



Title	Super-resolution imaging detects BP180 autoantigen in immunoglobulin M pemphigoid
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1 **Super-resolution imaging detects BP180 autoantigen in IgM pemphigoid**

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5 Running head: IgM pemphigoid

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1 **Abstract**

2 Bullous pemphigoid is generally caused by IgG autoantibodies against hemidesmosomal BP180
3 and/or BP230. Recently, the concept of IgM pemphigoid has been proposed. A 23-year-old
4 Japanese woman presented with a 4-month history of severely itchy papules showing
5 subepidermal separations with mild neutrophil infiltration. Direct immunofluorescence (DIF)
6 revealed IgM deposits at the dermal-epidermal junction, but neither IgG nor IgA deposits. Indirect
7 immunofluorescence on 1 M NaCl-split skin demonstrated deposits on the epidermal side. The
8 optical density (OD) value of a modified IgM ELISA for full-length BP180, but not for BP180-
9 NC16A, was increased. The patient was diagnosed with IgM pemphigoid and was treated with
10 diphenyl sulfone at 50 mg/day without recurrence. To confirm the precise autoantigen, we tried
11 to obtain super-resolution imaging. The deposition pattern of IgM autoantibodies seemed to be
12 oriented parallel to that of BP180. The detailed images detect that DIF deposits apart from BP180-
13 NC16A staining, but are close to type VII collagen-NC1 staining. This result suggests that the
14 IgM autoantibodies in the patient might target the C-terminus of BP180. IgM pemphigoid is still
15 not a widely accepted concept, and the clinical course remains unknown. We will carefully follow
16 up the patient. Super-resolution images may help to detect precise autoantigens in autoimmune
17 blistering diseases.

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1 Introduction

2 The diagnoses of autoimmune blistering diseases, including bullous pemphigoid (BP) and
3 pemphigus, are confirmed based on a combination of characteristic clinical findings, histological
4 features, and immunological findings. Immunological tests are classified as direct immune
5 fluorescence (DIF) tests, which detect tissue-bound autoantibodies, and serological tests, such as
6 indirect immunofluorescence (IIF), enzyme-linked immunosorbent assays (ELISAs), and
7 immunoblotting. We previously investigated the tissue-bound immunoglobulin isotypes in 100
8 cases of BP patients and found that 17% of BP patients demonstrated IgM deposits at the dermal-
9 epidermal junction (DEJ)¹. However, they showed IgG deposits as well as IgM, and there were
10 no patients with only IgM autoantibodies. This is because IgG autoantibodies are mandatory for
11 diagnosing BP.²

12 Recently, the concept of IgM pemphigoid has been proposed³. We present a case showing
13 histological subepidermal blistering associated with IgM deposits at the DEJ.

15 Case report

16 A 23-year-old Japanese woman presented with a 4-month history of severely itchy papules on her
17 upper extremities. Despite treatment with topical corticosteroids and topical antibacterial drugs,
18 no improvement was achieved. Clinical examination revealed papules associated with small,
19 round erosions and pustules distributed on the lateral side of her upper limbs (Figure 1a, and b).
20 Histopathological examination showed subepidermal separation with mild neutrophil infiltration
21 (Figure 1c). There are necrotic epidermal keratinocytes in the blister roof. Although anti-nuclear
22 antibody (ANA) was detected as 1:80, neither anti-dsDNA nor anti-Sm antibodies were found.
23 She had no photosensitivity, arthralgia, or aphtha, and the absence of these suggested systemic
24 lupus erythematosus (SLE). DIF revealed linear IgM and faint C3 deposits at the DEJ (Figure 1d),

1 but neither IgG nor IgA deposits. IIF on 1 M NaCl-split skin (ssIIF) demonstrated IgM deposits
2 on the epidermal side (1:10 dilution, Figure 1e). A chemiluminescent enzyme immunoassay test
3 showed no IgG autoantibodies against BP180-NC16A. For reference, ELISAs against full-length
4 BP180, BP180-NC16A, and type VII collagen (COL7) were performed using HRP-conjugated
5 anti-human IgM antibody as the secondary antibody. The optical density (OD) of full-length
6 BP180, but not BP180-NC16A or COL7, was greater than in healthy subjects (H) and BP patients
7 (serum dilution 1:100, 2nd Ab 1:10,000, Pt OD=0.252, H OD=0.086, BP OD=0.103).
8 Immunoblotting using epidermal and dermal extracts showed no IgM reactivity (data not shown).
9 Based on these results, the patient was diagnosed with IgM pemphigoid. Treatment with oral
10 diphenyl sulfone at 50 mg/day resulted in complete remission, and 6 months have passed without
11 recurrence.

