Abundant neutrophil extracellular traps in thrombus of patient with microscopic polyangiitis

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This is a case study of a patient diagnosed with microscopic polyangiitis (MPA) and complicated with deep vein thrombosis (DVT), who died of respiratory failure despite treatment. Autopsy revealed severe crescentic glomerulonephritis and massive alveolar hemorrhage. The thrombus contained abundant neutrophils. Although it is reported that patients with ANCA-associated vasculitis (AAV) have an increased risk of DVT, it remains elusive why they are prone to thrombosis. A recent study has demonstrated the presence of neutrophil extracellular traps (NETs), a newly recognized mode of neutrophil cell-death, in glomerular crescents of MPA patients. Interestingly, NETs were identified in the thrombus as well as in the glomerular crescents in the present case. When compared to other thrombi unrelated to MPA, the amount of NETs was significantly greater in the MPA patient. On the other hand, NETs are critically involved in thrombogenesis because histones within NETs can bind platelets and blood coagulants. Although this is important in regard to containment of microbes within NETs, excessive NETs could cause thrombosis. The collective findings suggest the possibility that thrombosis could be critically associated with MPA via NETs, and that NETs could be a therapeutic target in MPA patients.

Keywords: MPO-ANCA, microscopic polyangiitis, neutrophil extracellular traps, deep vein thrombosis, histone-citrullination

CASE PRESENTATION

A 56-years-old woman was admitted to the section of Internal Medicine because of fever and tender swelling of the left leg that began 2 weeks ago. Urinalysis revealed microhematuria (30–49/high power field) and proteinuria (100–300 mg/dl). Hematological examinations showed leukocytosis with white blood cell counts of 16,410/µl. Hematological examinations showed leukocytosis with white blood cell counts of 16,410/µl, anemia with hemoglobin of 6.9 g/dl, and normal platelet counts of 24.0 × 10⁹/µl. Blood chemistry demonstrated elevated levels of blood urea nitrogen (22.9 mg/dl) and creatinine (2.85 mg/dl). The serum level of C-reactive protein was also elevated (7.39 mg/dl). Myeloperoxidase-anti-neutrophil cytoplasmic antibody (MPO-ANCA) was positive (836 units/ml); while, other autoantibodies, including proteinase 3-ANCA, anti-glomerular basement membrane antibody, and anti-phospholipid antibody, were negative. In coagulation tests, fibrin degradation products (D-dimers) were negative. In coagulation tests, fibrin degradation products (D-dimers) were negative. The glomerular findings were consistent with pauci-immune crescentic glomerulonephritis of MPA. Alveolar hemorrhage was also considered as a sign of MPA, though typical capillaritis could not be identified in the lungs. The thrombus was relatively, fresh and contained abundant neutrophils (Figures 1C,D).

In the thrombus, no microbe was detected by special staining techniques, including Gram stain, Giemsa stain, and Periodic acid-Schiff reaction. Autopsy revealed diffuse crescentic necrotizing glomerulonephritis without immunoglobulin deposition and massive alveolar hemorrhage with neutrophil infiltration (Figures 1A,B). The glomerular findings were consistent with pauci-immune crescentic glomerulonephritis of MPA. Alveolar hemorrhage was also considered as a sign of MPA, though typical capillaritis could not be identified in the lungs. The thrombus was relatively, fresh and contained abundant neutrophils (Figures 1C,D). In the thrombus, no microbe was detected by special staining techniques, including Gram stain, Giemsa stain, and Periodic acid-Schiff reaction.
generation of MPO-ANCA. Alveolar hemorrhage due to capillaritis in the lungs is a frequent complication and is sometimes fatal. It is reported that AAV patients have an increased risk of developing DVT, especially during the active stage of the disease (Stassen et al., 2008). Vasculitis possibly triggers thrombosis through the action of inflammatory cytokines and other substances related to the injury of vascular endothelial cells. However, the formation of thrombus does not always occur in the affected vessels. Thus, it remains elusive why AAV patients are prone to thrombosis.

