Usefulness of a Red Chromagen in the Diagnosis of Melanocytic Lesions of the Conjunctiva

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IMPORTANCE Immunohistochemical analyses may assist in the diagnosis of precancerous and cancerous conjunctival lesions.

OBJECTIVE To use Vector Red (VR) to identify an immunologic marker that is sensitive for all melanocytes and another that is sensitive and specific for activated and/or atypical conjunctival melanocytic lesions (MLs).

DESIGN, SETTING, AND PARTICIPANTS Eight specimens each of control lesions (normal conjunctiva and normal uvea as well as choroidal melanoma) and 8 from the diagnostic categories (conjunctival nevus, primary acquired melanosis with mild or no atypia, primary acquired melanosis with moderate to severe atypia, and conjunctival melanoma) that provided sufficient quantity and quality of tissue were available for processing. The specimens were obtained from the Ophthalmic Pathology Laboratory, The Ottawa Hospital, from 2005 to 2013. The specimens were immunolabeled with human melanoma black 45 (HMB45), melanoma antigen recognized by T cells 1 (Melan-A), S100, and Ki67 using VR and a double pannemelanoma cocktail (dPANMEL) using 3,3′-diaminobenzidine (DAB) and VR. The HMB45-immunolabeled specimens were additionally developed with DAB, with and without overnight bleaching with hydrogen peroxide, 4%. Data were collected by 2 pathologists who were masked to sample grouping.

MAIN OUTCOMES AND MEASURES Differentiation between benign and malignant MLs based on immunomarker profile.

RESULTS Immunoreactivity was best visualized in specimens with VR. Melan-A labeled all melanocytes (100% sensitivity; panmelanocyte marker) without discriminating between benign and malignant lesions (0% specificity). Atypical melanocytes were most specifically labeled with HMB45 (96% specificity, 97% sensitivity; atypia marker). In primary acquired melanosis specimens, we found that the percentage of HMB45 (P < .001), S100 (P < .001), and Ki67 (P ≤ .02) positivity increased significantly with worsening atypia.

CONCLUSIONS AND RELEVANCE We recommend VR, which rarely requires specimen bleaching, as the standard substrate for immunohistochemical analysis of conjunctival MLs. We found Melan-A and HMB45 to best characterize MLs. In conjunctival MLs, the use of VR with Melan-A and HMB45 provides substantial sensitivity for all melanocytes and for atypical melanocytes, respectively, and reduces specimen-processing time for laboratories performing immunohistochemistry on MLs.

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Although most melanocytic lesions (MLs) of the conjunctiva are benign and thus do not progress to melanoma, certain types are prone to becoming malignant and need to be readily identified. Of the various melanocytic conjunctival lesions, the most concerning is conjunctival melanoma. Conjunctival melanoma is associated with an estimated mortality rate of 30% in 10 years. It has been reported that 50% to 75% of conjunctival melanomas develop from primary acquired melanosis (PAM), which is a frequent lesion of the conjunctiva consisting of melanin accumulation in squamous cells or melanocyte hyperplasia. It is present in 36% of the white population and is subcategorized as with or without atypia. PAM with atypia has a 13% to 46% chance of progressing to melanoma, whereas PAM without atypia is a benign lesion. The rate of transformation into melanoma increases with the degree of atypia, leading some groups to propose that PAM with severe atypia be classified as melanoma in situ. Distinction between benign and malignant MLs can be difficult clinically and generally requires histologic examination for diagnosis. In our experience, an accurate diagnosis can be best obtained by identifying a sensitive and specific immunohistologic marker of all melanocytes and another marker that is sensitive and specific for atypia.

In most centers in North America, immunohistochemical analysis of heavily pigmented MLs of the conjunctiva relies almost exclusively on 3,3'-diaminobenzidine (DAB) as a brown substrate. Use of DAB may require bleaching of samples to remove the confounding melanin pigment, but bleaching can affect cellular antigenicity and may be incomplete. We evaluated an alternative substrate, Vector Red (VR; Leica Biosystems, Inc), whose vibrant red color is distinct from that of melanin pigment. Therefore, we also assessed the samples for the presence of VR, which generally renders bleaching unnecessary.

