic component as this manifestation is likely to be shared by SLE-affected siblings.\textsuperscript{62}

Subsequent to the previously cited genetic linkage work, a number of other studies have found the genetics of SLE to be related to thrombocytopenia (table 1). In most of these studies, the genetic effect was enhanced by comparing SLE with or without thrombocytopenia, or by limiting the analysis to patients with thrombocytopenia. However, in a few studies, the genetic allele under investigation showed a statistical relationship to the presence of thrombocytopenia, not to the disease itself.\textsuperscript{53} Whether these findings represent genetics directly related to the mechanism of low platelets or to thrombocytopenia as a marker of severe disease remains to be determined. Most of these studies parsed SLE by many manifestations with a few studies making statistical correction for multiple comparisons. We conclude that if such corrections were made then many of the findings (see table 1) would lose statistical significance.

**Clinical presentation**

Thrombocytopenia in SLE can present in multiple ways. Isolated ITP may be the first manifestation of SLE and precede other aspects of SLE by months or even years. Some individuals, 12% in one series of 115 patients with ITP, go on to develop SLE\textsuperscript{64}; therefore, some patients with SLE have isolated ITP prior to developing classifiable SLE. However, the number of patients with SLE who present initially with ITP is not precisely known.

Thrombocytopenia in patients with established SLE can be thought of broadly in two categories, although these are not exclusive.\textsuperscript{65} One group of patients has thrombocytopenia as part of a generalised exacerbation of SLE. These patients can have very low platelet counts with danger of life-threatening haemorrhage. The platelet count in these patients usually responds acutely to treatment with glucocorticoids. Approximately the other half of patients with SLE with thrombocytopenia has a more chronic form that is at times present even when other aspects of the disease are quiescent. These patients may not respond as well to glucocorticoid therapy. However, they are also more likely to have only a modest decrease in the platelet count that may not require specific therapy. Overall, 10–15% of patients with SLE have thrombocytopenia as a manifestation of their disease.

In addition to life-threatening haemorrhage as a direct result of low platelets, other serious SLE manifestations occur more frequently among patients with SLE with thrombocytopenia. These correlates of low platelet count include neuropsychiatric manifestations,\textsuperscript{66} haemolytic anaemia,\textsuperscript{65} 67 antiphospholipid syndrome\textsuperscript{45} and renal disease.\textsuperscript{65} 68 Our group studied thrombocytopenia in a large cohort of 179 families in which each family had at least two members with SLE.\textsuperscript{57} Thrombocytopenia was strongly associated with several manifestations of SLE including haemolytic anaemia, neuropsychiatric disease and renal disease. Almost half of the patients with either thrombocytopenia or haemolytic anaemia also had the other manifestation. In addition, thrombocytopenia was associated with aPL, antiribonucleoprotein and anti-Ro (the last in African-American patients only). Results show that SLE is more severe in the families with a patient with thrombocytopenic SLE.\textsuperscript{57}

In addition to the association with more severe disease, data show an association between thrombocytopenia and outcome. Although patients with SLE rarely die of bleeding complications, those patients with thrombocytopenia have a poorer prognosis.\textsuperscript{54} 54 68–72 Two studies of SLE, both large and long term, have shown that thrombocytopenia was the only, or nearly the
only, independent risk factor for early mortality in SLE. These studies involved European-American, Hispanic and African-American patients with SLE. Other studies involving different ethnic groups and other parts of the world (Chile, Canada and Southern China) also demonstrate poorer survival in patients with SLE with thrombocytopenia. While a few studies show no influence of thrombocytopenia on survival, most do show an effect with the relative risk for death during the period of follow-up being increased from 1.5-fold to 45-fold. Thus, based on outcome studies and cross-sectional studies of disease associations, thrombocytopenia can be regarded as an important prognostic indicator for SLE patient survival.

Medical treatment
Thrombocytopenia in patients with SLE presents a wide range of clinical scenarios ranging from mild and asymptomatic, requiring observation only, to severe and immediately life-threatening, requiring aggressive immunological and/or surgical therapy. No randomised controlled clinical trials are available to guide therapy, and future such trials evaluating different therapies for thrombocytopenia in SLE are unlikely. With a few notable exceptions, retrospective case series are the most prevalent types of studies published. These studies have inherent problems such as non-randomisation that can bias conclusions. Fortunately, most patients with SLE with thrombocytopenia need only expectant observation, not specific treatment. With a platelet count >40 000/mm³, no specific treatment for the thrombocytopenia is required unless there is excessive bleeding. In fact, most patients do not need therapy as long as the platelet count exceeds 20 000/mm³. On the other hand, in patients with very low platelet counts or modestly low platelet counts along with bleeding, glucocorticoid is the first-line therapy. Arnal et al studied 59 patients with SLE with thrombocytopenia, who were treated at five French centres. Of these 59 patients, 57 received oral glucocorticoid as first and sole therapy; and of these, 50 were evaluated long term (the remaining 9 received some other therapy in addition to glucocorticoid and were excluded from the evaluation). Of these 50, 40 had an acute response to glucocorticoid therapy that resulted in a rise in the platelet count. However, only 11 had a sustained response in mean follow-up of 78 months. Also, 8 of these 11 patients had normal platelet counts and were free from therapy after an average of 13 months of glucocorticoid therapy. Thus, the sustained remission rate was low (22%), and ultimately, 78% of the patients were classified as long-term responders.

| Author | No. of patients | Ethnicity | Gene (SNP) | Technique | Effect size |
|--------|----------------|-----------|------------|-----------|-------------|
| Scofield | 184 families* | North Am | 11p13 near CD44 | Genetic linkage | LOD score=3.71 in all LOD score=5.71 in AA OR=2.1 |
| Trivedi | 252 | North Am | Osteopontin/rs11730582C | Candidate gene/SNP typing genetic association | OR=2.62 |
| Piotrowski | 199 | Poland | Monocyte chemoattractant protein 1/rs1024611 | Candidate gene/SNP typing genetic association | OR=8.0 |
| Amengual | 134 | Japan | Human platelet antigen 6 | Candidate gene/RFLP genetic association |
| Nolsoe | 126 families* | North Am | FAS and FAS ligand | Candidate gene/SNP typing transmission disequilibrium p=0.006 |
| Namjou | 7490 | North Am | TRAF6/rs5030470 | Candidate gene/SNP typing genetic association OR=0.57 |
| Jeon | 147 | Korea | IL-6 3'IL-6 33 | Candidate gene/VNTR K9 logistic regression inheritance models p=0.02 |
| Jeon | 147 | Korea | IL-6/-278AC | Candidate gene/SNP typing genetic association p=0.006 |
| Chan | 107 | Taiwan | Suppressor of cytokine signalling 1/-1478CA/del | Candidate gene/SNP typing dominant inheritance model p=0.007 |
| Kim | 148 | Korea | C reactive protein/-390CA | Candidate gene/SNP typing genetic association p=0.043 |
| Warchol | 102 | Poland | Catalase/-330CT | Candidate gene/RFLP typing recessive inheritance model for CC genotype OR=7.4 p=0.0017 |
| Hong | 183 | Korea | FcgammaRIIIB/NA1/NA2 | Candidate gene/SNP typing genetic association OR=2.4 p=0.04 |

*Families in these studies all had at least two patients with SLE.
AA, African-American; IL, interleukin; LOD, logarithm of odds; RFLP, restriction fragment length polymorphism; SNP, single-nucleotide polymorphism.
term failures. In this same study, 10 patients were treated with high-dose intravenous methylprednisolone with an initial response rate of 60%; however, no patient had a sustained response, although one patient with a sustained response has been reported. Thus, oral or high-dose intravenous glucocorticoids produce a response in the majority of patients initially, but sustained response to this therapy is unlikely. Nonetheless, this therapy may be extremely useful in the patient with severe thrombocytopenia.