12
13 The epidermal-side IgM deposits as shown by ssIIF and the elevated OD as determined by the
14 modified full-length BP180 ELISA suggested IgM autoantibodies against BP180. However, the
15 result was for reference, because the ELISA is not an established one. To confirm the precise
16 autoantigen, we performed super-resolution imaging by using a Nikon N-SIM⁴ and super-
17 resolution radial fluctuations (SRRF), which processed pictures taken by Keyence fluorescent
18 microscopy. Briefly, a DIF sample was co-stained with the anti-BP180-NC16A domain (primary
19 Ab: TS39-3⁵, secondary Ab: TRITC-conjugated anti-mouse IgG) or the anti-COL7-NC1 domain
20 (primary Ab: vWFA2⁶, secondary Ab: TRITC-conjugated anti-rabbit IgG). In N-SIM images, the
21 deposition pattern of IgM autoantibodies (green) seems to be oriented parallel to that of BP180
22 (red) (Figure 2a). In contrast, COL7 staining (red) shows linear staining at the DEJ and not
23 oriented parallel to IgM deposits (green) (Figure 2b). Three-dimensional images are shown in
24 supplementary files. In addition, SRRF images show BP180-NC16A (red) to be separated from

1 DIF deposits (green) (Figure 2c). In contrast, COL7-NC1 (red) is close to DIF deposits (green)
2 (Figure 2d). Schematics of double staining in DIF and BP180/COL7 are shown in the inserts of
3 the figures. This result also suggested that the IgM autoantibodies of the patient might have
4 targeted the C-terminus of BP180.

5

6 **Discussion**

7 The clinical manifestations in the present case were characterized by predominant papules with
8 no obvious blisters. However, the several small, round erosions might suggest blister formation.
9 A histological examination demonstrated subepidermal blisters associated with neutrophil
10 infiltrates. Based on these findings, we initially considered several differential diagnoses, such as
11 dermatitis herpetiformis (DH), bullous SLE (BSLE), linear IgA bullous dermatosis (LAD), and
12 epidermolysis bullosa acquisita (EBA) (Table 1). Of these, DH and LAD were excluded due to
13 the absence of IgA deposits in DIF². The DIF in DH is characterized by granular IgA deposits
14 within the dermal papillae or at the DEJ⁷. In addition, IgA tissue transglutaminase (tTG) and IgA
15 epidermal transglutaminase (eTG) antibodies are often elevated in DH. This patient showed no
16 elevated tTG or eTG IgA by ELISA (data not shown). BSLE may demonstrate IgM deposits at
17 the DEJ as in our case, in the so-called lupus band test. However, the autoantigen for BSLE is the
18 same as that for EBA, i.e., COL7⁸. Therefore, BSLE and EBA show dermal-side deposits of
19 autoantibodies by ssIIF⁸. The present patient showed epidermal-side deposits by ssIIF, but BSLE
20 and EBA were ruled out. The final diagnosis of IgM pemphigoid was made.

21

22 Several IgM-mediated pemphigoid diseases have been reported, such as IgM pemphigoid, IgM
23 EBA, and IgM mucous membrane pemphigoid^{3,9,10}. However, significance of IgM-mediated
24 pemphigoid diseases remains disputed. Recently, three cases of IgM pemphigoid were reported³,

1 but the clinical features differed in histology and treatment from our case. The clinical
2 manifestations in reported cases differed slightly from those of conventional BP. They showed
3 no obvious tense blisters, but demonstrated erythema and erythematous papules associated with
4 itch. Even histological examination did not reveal subepidermal separation in the previous three
5 cases. The dermal infiltrates with lymphocytes and eosinophils were major findings. In our case,
6 we observed severe edematous changes accompanied by necrotic keratinocytes. These findings
7 differ from those of our case. However, they clearly demonstrate deposits of IgM, but not of IgG
8 or IgA, at the DEJ by DIF. Serum titer levels determined by ssIIF were not so high, but they
9 successfully identified the autoantigens by immunoblotting using recombinant BP180 protein.
10 Immunoblotting revealed specific IgM autoantibodies that reacted against the NC16A domain in
11 1 out of 3 cases and against the ectodomain in 3 out of 3 cases. In our patient, immunoblotting
12 using epidermal extracts did not detect autoantigens. Instead of immunoblotting, we tried an
13 ELISA using anti-human IgM antibody as the secondary antibody. The OD value was higher in
14 the full-length BP180 ELISA than in the healthy control or in conventional BP patients. The
15 COL7 and BP180-NC16A ELISAs found no elevated OD values. This result suggests that our
16 patient had IgM autoantibodies to BP180, especially to the ectodomain but not to the NC16A
17 domain. Interestingly, Boch et al. tried to demonstrate the pathogenicity of IgM autoantibodies
18 and found that patient sera induced the internalization of BP180, which suggests a pathogenic
19 antibody³. In our case, we were unable to obtain enough serum to investigate the pathogenicity.
20
21 To identify the autoantigen, we performed the double staining of DIF and BP180/COL7 and made
22 observations by super-resolution imaging. It is known that high-magnification DIF may be able
23 to distinguish the pattern of BP180 and COL7. BP180 and COL7 are observed in a u-serrated and
24 an n-serrated pattern, respectively¹¹. In our case, it was hard to identify a u- or n-serrated pattern.