**Methods**

Retrospective and prospective case series were conducted. Methods for securing human tissue were humane and included proper written informed consent in adherence to the Declaration of Helsinki. The participants did not receive financial compensation. The protocol was approved by the University of Ottawa Hospital Research Ethics Board. This case series was conducted using the resources of the Ophthalmic Pathology Laboratory, University of Ottawa Eye Institute, and the Department of Pathology in The Ottawa Hospital.

This study included a minimum of 8 specimens of each diagnostic category, including nevus, PAM with atypia separated into mild and moderate to severe, PAM without atypia, and conjunctival melanoma (Table 1). Only the PAM specimens showing melanocyte hyperplasia were included in the present study. Atypia involving less than one-third of the epithelial thickness is classified as mild, less than two-thirds is considered moderate, and close to full thickness is considered severe. Specimens used in this study were collected from January 1, 2005, to March 31, 2013. We included consecutive paraffin-embedded specimens of a given diagnostic category. The specimens that did not have a sufficient amount or quality of tissue for processing were excluded.

We examined the histochemical and immunohistochemical profiles of these specimens and compared them with those of control specimens consisting of normal conjunctiva and normal uvea as well as choroidal melanoma in enucleated globes.

On each specimen, the following melanocytic immunolabelings were performed using antibodies against the following antigens (Supplement [eTable]): double pann melanoma cocktail (dPANMEL), S100, human melanoma black 45 (HMB45), melanoma antigen recognized by T cells 1 (Melan-A), and Ki67. We hereinafter refer to these antibodies by the antigen that they are raised against. We also stained for hematoxylin-eosin with hydrogen peroxide, 4% (H2O2), bleaching and with potassium permanganate/oxalic acid bleaching. The specimens immunolabeled with HMB45 were processed separately with the DAB substrate and the VR substrate methods, as well as with 4% H2O2 bleach with the DAB substrate. The dPANMEL was developed concurrently with the DAB and Fast Red (Biocare Medical) substrates, hence it is referred to as a “double” pann melanoma cocktail. The remaining markers were developed with only the VR substrate.

Immunoreactivity and analysis were undertaken in a masked manner by 2 separate pathologists (S.B. and B.B.) and scored semiquantitatively using brightfield microscopy (original magnification ×400). Mean values of the 2 scores were used. Staining for dPANMEL, S100, HMB45, and Melan-A were graded on a scale of 0 to 4+, with 0 denoting 0% of staining present in melanocytic cells, 1+ representing less than 25%, 2+ indicating less than 50%, 3+ showing less than 75%, and 4+ representing 100% of the cells.
**Sample Population**

Apart from controls, 35 specimens from 32 individuals were included in our study, consisting of 11 compound nevi, 10 PAM specimens with mild to no atypia, 6 PAM specimens with moderate to severe atypia, and 8 conjunctival melanomas, 6 of which also showed moderate to severe atypia (Table 1). Control tissue specimens were obtained from 27 individuals; 10 of these were uveal melanoma with large adjacent areas of normal choroid, 9 were choroid from phthisical eyes, and the remaining 8 were conjunctiva with benign pterygiums.

**Panmelanocytic Marker**

In a noninferiority comparison, antigenicity for Melan-A was similar to that of the dPANMEL cocktail in all benign and malignant melanocytic cells (Figure 1), showing 100% sensitivity (Table 2). However, neither the dPANMEL cocktail nor Melan-A was able to distinguish between benign and malignant cells (0% specificity). For a given lesion, reactivity against the dPANMEL cocktail was present in more than 75% of melanocytic cells. Similarly, in all but 2 specimens, Melan-A was present in more than 75% of melanocytic cells. In those 2 specimens, Melan-A antigenicity was positive in more than 50% of melanocytic cells.