Danazol, a weak androgenic steroid, has also been used in the treatment of thrombocytopenia caused by SLE, although its complete mechanism of action is still unknown (table 2). Several case reports demonstrate success in patients that have failed other treatments. In a randomised controlled blinded trial of danazol in seven patients with mild SLE, the main effect noted was improvement of thrombocytopenia. With 1 month of danazol therapy, preceded and followed by 1 month of placebo, the three patients with thrombocytopenia all had improvement of the platelet count. In another study, West and colleagues used danazol (800 mg/day initially for 8 weeks) in six patients with SLE with severe thrombocytopenia, all of whom had failed glucocorticoid treatment. Four of the six had failed splenectomy. At 8 weeks, all had normal platelet counts and were on lower doses of glucocorticoid. Five were followed for 1 year, and all maintained a normal platelet count on lower doses of danazol, ranging from 200 to 600 mg/day. However, there was no evidence in this study of a reduction of platelet-bound immunoglobulin or circulating immune complexes. In 1997, four patients with SLE were reported with thrombocytopenia refractory to prednisone in whom danazol restored a normal platelet count. A sustained response was noted in follow-up of 18–36 months. The Arnal study had 18 of 59 French patients on danazol in addition to prednisone. Danazol was added in 12 of the 18 patients because they had failed another treatment. A sustained response was noted in nine with mean follow-up of 28 months. Another relatively large study of danazol followed 16 consecutive patients with SLE with thrombocytopenia from a single centre over a 5-year period. All had a good or excellent response within two months to danazol, which was started at 200 mg/day and increased by 200 mg every four weeks until a response was noted. All patients had failed oral glucocorticoid and five had not responded to splenectomy. In an average follow-up of 18.2 months (range from 2 to 49 months), danazol was tapered to between 200 and 400 mg/day without a recurrence of thrombocytopenia. Thus, the data indicate that danazol is an effective therapy for thrombocytopenia in SLE, even after failure of glucocorticoid.

Another medical therapy is hydroxychloroquine. Arnal et al treated 11 of 59 patients with hydroxychloroquine, which was added to oral glucocorticoid in all patients. Of these 11 patients, 7 had a sustained response in mean follow-up of 31 months, with prednisone dose <0.2 mg/kg/day in all 7 patients. There is no other report of hydroxychloroquine therapy in SLE thrombocytopenia to our knowledge. One patient has been reported to respond favourably to dapsone, which was begun for the treatment of cutaneous involvement of SLE.

Another useful therapy is intravenous immunoglobulin (IVIG), although the effectiveness is also short term. Maier et al studied seven patients with SLE who received IVIG 400 mg/kg for five consecutive days and then monthly for 1 year. Four had a favourable response at 5 days, but the platelet count was maintained in only two at 28 days, with only one patient having a sustained response at 1 year. Another report also demonstrates the short-term efficacy of IVIG but no long-term response. Meanwhile, other reports have demonstrated the efficacy of this treatment in the acutely bleeding thrombocytopenic patient with SLE.

Other immunosuppressants have been studied in SLE-related thrombocytopenia. In an early study by Ahn and colleagues, vincristine was used in 10 patients, 3 of which had convincing SLE by application of present criteria. Two of the three patients responded positively to vincristine, although the duration of the responses was not reported. Nevertheless, therapy with vincristine can be limited by the side effects, which include neuropathy and bone pain. Cyclosporin, in low doses, has also been successfully employed, including in three patients who were not responsive to multiple therapies and in whom clinically important bleeding was occurring. In addition, cyclosporin improved platelet counts in 3 out of 3 thrombocytopenic patients among 16 who were receiving the drug for SLE therapy. The cytotoxic agent cyclophosphamide had a positive effect in a patient with SLE who had recurrent thrombocytopenia 7 years after splenectomy but who failed intravenous glucocorticoids and a short course of danazol. Boumpas et al treated seven patients with thrombocytopenic SLE with cyclophosphamide and found platelet count recovery in all between 2 and 18 weeks. Six of these seven patients received the drug for renal disease and one for thrombocytopenia alone. In follow-up ranging from 12 to 74 months, all patients maintained a normal platelet count only on low-dose prednisone, but two patients required maintenance doses of cyclophosphamide.

There are case reports of the successful treatment of thrombocytopenia with mycophenolate mofetil. The experience of Arnal et al was not nearly as positive with regard to immunosuppressant therapy for thrombocytopenia. Of their 59 patients with SLE-associated thrombocytopenia, 14 received immunosuppressant-containing regimens, which included azathioprine, cyclosporine, cyclophosphamide, vincristine or vinblastine added to prednisone, splenectomy, IVIG, danazol or hydroxychloroquine. Only 2 of the 14 patients receiving immunosuppressants had a sustained platelet response, and both were on vinblastine. In fact, better responses
were found in the patients on non-immunosuppressive therapy, but those 14 patients given immunosuppressive therapy may have been sicker.

Biological treatment

The newer biological therapies may be an important alternative in patients with SLE with thrombocytopenia. There are data in regard to use of B cell-depleting therapy with rituximab in patients with SLE with thrombocytopenia. Lateef et al. used this drug in the treatment of 10 patients with refractory disease, of whom 3 had thrombocytopenia. The indication for rituximab was persistent, severe thrombocytopenia in two of these three. All three had undergone several unsuccessful therapies prior to rituximab treatment, including cyclophosphamide, mycophenolate, cyclosporine, hydroxychloroquine and glucocorticoid. The platelet count rose in all three patients, and in two of the three the rise was sustained and to >100×10⁹/L (100 000/mm³). Two of the three had AIHA and one had both. Two of these had a relapse at 48 and 64 weeks from the treatment. Both of these received a second course of rituximab with platelet count rising to >100×10⁹/L (100 000/mm³). Two of the five had glucocorticoid therapy stopped while the other three continued on intermittent glucocorticoid.

IL-11 is a thrombopoietic factor produced by bone marrow stromal cells, and recombinant human IL-11 is approved for use in the USA for the treatment of cancer chemotherapy-induced thrombocytopenia. In one report, this drug was used in a 38-year-old patient with SLE with life-threatening thrombocytopenia associated with intrabrachial bleeding. The platelet count had not responded to IVIG, high-dose methylprednisolone, cyclophosphamide or plasma exchange, but did respond to IL-11 over a 5-day period with platelets rising to 50 000/mm³ and control of bleeding.