1 There are several methods to get super-resolution imaging, such as N-SIM and SRRF^{12,13}. The
2 resolutions of N-SIM and SRRF are approximately 200 nm and 70 nm, respectively. At the
3 basement membrane zone, the length of BP180 is more than 200 nm, and the NC16A domain is
4 only 100 nm from the C-terminus¹⁴. In addition, hemidesmosomes and anchoring fibrils are
5 approximately 100 nm apart¹⁵. This means that BP180 and COL7 could be distinguished using
6 super-resolution imaging. Figure 2 (a, b) and reconstructed 3D images (supplementary file)
7 suggest that the DIF staining pattern of IgM is oriented parallel to that of BP180 compared to
8 COL7. Furthermore, SRRF images (Figure 2c, d) suggest that IgM autoantibodies might target
9 the C-terminus of BP180. These results indicate that super-resolution imaging may help to detect
10 the precise autoantigens in autoimmune blistering diseases.

11

12 In conclusion, the data suggest a case of IgM pemphigoid, a rare autoimmune subepidermal
13 blistering disease. IgM pemphigoid is not still widely accepted, and the clinical course remains
14 unknown. We will pay attention to recurrence, including immunoglobulin class switching, and
15 will follow up the patient.

16

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19 immunoblotting and ELISA.

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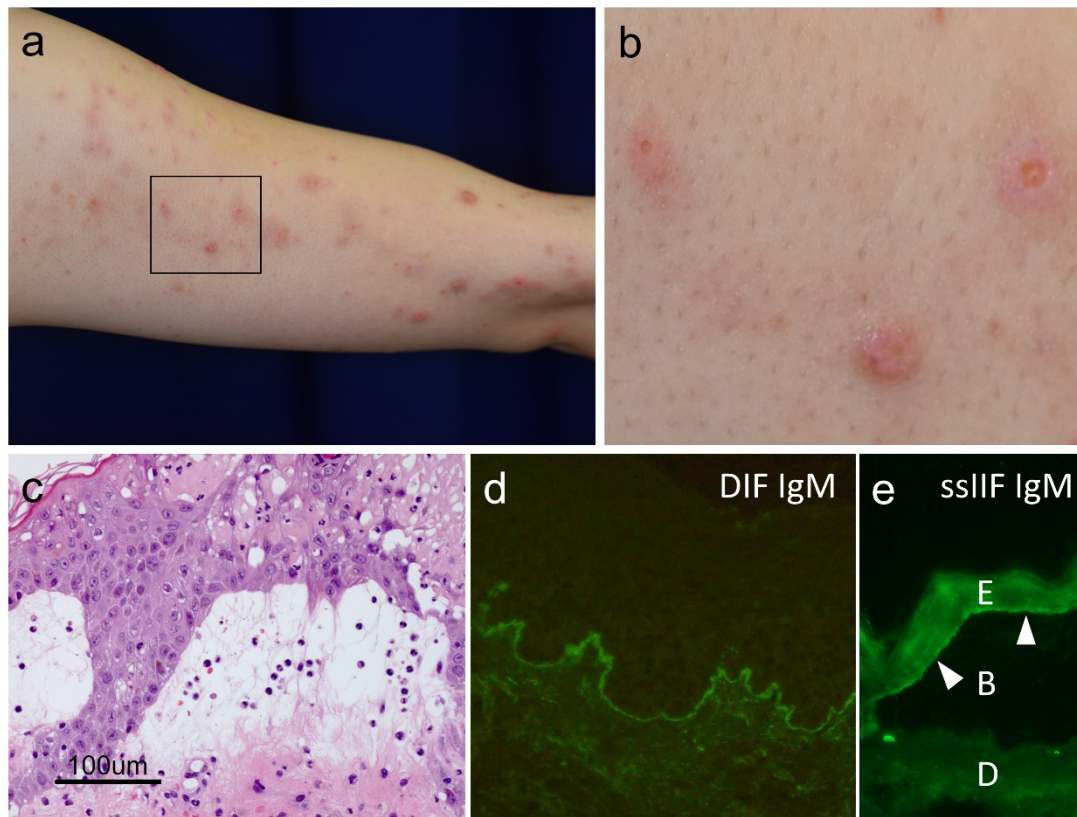
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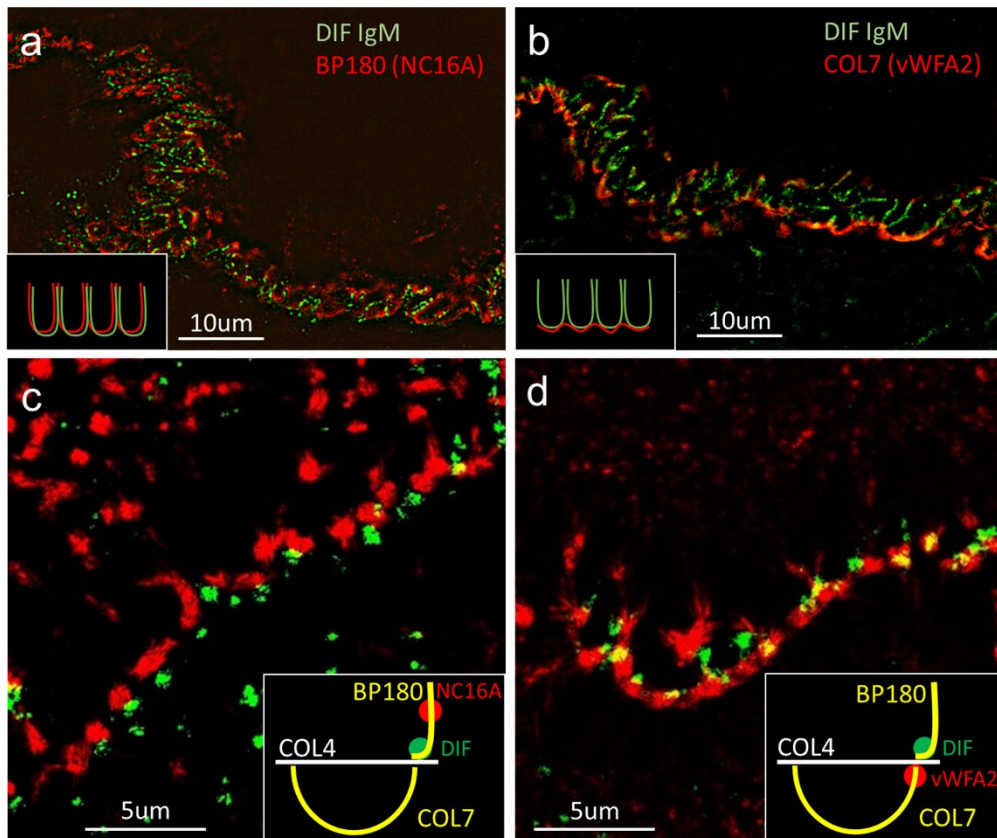
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1 Figure legends