**Marker for Atypia**

Atypical melanocytes were most specifically labeled with HMB45 (96% specificity, 97% sensitivity) (Table 2). The percentage of HMB45- and Ki67-positive cells increased significantly with worsening atypia (Figure 2). Negative staining for S100 was displayed by 38% of normal conjunctival melanocytes and 45% of PAM specimens. Based on control values, Ki67 of 3% or lower was deemed negative. Because only melanocytic cells were studied in this project, specificity for stains for all melanocytes could not be meaningfully calculated. Antigenicity against all 3 markers was similar to that of the dPANMEL cocktail and developed with VectorRed, which can be easily confused with melanin pigmentation (original magnification ×400). C, Staining of melanoma antigen recognized by T cells 1 (Melan-A) developed with VectorRed is readily distinguishable from the melanin pigmentation in the same cells (original magnification ×400). D, In a noninferiority comparison, antigenicity for Melan-A is similar to that of dPANMEL (antibodies against tyrosinase, S100, and MART-1) in all benign and malignant melanocytic cells. The extent of staining is indicated as 1+ representing less than 25%, 2+ indicating less than 50%, 3+ showing less than 75%, and 4+ representing 100% of the cells. The limit lines indicate SE; limit lines are not shown where SE values were too small.

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Discussion

Historical Perspective

PAM has undergone numerous revisions in its characterization and classification, corresponding to changes in our understanding of its natural history and appropriate management. Historically, PAM had been clinically classified as precancerous or cancerous melanosis. Reese8 found that 17% of these lesions, which he clinically classified as precancerous, developed into melanoma. Patients with these lesions had been advised to undergo radical surgical interventions, including exenteration.

Zimmerman9 argued against excessive surgical interventions based on clinical appearance and instead proposed that these MLs be classified on the basis of their histologic features. Zimmerman and Sobin10 coined the term acquired melanosis and divided the classification into 2 stages: benign acquired melanosis and cancerous acquired melanosis. He further updated the former term to primary acquired melanosis, which was later adopted by the World Health Organization.10,11 Folberg et al2,5 determined that malignant transformation is only associated with PAM showing histologic features of atypia. They concluded that 68% of their specimens with PAM had atypical histologic features, with 46% of these cases progressing to melanoma. More recently, Shields et al,5 after reviewing a larger patient set from an institutional oncology center, concluded that less than 8% of all PAM specimens contained severe atypia and that 13% of PAM with atypia progressed to melanoma.

However, Ackerman, a dermatologist who was an investigator in one study,7 contested classifying these MLs as PAM with atypia because he believed that the term implies benign abnormalities. He advocated referring to these lesions as melanoma in situ, similar to that of other premalignant analogous lesions found in cutaneous tissues. However, many in the ocular pathology and oncology fields were reluctant to classify these lesions as melanoma in situ because at least 36% of white individuals have an ocular lesion that would satisfy the clinical criteria for PAM.4,12 Furthermore, conjunctival melanosis is a relatively rare condition, accounting for less than 3% of all ocular malignant neoplasms.19 Most conjunctival melanomas arise from PAM, suggesting that the nomenclature of PAM requires additional refinement and subcategorization. More recently, Novais et al,14 in their review of more than 10,000 ocular specimens, found that 39% of 85 melanocytic conjunctival specimens were PAM, with 21% showing atypia.

Sugiera et al20 further echoed the proposal of Ackerman et al7 as to classifying these lesions as befitting of their pathologic potential for malignancy. Extrapolating from these clinical and histologic findings, Damato and Coupland3 concluded that a broad clinical/pathologic entity such as PAM cannot convey the appropriate clinical prognosis for a given histologic finding in that it included benign lesions, such as hyperpigmentation, and also potentially malignant lesions with severe atypia. To this effect, Damato and Coupland proposed to limit PAM as a clinical diagnosis and introduced conjunctival melanocytic intraepithelial neoplasia as the counterpart pathological diagnosis, with a grading system based on both the cytologic and architectural characteristics of a given melanocytic proliferation. At present, most ophthalmic pathologists in North America, including our group, follow the histologic classification proposed by Zimmerman of PAM occurring without or with atypia, which may be mild, moderate, or severe.9,10