Surgical treatment

Splenectomy has been used in patients with SLE with thrombocytopenia with success; however, many of the earlier studies on this procedure failed to define or report follow-up of the patients. Coon reported 18 patients with SLE in whom the principal reason for splenectomy was thrombocytopenia, in which only one patient was said to have periodic relapses requiring glucocorticoid. Unfortunately, neither the individual nor the mean length of follow-up is given, although eight patients were followed <1 year. Similarly, in another study of splenectomy for patients with glucocorticoid-resistant thrombocytopenia in SLE, of 12 patients 8 had excellent outcomes. Another report of six patients with SLE with thrombocytopenia shows five off therapy, but again the length of follow-up is not well defined. One other uncontrolled, but more well described, study of splenectomy in SLE-induced thrombocytopenia has had much less favourable results. Among 14 patients with SLE undergoing splenectomy over a 22-year period, 5 had persistently low platelets, 3 recurred within 6 months, 3 returned >6 months after their surgery and only 2 had a normal platelet count without glucocorticoid therapy.

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Table 2  Use of danazol in systemic lupus erythematosus (SLE) thrombocytopenia

| Author     | No. | Design  | Remission (%) | Dose | Duration | Comment                                      |
|------------|-----|---------|---------------|------|----------|----------------------------------------------|
| Marino⁷⁶   | 3   | Series  | 3 (100%)      | 200–600 | Prolonged | Failed intravenous Ig, intravenous glucocorticoids and splenectomy |
| Agnello⁷⁷ | 3   | RBPCT   | 3 (100%)      | 600   | 1 month  | Mild SLE, 7 patients in trial, 3 with low platelets |
| West⁷⁹    | 6   | Series  | 6 (100%)      | 800   | 1 year   | All failed glucocorticoids, 4/6 failed splenectomy |
| Blanco⁷⁸  | 4   | Series  | 4 (100%)      | 400–800 | 18–36 months | All failed glucocorticoids and at least one other drug |
| Cervera⁸⁰ | 16  | Series† | 16 (100%)     | 200†  | 2–49 months | All failed glucocorticoids, 5 failed splenectomy |
| Amarí⁷⁴   | 18  | Series  | 9 (50%)       | 400–600 | 28 months | All treated with glucocorticoids |

Dose is given as milligram per day.
†This was a consecutive series of patients with SLE with thrombocytopenia and bleeding.
‡200 mg/day initially, then increasing 200 mg each week until a response was noted.
RBPCT, randomised blinded placebo-controlled trial.

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Among the 59 patients followed by Arnal et al.,107 17 underwent splenectomy with a sustained response in 65%, in follow-up ranging from 3 to 209 months (mean 65 months). One patient among those undergoing a splenectomy died of *Staphylococcus aureus* sepsis while no patient with an intact spleen did so. Thus, uncontrolled studies of splenectomy have given mixed results with recurrence of thrombocytopenia relatively common.

One group has attempted a controlled, matched study of splenectomy in SLE.107 Fifteen patients with SLE undergoing splenectomy for haemocytopenias were compared with 15 matched patients with SLE with haemocytopenias who had not undergone splenectomy. The patients were highly similar in all clinical aspects prior to splenectomy. Clinical course after splenectomy was compared with an equivalent period in the matched patients. In the splenectomised group, there was a higher incidence of death (4 vs 1), cutaneous vasculitis, higher-dose prednisone requirements, more immunosuppression (10 vs 3) and more infection (18 vs 2). Two of the splenectomy patients died of infection. Remarkably, the degree and number of haemocytopenias were similar between the two groups after splenectomy compared with the control period in the patients not undergoing a splenectomy. In contrast, a different study followed nine patients with SLE undergoing splenectomy for thrombocytopenias who had not undergone splenectomy. The clinical course after splenectomy was compared with an equivalent period in the matched patients. In the splenectomised group, there was a higher incidence of death (4 vs 1), cutaneous vasculitis, higher-dose prednisone requirements, more immunosuppression (10 vs 3) and more infection (18 vs 2). Two of the splenectomy patients died of infection. Remarkably, the degree and number of haemocytopenias were similar between the two groups after splenectomy compared with the control period in the patients not undergoing a splenectomy.

**Summary**

Many patients with thrombocytopenia as a manifestation of SLE can be watched without specific treatment directed at the low platelet count, and the great majority of those requiring treatment can be successfully managed. For acute treatment, glucocorticoid is the mainstay of therapy, but a sustained response is unlikely. Either danazol or hydroxychloroquine can be added to glucocorticoid therapy, followed by slow taper of the glucocorticoid. If these therapies are not effective, then a trial of immunosuppressive therapy may be warranted in the form of cyclophosphamide. Very low dose cyclosporin or vincristine can also be considered. There are emerging data that rituximab is an effective therapy in patients with refractory thrombocytopenia. As emphasised by an editorial,109 splenectomy results in a 50–66% remission rate, but the only controlled trial in regard to splenectomy as a therapy for thrombocytopenia in SLE indicates a very high rate of subsequent infection, which may be life threatening. Thus, splenectomy should be reserved as a last resort in patients with SLE. For emergent treatment of thrombocytopenia in the patient with SLE, several therapies will likely be given simultaneously. Both high-dose glucocorticoid and IVIG have been shown to be effective in this situation and can be used together. One report found IL-11 useful, and this drug should be considered in a patient not responding adequately to the first two choices. Finally, plasma exchange is of proven benefit in thrombotic thrombocytopenic purpura (TTP) and has been effective in several patients with SLE with serious, glucocorticoid-refractory thrombocytopenia and bleeding.110 111 Use of aphaeresis should be considered in a patient with thrombocytopenia and life-threatening bleeding not responsive to other therapies.

**AUTOIMMUNE HAEMOLYTIC ANAEMIA**

**Introduction**

The ACR and SLICC criteria recognise AIHA with reticulocytosis as one of the criteria for the classification of SLE, while the SLICC criteria also include a positive Coombs test as a criterion.

**Pathogenesis**

Antibodies to erythrocyte antibodies in SLE are mainly warm-type IgG. aPL antibodies associate with Coombs-positive haemolytic anaemia in patients with SLE.112 aCL antibodies, IgG and IgM, are more common in patients with SLE with AIHA.113 Lang et al.,114 in their comparative study, provided evidence delineating the role of aCL antibody in AIHA.

The lupus-prone mice, New Zealand black, produce antihuman 3-specific antibodies.115 Antiband 3 IgG antibodies are also possibly involved in removal of aging red blood cells from the circulation of healthy individuals.116 As in primary AIHA, warm-type IgG react with band 3 anion transport protein. Regardless of this knowledge, an association between AIHA in patients with SLE and antigen specificity has not been determined. Underexpression of CD55 and CD59 has been shown on erythrocytes of patients with SLE-associated AIHA.117 These membrane proteins serve as protection against complement-induced cell lysis. The underexpression of these proteins can be associated with autoimmune haemolysis.118 Even though many associations have been made, still no conclusions have been drawn regarding antigen specificity of antisybocyte antibodies.

**Clinical findings and establishing diagnosis**

AIHA can be diagnosed in a stepwise manner. First, the anaemia must be established as haemolytic, which can be ascertained by serum biochemistry of haemolytic markers (eg, haptoglobin, lactate dehydrogenase, indirect bilirubin), presence of reticulocytosis and by examination of the peripheral blood smear. Second, using direct antiglobulin test, the clinician should determine whether autoimmunity against red blood cells is triggering haemolysis. Lastly, identification of the type of antibody responsible for haemolysis has to be defined. Warm-acting-AIHA and cold-acting-AIHA are based on the optimal temperature of antigen–antibody reactivity. This multilayered approach should lead to diagnosis or exclusion of the diagnosis of AIHA in patients with SLE.