A recent study has demonstrated the presence of neutrophil extracellular traps (NETs), a newly recognized mode of neutrophil cell-death, in glomerular crescents of MPA patients (Kessenbrock et al., 2009). Kessenbrock et al. suggested that MPO-ANCA could bind with activated neutrophils and accelerate NETs formation. Intrinsically, NETs play roles in the innate immune response to microbes, in which the meshwork is composed of DNA fibers that comprise histones and antimicrobial proteins including MPO (Brinkmann et al., 2004). Under physiological condition, NETs are induced following phagocytosis in order to trap and kill surviving microbes, and are adequately digested subsequently. However, aberrant formation and disordered regulation of NETs could be implicated in the production of MPO-ANCA and subsequent development of MPA (Nakazawa et al., 2012; Ray, 2012). In addition, the extracellular DNA in NETs could accelerate MPO-ANCA production via activation of plasmacytoid dendritic cells and B cells in a toll-like receptor 9-dependent manner (Hurtado et al., 2008).

On the other hand, NETs are critically associated with thrombosis because histones within NETs can bind platelets and blood coagulants (Xu et al., 2009; Fuchs et al., 2010). NETs induce the formation of a firm thrombus with red blood cells and fibrin. Although the synergy of antimicrobial and pro-thrombotic functions of NETs is considered to be valuable in the inclusion of microbes in the NETs, excessive NETs formation conversely causes thrombosis. Thus, we focused on NETs in order to understand the association of thrombosis with MPA.

RESULTS AND DISCUSSION
In the present case, the immediate initiation of immunosuppressive therapy was precluded because the possibility of bacterial pneumonia could not be totally ruled out. Unfortunately, the inevitable delay in the initiation of treatment could be attributed to the patient demise. Therefore, development of alternative therapeutic strategies other than immunosuppressive therapy is desirable for treatment of patients with MPA.

Using the autopsy materials, we investigated the presence of NETs in the glomeruli and thrombus. As previously shown (Kessenbrock et al., 2009), NETs were identified in the glomerular crescents (Figures 1E–G). Interestingly, NETs were also identified in the thrombus (Figures 1H–J). Citrullination of histones is essential for the induction of NETs (Li et al., 2010). It is considered that histone-citrullination correlates with chromatin decondensation during NETs formation. Thus, we next investigated the

![FIGURE 1 | Autopsy findings. (A) Crescentic necrotizing glomerulonephritis. (B) Alveolar hemorrhage with neutrophil infiltration. (C, D) DVT: neutrophils were abundant in the thrombus. (E–G) NETs in the glomerulus. Blue: DNA stained by DAPI. Red: MPO. NETs were present in the crescent. (H–J) NETs in the thrombus. The detection of NETs was performed similar to the renal specimens. Original magnification: \( \times 40 \) (C), \( \times 200 \) (B), \( \times 400 \) (A, D, E–J).

![FIGURE 2 | Comparison of NETs in thrombi derived from patients with diverse diseases. In order to detect citrullinated histones in thrombi from patients with MPA (A) and other diseases [B: bacterial sepsis, C: post-operative pulmonary embolism (PE)], immunohistochemistry was performed using anti-citrullinated H3 antibody. Original magnification: \( \times 200 \) (A–C). (D) Comparison on the amount of NETs among thrombi derived from patients with MPA (present case), bacterial sepsis, and post-operative PE. *\( p < 0.05 \), **\( p < 0.01 \).]
degree of histone-citrullination in the thrombus. Results showed that extensive histone-citrullination was observed in the thrombus of the MPA patient (Figure 2A). When compared to other thrombi not associated with MPA, namely, the thrombi from a patient who died of bacterial sepsis (Figure 2B) and from one who died of post-operative pulmonary embolism (Figure 2C), the area of histone-citrullination was larger in the MPA patient. In order to quantify the degree, five photographs under high power view (×400) were taken at random. The area of citrullinated H3 was quantified by Image J software and then standardized view.

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