Immunohistochemical Characterization of Conjunctival Lesions

Conjunctival melanoma arises primarily from PAM in 50% to 75% of the cases.2,3 The remaining cases develop de novo, with a small percentage arising from nevi, usually with active junctional components.12,16 As discussed above, malignant potential thus far has been identified primarily in PAM with histologic atypia. It is therefore paramount to accurately identify these lesions. Ideally, one would prefer to use 2 single antibodies that display high sensitivity and specificity for staining either all or only atypical, potentially malignant melanocytic lesions. Several markers have been shown17,18 to label melanomas, but the relative performance of each marker in the conjunctiva remains unclear. In particular, these markers have yet to be evaluated in terms of their usefulness for distinguishing between degrees of atypia in PAM. To identify immunohistochemical markers for the characterization of these conjunctival melanocytic lesions, we examined a candidate marker list including melanoma cocktail (anti–Melan-A and HMB45), panmelanoma cocktail (anti–Melan-A, HMB45, and antityrosinase), dPANMEL cock-
Figure 2. Markers of Atypia

A, In row 1, a representative case of primary acquired melanosis (PAM) with mild atypia showing extensive absence of immunogenicity for S100 Vector Red (VR) (a), human melanoma black 45 (HMB45) VR (b), and Ki67 VR (c) compared with the panmelanocytic marker, melanoma antigen recognized by T cells 1 (Melan-A) VR (d) (for all, original magnification ×400). Row 2 shows another specimen of PAM with moderate and thus worsening atypia than in row 1, with a larger proportion of the melanocytic cells stained positive for the 4 markers (S100 VR in a; HMB45 VR in b; Ki67 VR in c; and Melan-A VR in d) (for all images, original magnification ×400). In row 3, a case of PAM with severe atypia, antigenicity for S100 VR (a), HMB45 VR (b), Ki67 VR (c), and Melan-A VR (d) is more extensive in greater than 75% of melanocytic cells, with Ki67 being less informative, although it is expressed in approximately 75% of the thickness of the lesion (for all images, original magnification ×400). B, Antigenicity against S100 VR, HMB45 VR, and Ki67 VR increase in PAM with increasing atypia. However, S100 is extensively positive in benign melanocytes as exemplified in specimens of normal conjunctiva and choroid as well as in nevi. The usefulness of Ki67 is confounded by nonspecific staining in active basal epithelium, infiltrating lymphocytes, and nevus cells in the junctional region. The extent of staining is indicated as 1+, representing less than 25%; 2+ indicating less than 50%; 3+ showing less than 75%; and 4+ representing 100% of the cells. The limit lines indicate SE.

*P < .001 for S100 and HMB45, PAM without to mild atypia vs PAM with moderate to severe atypia, and comparing PAM without to mild atypia vs conjunctival melanoma.

*P = .02 for Ki67 (in PAM without to mild atypia vs in PAM with moderate to severe atypia).

*P = .001 for Ki67 (in PAM without to mild atypia vs in conjunctival melanoma).
detection. However, the reliability of the dPANMEL cocktail as a diagnostic tool is in doubt because of nonmelanocytic staining. In particular, its S100 component stains not only for melanocytes but also for other cell types in the conjunctiva, such as benign and malignant cells derived from cells of neural crest origin (including Schwann and glial cells), antigen-presenting cells, macrophages, and metastatic breast carcinoma.26 Also, in the context of the conjunctiva, melanocytic cells display diminished and variable S100 antigenicity.27

Conversely, of particular interest is Melan-A, which labels a cytoplasmic antigen present in melanosomes (Supplement [eTable]).18 In cutaneous melanomas, S100 has been claimed by some28 to be more sensitive than Melan-A for the detection of melanocytic cells. In ocular tissues, the usefulness of Melan-A is controversial.24 Melan-A shows superior reactivity in choroidal melanoma compared with S100.29,30 However, in the conjunctiva, Melan-A immunoreactivity is variable. In a study involving 13 conjunctival melanoma specimens, all tumor samples reacted to Melan-A, but the reactions were much weaker than reactivity to S100. In a subsequent study, Keijser et al24 concluded that Melan-A was a poor marker for conjunctival melanocytes, with 44% of conjunctival melanoma and 30% of PAM specimens showing negative antigenicity. Conversely, other studies involving similar sample sizes concurred with our findings showing that both the intensity and the pervasiveness of Melan-A staining are stronger in conjunctival melanoma, PAM, and nevi than is S100 immunoreactivity.