Patients with AIHA present with constitutional signs and symptoms of anaemia, including fatigue and dyspnoea on exertion. Patients with SLE with AIHA can...
have other concomitant autoimmune haematological manifestations. For example, patients with SLE can present with AIHA and thrombocytopenia concomitantly or sequentially, which is known as Evans syndrome. Patients with Evans syndrome may have frequent relapses, once glucocorticoids have been tapered or stopped. Hence, when a diagnosis of AIHA in patients with SLE has been established, monitoring for the development of thrombocytopenia is important.

**Treatment**

Glucocorticoid therapy is first-line treatment for AIHA. A majority of patients show a clear response to therapy (Hg >10 g/dL) within the first three weeks of treatment. Once response has been achieved, glucocorticoid should be tapered. About 10% of patients do not respond to this therapy and will require a second-line treatment.

Many drugs have been used as second-line agents. Patient eligibility criteria for second-line therapy have been proposed (table 3). Still there is no general consensus on the best second-line agent. Drugs reported in the treatment of refractory AIHA in SLE include IVIG, azathioprine and other immunosuppressive medications as well as danazol and rituximab. A series of 26 patients with SLE from France with AIHA is informative. The aim of the study was to evaluate the response to treatment as well as the long-term outcome in a cohort of patients in whom severe AIHA was the primary SLE manifestation. Glucocorticoids were used as a first-line treatment in all patients. Oral prednisone (mean dose of 1 mg/kg) was used as the first-line treatment in 13 patients. The other 13 patients received high-dose methylprednisolone as an initial treatment. An initial response was obtained in 25 patients. Ten patients received hydroxychloroquine, five patients received azathioprine and five patients received one or several immunosuppressants for refractory AIHA. IVIG was given to two patients, and four patients underwent splenectomy. Seven patients experienced a relapse of AIHA. At the time of relapse, most of the patients were free of treatment or were receiving a low-dose glucocorticoid. Overall, 100% of the patients were in remission, which was complete in 85% of the patients. The authors concluded glucocorticoids were the treatment of choice and that splenectomy did not have a place in AIHA treatment. Patients refractory to the conventional treatment can be treated with immunosuppressive drugs, danazol or rituximab. Hence, second-line treatment is not established and will vary from patient to patient.

Recently, treatment of AIHA with rituximab has been undertaken. Long-term safety and efficacy of B cell depletion with rituximab for AIHA in patients with paediatric SLE was assessed in a study by Kumar et al. Nine patients were included in the study, which suggested rituximab therapy is safe and efficacious, inducing long-term clinical remission. Similarly, in a case report, a patient responded to rituximab after exhaustive second-line treatment strategies failed. Clinical and immunological response to rituximab treatment was evaluated in another dose-escalating study of rituximab for the treatment of SLE and Evans syndrome. Scheiberg et al also retrospectively evaluated patients with various autoimmune disorders who were refractory to other treatment modalities. This analysis favoured rituximab for both safety and efficacy. Although rituximab is a promising drug, multicentre randomised controlled trials are required to establish long-term optimal dosing, efficacy and safety of this drug for AIHA in patients with SLE who are refractory to other second-line treatments. Unfortunately, because AIHA is an uncommon manifestation, such trials are not likely forthcoming.

**Summary**

AIHA is one of the common aetiologies of severe anaemia in patients with SLE. Reports regarding its diverse clinical presentation and heterogenous association to other autoimmune manifestations make prompt attention essential. While glucocorticoids are used as first-line therapy in patients with SLE with AIHA, there are no high-quality data to guide second-line treatments. Unfortunately, because AIHA is an uncommon manifestation, such trials are not likely forthcoming.

**THROMBOTIC THROMBOCYTOPENIC PURPURA**

**Introduction**

The description of presentation of a teenage girl by Moschowitz, in the early 20th century, drew attention towards this previously unnoticed disease affecting multiple organs. Karl Singer, however, introduced the term thrombotic thrombocytopenic purpura >20 years later. In 1964, Amorosi and Ultmann defined the

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**Table 3** Proposed criteria for use of second-line therapy in refractory systemic lupus erythematosus-associated haemolytic anaemia

| Basis of criteria | Comment |
|-------------------|---------|
| Time based        | No response to glucocorticoid in 3 weeks |
|                   | >15 mg/day of prednisone* for maintenance |
|                   | 15 mg/day to 0.1 mg/kg/day* |
|                   | <0.1 mg/kg/day |
| Dose based        | Second-line therapy required |
|                   | Second-line therapy encouraged |
|                   | No second-line therapy |

*Or the equivalent of 15 mg of prednisone.
classic pentad of clinical features of TTP, namely thrombocytopenia, microangiopathic haemolytic anaemia (MAHA), neurological symptoms and signs, renal symptoms and signs, and fever. The evidence favours an autoimmune aetiology in many patients. 125 The association of TTP and SLE has been sporadically reported in the literature. These two separate clinical entities appear to run parallel on multiple fronts leading to diagnostic and management concerns. 126 TTP is not recognised as a criterion for classification of SLE.

Pathogenesis
The main pathogenic feature of TTP is the formation of platelet aggregates within the microcirculation. 127 An autoimmune aetiology is suggested based on multiple observations. 127 Occurrence of TTP in association with autoimmune diseases, especially SLE, is one piece of evidence for an autoimmune aetiology. Furlan et al investigated the prevalence of von Willebrand factor (vWF) cleaving protease (a disintegrin and metalloproteinase with a thrombospondin type 1 motif, member 13 (ADAMTS-13)) deficiency in patients with familial and non-familial forms of TTP. Familial deficiency was caused by a constitutional deficiency of the protease, whereas an inhibitor of vWF-cleaving protease was responsible in the non-familial TTP. 128 Tsai et al also studied the activity of ADAMTS-13 and sought inhibitors against this protease in the plasma of patients with acute TTP; patients with other diseases and normal subjects. Inhibitory activity was detected in 26 of 39 plasma samples from patients with TTP. The inhibitors were IgG antibodies. 129

Clinical features
TTP is clinically diagnosed based on the presence of characteristic features of fever, thrombocytopenia, MAHA with presence of schistocytes, neurological and/or renal impairment. There is considerable overlap between TTP and SLE regarding presenting features. 126 The traditional estimate for the diagnosis of TTP in SLE is 1–4%. Postmortem examination of patients with SLE by Devinsky et al 130 suggested even higher numbers of patients with this association. Also, different patterns of association have been suggested in various clinical reports. Although the diagnosis of SLE usually precedes that of TTP. 131 There are instances of TTP preceding or occurring simultaneously with the diagnosis of SLE. 132

A study carried out in the Hospital for Sick Children in Toronto reported an association between childhood onset TTP and SLE. The clinical course of all five patients diagnosed with TTP from 1975 to 1998 was compiled. In addition, all childhood-onset TTP (ages 6–20) reported in the literature over the same period was reviewed. The clinical presentation of paediatric patients with TTP was similar to that observed in adults. Of the five patients initially diagnosed with TTP, three were diagnosed with SLE within three years and the other two patients fulfilled three ACR classification criteria for SLE within four years of TTP onset. In total, 35 patients were selected from the review of literature, and of these, 9 fulfilled >4 criteria ACR criteria for SLE and 8 were found to have incipient SLE. The authors concluded that TTP in childhood is commonly associated with SLE. 133 Most recently, 5508 patients followed at the paediatric rheumatology unit of a university hospital from 1983 to 2010 were retrospectively reviewed. In total, 279 patients met the ACR classification criteria, and 2 of them had TTP. 134 Thus, these sets of data indicate that TTP in childhood may evolve to juvenile onset SLE.