3 Figure 1 Clinical, histological, and immunological findings

- 4 a) Severe itchy eruptions on the lateral side of the upper limbs. b) Small, round erosions at the
 5 center of papules (close view of the square from a). c) Subepidermal separations with necrotic
 6 keratinocytes accompanied by neutrophil and lymphocyte infiltrates. d) IgM deposits at the DEJ
 7 observed by DIF. e) IgM deposits at the epidermal side in 1M NaCl-split skin IIF (ssIIF). E:
 8 epidermis, B: blister, D: dermis.



2 Figure 2 Super-resolution imaging
 3 N-SIM images (a, b) and SRRF images (c, d). Double staining of DIF IgM (green), the BP180-
 4 NC16A domain (TS39-3, red, a and c) and the COL7-NC1 domain (vWFA2, red, b and d). The
 5 inset images are schematics of double staining of DIF and BP180/COL7. COL4: collagen IV
 6

	IgM pemphigoid	DH	LAD	BSLE	EBA
Autoantigen	BP180	tTG, eTG	LAD-1, LABD97	COL7	COL7
Histology	subepidermal blister (may be absent), lymphatic or eosinophil infiltration	subepidermal blister, neutrophil infiltration, microabscess	subepidermal blister, neutrophil infiltration	subepidermal blister, neutrophil infiltration	subepidermal blister, neutrophil infiltration
DIF (isotype, staining pattern)	IgM linear along the DEJ	IgA granular within the dermal papillae or along the DEJ	IgA linear along the DEJ	IgM, IgG along the DEJ	IgG linear along the DEJ
ssIIF	epidermal side	(-)	epidermal side	dermal side	dermal side

1 Table 1: Differential diagnosis of IgM pemphigoid

2 DH: dermatitis herpetiformis, LAD: linear IgA bullous dermatoses, BSLE: bullous systemic

3 lupus erythematosus, EBA: epidermolysis bullosa acquisita, eTG: epidermal transglutaminase,

4 tTG: tissue transglutaminase, COL7: type VII collagen, DEJ: dermal-epidermal junction, ssIIF:

5 indirect immunofluorescence on 1M salt-split skin