Marker for Atypia

Although S100 does not appear to be a panmelanocytic stain in conjunctival tissue, antigenicity against S100 increases with worsening atypia. Historically, S100 had been the only marker available to assess the degree of progression of atypia in PAM and conjunctival melanoma.17,21,23,31 However, S100 is not an ideal marker for atypia because a large proportion of nonhyperproliferative and histopathologically normal conjunctival melanocytes, along with benign nevus cells, stain positive for S100.

Since the early 1990s, HMB45 had been assessed for its ability to identify malignant melanocytes.21,31 It labels a cytoplasmic protein that is present in fetal melanocytes but is absent in normal adult melanocytes, and the reappearance of this antigen signals cellular dysregulation (Supplement [eTable]).31 Those studies found the usefulness of HMB45 as a marker of atypia to be questionable. However, upon reevaluation in the 2000s, the immunoreactivity of HMB45 was observed by several groups21,18,23 to correlate strongly with a worsening degree of atypia in the conjunctival MLs. Of these 3 studies, only the investigation conducted by Sharara et al17 assessed PAM in terms of with and without atypia in sufficient numbers for statistical analysis.

Another marker of cellular proliferation, Ki67, identifies an nuclear antigen that is present in non-gap 0 stage cells.22 In previous studies22-33 in uveal melanomas, reactivity against Ki67 correlated strongly with proliferative activity following treatment with radiotherapy, which is an important prognostic indicator. Thus far, only 2 studies have been conducted to assess the value of Ki67 for identifying atypia. Chowers et al22 initially evaluated Ki67 in PAM and found an approximately 3-fold increase in Ki67 reactivity with increasing atypia consistent with the outcomes of the present study. Jakobiec et al18 similarly found increased Ki67 reactivity in conjunctival melanoma rather than in the overlying PAM within the same specimens. However, the usefulness...

**Figure 3. Vector Red (VR) Substrate and Bleaching**

A case of primary acquired melanosis with moderate to severe atypia showing extensive melanin pigmentation. Hematoxylin-eosin (A) requiring bleaching with either permanganate (B) or hydrogen peroxide. 4% (H2O2) (C). Bleaching with 4% H2O2 minimally affects antigenicity with human melanoma black 45 (HMB45) 3,3′-diaminobenzidine (DAB) (D) and HMB45 DAB with 4% H2O2 (E). Bleaching is not required when developed with VR (HMB45 VR) (F). For all images, original magnification ×400.
of Ki67 is confounded because it is not melanocyte specific in that it is present in any non–gap 0 stage cells and shows nonspecific staining in active basal epithelium, infiltrating lymphocytes and nevus cells, especially in the junctional region.

**Bleaching and Usefulness of VR Substrate**

More than 60% of MLs are pigmented; many of these require extensive bleaching for histologic and immunologic characterization. In PAM, where the degree of atypia has been shown to be predictive of its malignant potential, the cellular findings alone may not be sufficiently prognostic. In such cases, immunophenotypes can provide further diagnostic support. However, regardless of the specificity and sensitivity of a given antibody, the interpretation of our immunohistochemical results may often be confounded by the use of DAB, a common substrate for developing immunologic stains. Therefore, in many pathology laboratories. The dark brown color of this substrate is very similar to that of melanin pigment granules, making it difficult to distinguish between the two. Therefore, pigmented specimens often require extensive bleaching to examine their histopathological features. The potassium permanganate/oxalic acid method is effective in bleaching melanin, thus reducing processing time while facilitating interpretation. If the histologic findings are indeterminate, we then recommend an immunologic panel comprising Melan-A, HMB45, and Ki67 and developing with VR.

**Conclusions**

In conjunctival tissue, Melan-A has superior sensitivity and specificity for both benign and malignant melanocytic lesions compared with S100, HMB45, and Ki67. Conversely, HMB45 has shown the most sensitivity and specificity for identifying atypical melanocytic lesions. Furthermore, with the use of the VR substrate, we have negated the need for chemical depigmentation, thus reducing processing time while facilitating interpretation. For each specimen from a clinically worrisome pigmented conjunctival lesion, we recommend histochemical characterization first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado) followed by immunostaining first (hematoxylin-eosin, plus hematoxylin-eosin aficionado).