TTP in association with SLE may portend more deleterious outcomes. Zheng et al 135 carried out a retrospective analysis on clinicopathological features and prognosis on eight patients with lupus nephritis complicated with TTP. All eight patients received immunosuppressive therapies and seven underwent apheresis therapy. These patients received plasma exchange and/or immunoabsorption. During a median follow-up of 12 months in seven patients, one patient died and only three patients had stable renal function. 135

Letchuman et al 136 in their comparative study between January 2003 and December 2007 at Singapore General Hospital, also suggested SLE-associated TTP (sTTP) was more aggressive. Ten patients with idiopathic TTP (iTTP) and eight patients with sTTP were identified. But mortality was not different between the two groups (4/8, 50%, for iTTP; and 5/8, 62.5%, for sTTP). 136

Treatment
For half a century after Moschowitz’s description of the disease, TTP remained untreatable. In the 1970s, John Byrnes and colleagues found that TTP could be treated by daily infusion of fresh frozen plasma. 137 However, plasma exchange has now replaced infusion of plasma as the therapy of choice. Rock et al 138 carried out a prospective randomised trial comparing plasma exchange with plasma infusion for the treatment of TTP in 102 patients. Outcome was analysed towards the end of first treatment cycle (day 9) and after 6 months. Plasma exchange was documented to be more effective than plasma infusion in the treatment of TTP after both cycles. 138

Plasma exchange remains the principal treatment for the patients with TTP in SLE. But high-dose glucocorticoid, cyclophosphamide and rituximab are also used in concert with plasma exchange in patients presenting with sequential or concomitant TTP in SLE. Several recent reports demonstrate the successful use of rituximab. A 52-year-old African-American woman was started on glucocorticoid and plasmapheresis after being diagnosed with both TTP and SLE. Her platelet counts continued to drop even after 10 rounds of plasma exchange. She was then started on rituximab, and after the second dose, her platelet counts were normalised. She was discharged on this drug as an outpatient. 139 Thus, refractory TTP with normal ADAMTS-13 responded well to rituximab. 139

12 Fayyaz A, Igoe A, Kurien BT, et al. Lupus Science & Medicine 2015;2:e000078. doi:10.1136/lupus-2014-000078
Summary
TTP is a syndrome with diverse aetiologies that can involve a variety of pathogenic mechanisms. TTP and SLE are two separate clinical syndromes with overlapping features that can occur together either concurrently or sequentially. TTP in SLE may predict a less favourable outcome in regard to renal function. Treatment is plasma exchange, but rituximab may be useful in refractory disease.

MYELOFIBROSIS
Introduction
Myelofibrosis is characterised by clonal proliferation of myeloid stem cells accompanied by stromal production of fibrinous ground substance. These changes can be attributed to primary myeloproliferative disorders or can be a manifestation of various malignant, endocrine or inflammatory conditions. Acknowledgement of myelofibrosis as an aetiology of peripheral cytopenias in association with SLE is something recent. Myelofibrosis is not established as a classification criterion for SLE. Through review of the available literature, we conclude that myelofibrosis is definitely an uncommon manifestation of SLE.

Pathogenesis
Burkhard proposed the interplay between the immune reaction and bone marrow in SLE in the mid-20th century. In the light of discovery of ‘Hargaves cell’ in the bone marrow, that is, the LE cell, Burhhard suggested an integrating role of bone marrow pathology as an aetiology of haematological manifestations in patients with SLE. He also hypothesised that the regularity of bone marrow being a target in such patients could be attributed to disturbed equilibrium between protein production by the plasma cells and its proteolytic breakdown. The understanding of the pathogenesis of myelofibrosis is evolving and is far from definite. A variety of malignant and non-malignant conditions likely cause myelofibrosis as a non-specific reaction. Fibrosis, in general, is an imbalance between collagen synthesis and its breakdown. Circulating immune complexes, and autoantibodies in SLE, act on the megakaryocyte Fc-receptors and release growth factors, platelet-derived growth factor and transforming growth factor-β, all of which are known to induce collagen production. However, no specific antibodies are produced in patients with SLE who have myelofibrosis.

Due to inefficient haematopoiesis in patients with myelofibrosis, foci of extramedullary haematopoiesis (EMH) can occur in any organ. Bone lytic lesions associated with EMH due to myelofibrosis were described in one patient with SLE. The lesions were not biopsied to conclusively prove the suspected aetiology. Osteolytic lesions, however, are rare, even in primary myelofibrosis.

Clinical presentation
There have been 30 published cases of myelofibrosis secondary to clinically established SLE, according to our search (table 4), but only 29 had data. In total, 23 out of 29 patients were women, and 16 of 29 patients presented before 30 years of age. In contrast to SLE, primary myelofibrosis occurs mainly in middle-aged and elderly patients, the median age at presentation being 67 years. In 1969, the first two SLE-associated myelofibrosis were reported, both from Malaysia. Subsequently, the majority of published cases are among Caucasian or Mexican-American women, followed by African-American and Arab patients. Hence, from the literature available, the ethnicity predominance cannot be determined conclusively.

Presenting symptoms attributable to progressive anaemia or thrombocytopenia were prominent in all patients (table 4). In total, 12 of 18 patients had a palpable spleen on examination. Among 28, 23 had a haemoglobin of <10 g/dL at presentation. Of these 23 patients, 7 presented with severe anaemia with a haemoglobin of <6 g/dL. The leucocyte counts were invariably diminished among all 29 patients.

In a prospective, cross-sectional analytical study among 41 patients with SLE and peripheral cytopenias, bone marrow was found as a target organ affected by immune mechanisms. Of 41 patients, 20 had bone marrow abnormalities that were categorised into six groups. Hypocellularity was the predominant finding, affecting 10 of the 20 patients. Reticulin fibre was increased in bone marrow biopsies of five patients, but significant bone marrow fibrosis was found in one patient only. The
authors concluded that bone marrow examination should be recommended among patients who do not have improvement in their peripheral cytopenia after conventional therapy. But this study also documents that myelofibrosis is an uncommon finding among patients with SLE even with low peripheral blood cell counts.\textsuperscript{144}

Bone marrow hypoplasia was found to be a common abnormality among 23 patients studied by Feng \textit{et al.}\textsuperscript{145} who found 9 patients had hypoplastic bone marrow. Interestingly, in this study of bone marrow histology, the patient population was either taken off cytotoxic drugs at least a month before the study or were never on these drugs. In another study on bone marrow biopsies from 21 patients, Pereira also concluded bone marrow to be a target organ in SLE with peripheral cytopenia, but only one patient had myelofibrosis.\textsuperscript{146}

\textbf{Treatment}

The main treatment for SLE-associated myelofibrosis is glucocorticoid. Most patients, 23 of 28 whose status was known through published literature, survived (table 4). Improvement in peripheral blood cells counts and gradual resolution on repeat bone marrow biopsies was found in 17 of 25 patients who underwent a repeat bone marrow biopsy. A 54-year-old woman\textsuperscript{147} achieved improvement of her bone marrow architecture and normalisation of peripheral cell counts only after administration of high-dose IVIG therapy. These findings further establish bone marrow as a target site in patients with SLE.

An important advance in the understanding of primary myelofibrosis is the recognition of overactive Janus kinase (JAK)/signal transducer and activator of transcription (STAT) pathway signalling. A significant fraction of patients have activating mutations in JAK, the most common of which is JAK2V617F.\textsuperscript{148} These data led to clinical trials of the JAK inhibitor ruxolitinib. In randomised controlled clinical trials, this drug demonstrated efficacy with reduction of spleen size, decreased symptoms and increased life expectancy.\textsuperscript{149-151} Ruxolitinib was approved for therapy of myelofibrosis by the US Food and Drug Administration in 2012. Unfortunately, to our knowledge, ruxolitinib has not been used in SLE-associated myelofibrosis. Further, neither JAK sequence nor JAK/STAT signalling has been assessed in myelofibrosis in SLE.

\textbf{Summary}

Bone marrow abnormalities are common among patients with SLE and peripheral cytopenias. Myelofibrosis is well described but uncommon in such patients. If myelofibrosis is diagnosed early in the course of the disease, most of the patients have shown improvement in the bone marrow architecture. In contrast, well-established myelofibrosis may lead to death. In total, 8 out of 29 patients did not respond to the treatment and had drastic deterioration in their cell counts and eventually died as a direct result of myelofibrosis (table 4).

Given that routine bone marrow pathological examination as a diagnostic tool in SLE is not practical, studies of the role of MRI or isotope marrow imaging, in patients with SLE, especially those who decline repeat bone marrow biopsy, are desirable. Also, in patients who eventually do not respond to treatment, transformation of the marrow to acute leukaemia or other complications should be studied. Such advances may guide therapy to decrease mortality among this patient population.

\textbf{CONCLUSION}

Haematological abnormalities are common findings in patients with SLE. It is important to distinguish haematological abnormalities as either manifestation of SLE, consequence of SLE treatment or as a part of another blood dyscrasia. Our review considered neutropenia, lymphopenia, AIHA, thrombocytopenia, TTP and myelofibrosis. According to the literature, mild neutropenia is a common finding in SLE and requires no specific therapy. However, patients with severe neutropenia with opportunistic infection or the risk of such infection can be successfully treated with G-CSF. Severely low lymphocyte count may also predispose patients to opportunistic infections such that prophylactic therapy should be considered. However, specific therapy for lymphopenia in patients with SLE is not indicated. Many patients with thrombocytopenia as a manifestation of SLE can be watched without specific treatment, and the great majority of those requiring treatment can be successfully managed. AIHA is one of the common aetiologies of severe anaemia in patients with SLE. While glucocorticoids are used as first-line therapy in patients with SLE with AIHA, second-line treatments are undefined. TTP occurs with SLE, either concurrently or sequentially, especially among children with SLE. Myelofibrosis is well described but uncommon in patients with SLE. If myelofibrosis is diagnosed early in course of the disease, most patients show improvement in bone marrow architecture.

\textbf{FUTURE DIRECTIONS: WILL BIOLOGICS CHANGE THERAPY?}

As discussed above, rituximab is a useful drug in treating serious haematological disease in SLE. Belimumab is the first biological drug approved for use in SLE by regulatory agencies. The efficacy of this drug for the haematological manifestations of the disease has only begun to be evaluated. One study has combined the results of the two randomised placebo-controlled trials of belimumab in SLE and studied organ-specific domain response. This approach considers all haematological manifestations together, however. Among patients with no organ involvement at baseline, a significantly lower percentage had worsening of the haematology index in the belimumab 10 mg/kg group. However, there was no improvement and maybe even a worsening of the haematological index among patients with high serological activity at baseline.\textsuperscript{152} So, the response of the
individual haematological manifestations or for that matter a composite profile remains to be determined. Approval of belimumab may open a new era of therapy for SLE, similar to that opened when anti-TNF biologics were introduced for rheumatoid arthritis. There are a number of drugs in development that target B cells via CD20 or CD22, including but not limited to tabalumab, blisibimod, atasicept, ocrelizumab, and ofatumumab, as well as additional drugs targeting the BLYS pathway. Unfortunately, we do not find data concerning haematological complications of SLE and these new biologics.

Bortezomib is a proteasome inhibitor that is available for use in multiple myeloma. Animal data in SLE-prone mice suggest that this drug might be efficacious in SLE. Bortezomib reduces survival of antibody-producing plasma cells, a cell type not targeted by anti-CD20 biological therapy. Thus, bortezomib is theoretically an attractive candidate, but an SLE clinical trial of standard dosing for myeloma was recently withdrawn as there are important and serious side effects. Nonetheless, two case reports of treatment of patients with both SLE and multiple myeloma are of interest. One patient was treated with a modified lower dose regimen with disappearance of antinuclear antibodies and anti-Sm, and the SLEDAI dropped to zero. This included a resolution of lymphopenia. Another patient with SLE and myeloma was treated with higher-dose bortezomib. There was complete resolution of SLE-associated thrombocytopenia sustained for at least one year.

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REFERENCES
1. Lie TH, Rothfield NF. An evaluation of the preliminary criteria for the diagnosis of systemic lupus erythematosus. Arthritis Rheum 1972;15:532–4.
2. Tan EM, Cohen AS, Fries JF, et al. The 1982 revised criteria for the classification of systemic lupus erythematosus. Arthritis Rheum 1982;25:1271–7.
3. Feletar M, Ibanez D, Urowitz MB, et al. The impact of the 1997 update of the American College of Rheumatology revised criteria for the classification of systemic lupus erythematosus: what has been changed? Arthritis Rheum 2003;48:2067–9.
4. Petri M, Orbai AM, Alarcon GS, et al. Derivation and validation of the Systemic Lupus International Collaborating Clinics classification criteria for systemic lupus erythematosus. Arthritis Rheum 2012;64:2677–86.
5. Katasian E, Huo E, Luke KH, et al. Systemic lupus erythematosus and sick hemoglobinopathies: a report of two cases and review of the literature. Am J Hematol 1987;25:211–14.
6. Harvey AM, Shulman LE, Tumulty PA, et al. Systemic lupus erythematosus: review of the literature and clinical analysis of 138 cases. Medicine (Baltimore) 1954;33:291–337.
7. Arenas M, Abad A, Valverde V, et al. Selective inhibition of granulopoiesis with severe neutropenia in systemic lupus erythematosus. Arthritis Rheum 1992;35:979–80.
8. Haddy TB, Rana SR, Castro O, Benigni AB. Neutropenia: what is a normal absolute neutrophil count? J Lab Clin Med 1999;133:15–22.
9. Starkebaum G, Price TH, Lee MY, et al. Autoimmune neutropenia in systemic lupus erythematosus. Arthritis Rheum 1978;21:504–12.
10. Yamasaki K, Niho Y, Yanase T. Granulopoiesis in systemic lupus erythematosus. Arthritis Rheum 1983;26:516–21.
11. Rustagi PK, Currie MS, Logue GL. Complement-activating antineutrophil antibody in systemic lupus erythematosus. Am J Med 1985;78(6 Pt 1):591–7.
12. Kurien BT, Newland J, Paczkowski C, et al. Association of neutropenia in systemic lupus erythematosus (SLE) with anti-Ro and binding of an immunologically cross-reactive neutrophil membrane antigen. Clin Exp Immunol 2000;120:209–17.
13. Harmon DC, Weitzman SA, Stossel TP. The severity of immune neutropenia correlates with the maturational specificity of antineutrophil antibodies. Br J Haematol 1984;58:209–15.
14. Duckham DJ, Rhyne RL Jr, Smith FE, et al. Retardation of colony growth of in vitro bone marrow culture using sera from patients with Felty’s syndrome, disseminated lupus erythematosus, rheumatoid arthritis, and other disease states. Arthritis Rheum 1975;18:333–33.
15. Gergely P. Severe neutropenia in systemic lupus erythematosus. Arthritis Rheum 1978;21:295–7.
16. Matsuyama W, Yamamoto M, Higashimoto I, et al. T or F? An abnormal absolute neutrophil count? J Lab Clin Med 1992:771–6.
17. Glinski W, Gershwin ME, Budman DR, et al. The impact of the 1997 update of the American College of Rheumatology revised criteria for the classification of systemic lupus erythematosus: what has been changed? Arthritis Rheum 2003;48:2067–9.
18. Matsuyma W, Yamamoto M, Higashimoto I, et al. TNF-related apoptosis-inducing ligand is involved in neutropenia of systemic lupus erythematosus. Blood 2004;104:184–91.
19. Martinez-Banos D, Crispin JC, Lazo-Langner A, et al. Moderate and severe neutropenia in patients with systemic lupus erythematosus. Rheumatology (Oxford) 2006;45:994–8.
20. Sugimoto T, Soumura M, Tanaka Y, et al. Early morning neutropenia in a patient with systemic lupus erythematosus. Mod Rheumatol 2006;16:267–8.
21. Kondo H, Date Y, Sakai Y, et al. Effective simultaneous rhG-CSF and methylprednisolone “pulse” therapy in agranulocytosis associated with systemic lupus erythematosus. Am J Hematol 1994;46:157–8.
22. Euler HH, Harten P, Zeuner RA, et al. Recombinant human granulocyte colony stimulating factor in patients with systemic lupus erythematosus associated neutropenia and refractory infections. J Rheumatol 1997;24:2153–7.
23. Rivero SJ, Díaz-Jouanen E, Alarcon-Segovia D. Lymphopenia in systemic lupus erythematosus. Clinical, diagnostic, and prognostic significance. Arthritis Rheum 1978;21:295–305.
24. Bhuyan UN, Malaviya AN. Deficiency of T cells in blood and tissues and severity of infections in systemic lupus erythematosus. Indian J Med Res 1978;67:269–78.
25. Glinski W, Gershwin ME, Budman DR, et al. Study of lymphocyte subpopulations in normal humans and patients with systemic lupus erythematosus by fractionation of peripheral blood lymphocytes on a discontinuous Ficol gradient. Clin Exp Immunol 1976;22:228–38.
26. Laurence J, Wong JE, Nachman R. The cellular hematology of systemic lupus erythematosus. In: Lahita RG, ed. Systemic Lupus erythematosus. 2nd edn. New York: Churchill Livingstone, 1992:771–806.
110 patients studied prospectively. *Ann Rheum Dis* 1989;48:447–54.

74. Armal C, Piette JC, Leon J, et al. Treatment of severe thrombocytopenia associated with systemic lupus erythematosus: 69 cases. *J Rheumatol* 2002;29:75–83.

75. Eyanson S, Passo MH, Aldo-Benson MA, et al. Methylprednisolone pulse therapy for nonrenal lupus erythematosus. *Ann Rheum Dis* 1980;39:377–80.

76. Marino C, Cook P, Danazol for lupus thrombocytopenia. *Arch Intern Med* 1985;145:2591–2.

77. Agnello V, Pariser K, Gell J, et al. Preliminary observations on danazol therapy of systemic lupus erythematosus: effects on DNA antibodies, thrombocytopenia and complement. *J Rheumatol* 1983;10:862–7.

78. Blanco R, Martinez-Taboada VM, Rodriguez-Valverde V, et al. Successful therapy with danazol in refractory autoimmune thrombocytopenia associated with rheumatic diseases. *Br J Rheumatol* 1997;36:1095–9.

79. West SG, Johnson SC. Danazol for the treatment of refractory autoimmune thrombocytopenia in systemic lupus erythematosus. *Ann Intern Med* 1988;108:703–6.

80. Cervera H, Jara LJ, Pizarro S, et al. Danazol for systemic lupus erythematosus--a prospective pilot study. *Rheumatology (Oxford)* 2011;50:1640–4.

81. Chen H, Zheng W, Su J, et al. Low-dose rituximab therapy for refractory thrombocytopenia in patients with systemic lupus erythematosus--a prospective pilot study. *Rheumatology (Oxford)* 2011;50:1640–4.

82. Gonzalez-Nieto JA, Martin-Suarez I, Quattrini S, et al. The efficacy of romiplostim in the treatment of severe thrombocytopenia associated to Evans syndrome refractory to rituximab. *Lupus* 2011;20:1321–3.

83. Liang Y, Zhang L, Gao J, et al. Rituximab for children with immune thrombocytopenia: a systematic review. *PLoS ONE* 2012;7:e36698.

84. Kumar S, Benseler SM, Kirby-Allen M, et al. B-cell depletion for autoimmune thrombocytopenia and autoimmune haemolytic anaemia in pediatric systemic lupus erythematosus. *Pediatrics* 2009;123:e159–63.

85. Feinglass S, Deodhar A. Treatment of lupus-induced thrombocytopenia with recombinant human interleukin-11. *Arthritis Rheum* 2001;44:170–5.

86. Comyn WW. Splenectomy for cytophenias associated with systemic lupus erythematosus. *Am J Surg* 1988;155:391–4.

87. Ahn YS, Harrington WJ, Seelman RC, et al. Anti-CD20 therapy in patients with refractory systemic lupus erythematosus. *Ann Intern Med* 1989;105:971–2.

88. Hall S, McCormick JL, Jr, Greipp PR, et al. Splenectomy does not cure the thrombocytopenia of systemic lupus erythematosus. *Ann Intern Med* 1985;102:325–8.

89. Ahn YS, Harrington WJ, Seelman RC, et al. Anti-CD20 therapy in patients with refractory systemic lupus erythematosus. *Ann Intern Med* 1989;105:971–2.

90. Riviero SJ, Alger M, Alarcon-Segovia D. Splenectomy for hemorrhagia in systemic lupus erythematosus. A controlled appraisal. *Arch Int Med* 1979;139:773–8.

91. Hakim AJ, Machin SJ, Hughes D, et al. Thrombocytopenia in primary antiphospholipid syndrome and systemic lupus erythematosus: the response to splenectomy. *Semin Arthritis Rheum* 1998;28:20–3.

92. Alarcon-Segovia D. Splenectomy has a limited role in the management of lupus with thrombocytopenia. *J Rheumatol* 1995;22:1867–71.

93. Wail BA, Weinblatt ME, Agudelo CA. Plasmapheresis in the treatment of resistant thrombocytopenia in systemic lupus erythematosus. *South Med J* 1982;75:1277–8.

94. Sakamoto H, Takaoka T, Usami M, et al. Apheresis: clinical response to patients unresponsive to conventional therapy. *Trans Am Soc Artif Interv Organs* 1985;31:704–10.

95. Sthoeger Z, Sthoeger D, Green L, et al. Antibody-secreting cells in systemic lupus erythematosus. *Lupus* 1995;2:1149–51.

96. Sthoeger Z, Sthoeger D, Green L, et al. Antibody-secreting lymphoid cells in systemic lupus erythematosus. *Lupus* 1995;2:1149–51.

97. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane band 3 protein. *Am J Med* 1986;52:366–70.

98. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

99. Mattioli AC, Luque LA, Salgado JL, et al. The role of complement regulatory proteins in systemic lupus erythematosus. *Scand J Rheumatol* 1992;3:218–21.

100. Mattioli AC, Luque LA, Salgado JL, et al. The role of complement regulatory proteins in systemic lupus erythematosus. *Lupus* 1992;30:382–4.

101. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane band 3 protein. *Am J Med* 1986;52:366–70.

102. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

103. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane band 3 protein. *Am J Med* 1986;52:366–70.

104. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

105. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane band 3 protein. *Am J Med* 1986;52:366–70.

106. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

107. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

108. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

109. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.

110. Barker RN, de Sa Oliveira GG, Elson CJ, et al. Membrane protein band 3: localization of the active antigenic sites. *Arch Int Med* 1998;158:20–9.
125. Amorsio E, Ultmann J. Thrombotic thrombocytopenic purpura: report of 16 cases and review of the literature. Medicine (Baltimore) 1966;45:139.

126. George JN, Vesely SK, James JA. Overlapping features of thrombotic thrombocytopenic purpura and systemic lupus erythematosus. South Med J 2007;100:512–14.

127. Porta C, Caporali R, Montecucco C. Thrombotic thrombocytopenic purpura and autoimmunity: a tale of shadows and suspects. Haematologica 1999;84:260–9.

128. Furlan M, Robbi L, Galtiara M, et al. Willebrand factor-reacting protease in thrombotic thrombocytopenic purpura and the hemolytic-uremic syndrome. N Engl J Med 1998;339:1578–64.

129. Devinsky O, Petiton CK, Alonso DR. Clinical and neuropathological findings in systemic lupus erythematosus: the role of vasculitis, heart emboli, and thrombotic thrombocytopenic purpura. Ann Neurol 1988;23:590–4.

130. Stricker RB, Davis JA, Gershov J, et al. Thrombotic thrombocytopenic purpura complicating systemic lupus erythematosus. Case report and literature review from the plasmapheresis era. J Rheumatol 1992;19:1469–73.

131. Venkatesan V, Iyer S, Okkenhaug K, et al. Successful use of bortezomib in a patient with systemic lupus erythematosus and multiple myeloma. Ann Rheum Dis 2011;70:1344–5.

132. Vercammen R, Yaraghi M, Michiels M, et al. Efficacy and tolerability of repeated cycles of a once-weekly regimen of bortezomib in lupus. Rheumatology (Oxford) 2014;53:381–2.

133. Trivedi T, Franke BS, Green S, et al. Osteopontin alleles are associated with clinical characteristics in systemic lupus erythematosus. Journal of biomedicine & biotechnology 2011;2011:802581.

134. Amengual O, Atsumi T, Komano Y, et al. A polymorphism in human platelet antigen 6b and risk of thrombocytopenia in patients with systemic lupus erythematosus. Arthritis Rheum 2007;56:2803–5.

135. Nolsoe RL, Kelly JA, Pociot F, et al. Functional promoter haplotypes of the human FAS gene are associated with the phenotype of SLE characterized by thrombocytopenia. Genes Immun 2005;6:699–706.

136. Namjou B, Choi CB, Harley IT, et al. Evaluation of TRAF6 in a large multicenteral lupus cohort. Arthritis Rheum 2012;64:1960–9.

137. Jern JY, Kim KY, Kim HA, et al. Association between variable number tandem repeats within the 3rd flanking region of the interleukin-6 gene and systemic lupus erythematosus in Korean patients. Lupus 2011;20:1161–5.

138. Hong CH, Lee JS, Lee HS, et al. The interleukin 6 receptor alpha gene polymorphisms are associated with clinical manifestations of systemic lupus erythematosus in Koreans. Int Immunogenet 2013;40:356–60.

139. Chan HC, Ke LY, Chang LL, et al. Suppressor of cytokine signaling 1 gene expression and polymorphisms in systemic lupus erythematosus. Lupus 2010;19:696–702.

140. Jern JY, Kim HA, et al. C-reactive protein gene polymorphisms in disease susceptibility and clinical manifestations of Korean systemic lupus erythematosus. J Rheumatol 2009;36:2238–43.

141. Warchol T, Lienan M, Wudarski M, et al. Catalase -262C>T polymorphism in systemic lupus erythematosus (SLE) patients. Rheumatol Int 2008;28:1035–9.

142. Aragwal BR, Bhalla K, Dalvi R, et al. Myelofibrosis secondary to SLE and its reversal on steroid therapy. Indian Pediatr 1995;32:1207–10.

143. el Mouzan Mt, Ahmad MA, al Fadel Saileh M, et al. Myelofibrosis and pancytopenia in systemic lupus erythematosus. Acta Haematol 1986;80:219–21.

144. Foley-Nolan D, Martin MF, Rowbotham D, et al. Systemic lupus erythematosus presenting with myelofibrosis. J Rheumatol 1992;19:1303–4.

145. Fukuya H, Hirose W, Masuda T, et al. [A case of systemic lupus erythematosus presenting with myelofibrosis as a case of pancytopenia]. Ryumachi [Rheumatism] 1994;34:773–8.

146. Inoue Y, Matsubara A, Okuya S, et al. Osteopontin alleles are associated with systemic lupus erythematosus: reversal of fibrosis with high-dose corticosteroid therapy. Acta Haematol 1992;88:32–6.

147. Kaelin WG Jr, Spivak JL, Systemic lupus erythematosus and myelofibrosis. Am J Med 1986;81:935–8.

148. Kiss E, Gal I, Simikovic E, et al. Myelofibrosis in systemic lupus erythematosus. Leuk Lymphoma 2000;39:661–5.

149. Konstantopoulos K, Terpos E, Pinolakis H, et al. Systemic lupus erythematosus presenting as myelofibrosis. Haematologica 1998;83:153–6.

150. Matsouka C, Liouris J, Andrianakos A, et al. Myelofibrosis secondary to SLE and its reversal on steroid therapy. Intern Med 1998;37:714.

151. Paquette RL, Meshkinpour A, Rosen PJ. Autoimmune myelofibrosis. A steroid-responsive cause of bone marrow fibrosis associated with systemic lupus erythematosus. Medicine (Baltimore) 1994;73:145–52.

152. Pillai A, Gautam M, Williamson H, et al. Multisystem failure due to three coexisting autoimmune diseases. Intern Med 2009;48:837–42.

153. Ramakrishna R, Kyle PW, Day PJ, et al. Evans’ syndrome, myelofibrosis and systemic lupus erythematosus: role of procoagulants in myelofibrosis. Pathology 1995;27:255–9.

154. Raut DS, Saha S. Myelofibrosis secondary to SLE and its reversal on steroid therapy. Indian Pediatr 1996;33:522–3; author reply 23–4.