JEADV ISSN 1468-3083

ORIGINAL ARTICLE

Algorithmic reproduction of asymmetry and border cut-off parameters according to the ABCD rule for dermoscopy

G Pellacani,*† C Grana,‡ S Seidenari†

†Department of Dermatology and ‡Department of Computer Engineering, University of Modena and Reggio Emila, Via del Pozzo 71, 41100 Modena, Italy

Keywords
ABCD rule, computer vision, diagnosis, image analysis, melanoma

*Corresponding author,
tel. +39 59 4222464;
fax +39 59 4224271;
E-mail: pellacani.giovanni@unimo.it

Received: 25 July 2005,
accepted 15 September 2005

DOI: 10.1111/j.1468-3083.2006.01751.x

Abstract

Backgroud Semiquantitative algorithms were applied to dermoscopic images to improve the clinical diagnosis for melanoma.

Objective The aim of the study was to develop a computerized method for automated quantification of the 'A' (asymmetry) and 'B' (border cut-off) parameters, according to the ABCD rule for dermoscopy, thus reproducing human evaluation.

Methods Three hundred and thirty-one melanocytic lesion images, referring to 113 melanomas and 218 melanocytic nevi, acquired by means of a digital videodermatoscope, were considered. Images were evaluated by two experienced observers and by using computer algorithms developed by us. Clinical evaluation of asymmetry was performed by attributing scores to shape asymmetry and asymmetry of pigment distribution and structures, whereas computer evaluation of shape and pigment distribution asymmetries were based on the assessment of differences in area and lightness in the two halves of the image, respectively. Borders were evaluated both by clinicians and by the computer, by attributing a score to each border segment ending abruptly. Differences between nevus and melanoma values were evaluated using the chi-square test, while Cohen's Kappa index for agreement was employed for the evaluation of the concordance between human and computer.

Results Pigment distribution asymmetry appears the most striking parameter for melanoma diagnosis both for human and for automated diagnosis. A good concordance between clinicians and computer evaluation was achieved for all asymmetry parameters, and was excellent for border cut-off evaluation.

Conclusions These algorithms enable a good reproduction of the 'A' and 'B' parameters of the ABCD rule for dermoscopy, and appear useful for diagnostic and learning purposes.

Introduction

Surface microscopy improves the diagnostic accuracy of melanoma,[1–3] particularly when performed by experienced investigators. Numerous dermoscopic criteria have been found to be valuable for discriminating between benign and malignant melanocytic lesions. On the basis of pattern analysis[4] Stolz *et al*. and Nachbar *et al*. established the ABCD rule of dermoscopy.[5,6] Four main criteria were identified: asymmetry (A), abrupt border cut-off (B), colours (C) and differential structures (D), for the calculation of a final score. This method enabled a diagnostic accuracy of 90%.[6] According to this method, asymmetry, defined as the asymmetric distribution of dermoscopic structures, colours and shape with regard to two orthogonal axes, contribute approximately to 30% of the final score, whereas border cut-off represents less than 10% of the final score. Programs for image analysis, enabling the numerical description of the morphology of pigmented skin lesion images, have recently been developed. Some of these have provided a reproducible quantification of lesion features and an aid for clinical diagnosis.[7–15] Shape

asymmetry, texture non-homogeneity and skin lesion gradient are described by numerical data calculated by means of different algorithms in these programs. Although these descriptors were useful for melanoma diagnosis, correlation of computer and clinical evaluation was tested on only 40 cases, and only for the method of border cut-off evaluation proposed by Day.[16] Recently, we have described automatic methods for dermoscopic pattern identification in melanocytic lesion images. This is based on an approach that is similar to human perception, and achieves a very high correlation between human and computer evaluation.[17–22] A comparison between computer evaluation results of asymmetry and border in dermoscopic images and clinical evaluation of the same parameters is presented in this study, with the aim of developing an automated system mimicking human evaluation.

Materials and methods

Image data base

Three hundred and thirty-one images of pigmented skin lesions, referring to 113 melanomas and 218 melanocytic nevi, were studied. The study population corresponded to consecutive lesions that presented equivocal aspects at clinical or dermoscopic inspection and were excised in order to rule out a melanoma. Lesions of the face, scalp, palm and soles, and nodular lesions were not included in the study.

Images were acquired by means of a digital videomicroscope (VMS-110 A, Scalar Mitsubishi, Tama-shi, Tokyo, Japan) with a 20-fold magnification, allowing the whole lesion to be included in the monitor area. The instrument has been described elsewhere.[10] The images were digitized by means of a Matrox Orion frameboard and stored by an image acquisition program (VideoCap 8.09, DS-Medica, Milan, Italy), which runs under Microsoft Windows. The camera system is calibrated monthly to a set of colour patches with known colour properties (Gretag Machbet® Color Checker Chart, New Windsor, NY, USA). The colour profile obtained was adjusted on the white test patch between each patient examination, and according to the method proposed by Haeghen *et al.*[23] Some modifications were made to better adapt it to dermoscopic images.[24] The digitized images offer a spatial resolution of 768×576 pixels and a resolution of 16 million colours.

Dermatologists' evaluation

The images were evaluated by two clinicians that use the videomicroscopic technique on a regular basis. Each image was projected on the monitor in a random order. A grid dividing the lesion in to eight sectors along the main axes and along two axes 45° to the left and right of the major axis was superimposed over the image for border cut-off evaluation. Shape asymmetry, pigment distribution or structure asymmetry and number of sectors with abrupt cut-off were described by filling in an appropriate form. Blum *et al.*[25] analysed the outer shape if there was asymmetry along the major and/or the minor axes. One point was given for shape asymmetry on one axis, and two points for shape asymmetry on two axes. Similarly, Blum *et al.*[25] and Menzies *et al.*[26] evaluated asymmetry of pigment distribution and structures inside the lesion along the two main axes, giving a score of one point for pigment asymmetry on one axis and two points for pigment asymmetry on two axes. Stolz *et al.*[5] and Nachbar *et al.*[6] calculated overall asymmetry by considering shape and/or pigment distribution asymmetry along the two main axes, and, again, a score of one point was recorded for asymmetry on one axis and two points for asymmetry on two axes.

The border was evaluated separately for each sector and scored one if showing a sharp cut-off between lesion and skin and 0 if gradually fading into the skin. An overall 'B' score, ranging between 0 and 8, was obtained for each lesion by the addition of the single sector scores.[5,6]

Image analysis program and computer evaluation

The image analysis program was created using MS visual C++ 6.0, both for asymmetry and for border cut-off evaluation. The first step consisted of detection of the lesion border[27] and extraction of reference geometrical measures, such as centroid and main inertia axes, according to standard algorithms. A training set of 30 images of pigmented skin lesions was employed for the identification of thresholds, on the basis of the best discriminating accuracy, and was not further considered in the study.

Shape symmetry was calculated as the proportion of coincidental points between the two halves of the image obtained along the major and minor axes. Ninety per cent of coincidental pixels was considered the threshold for shape asymmetry and a score was automatically attributed to each axis: 0 if equal to or greater than 90%, and 1 if lower.

Pigment distribution asymmetry evaluation was based on the comparison of the difference in lightness between the two halves of the lesion along the two main axes (fig. 1). The lesion was first converted into a luminance image. Subsequently, the mean luminance was obtained for each half lesion along the two main axes and the difference was calculated along the major and minor axes. Differences in shades of light equal to or greater than 6 out of 256 luminance levels (grey scale) was considered the threshold for pigment asymmetry and a score of one point was automatically attributed to each axis.

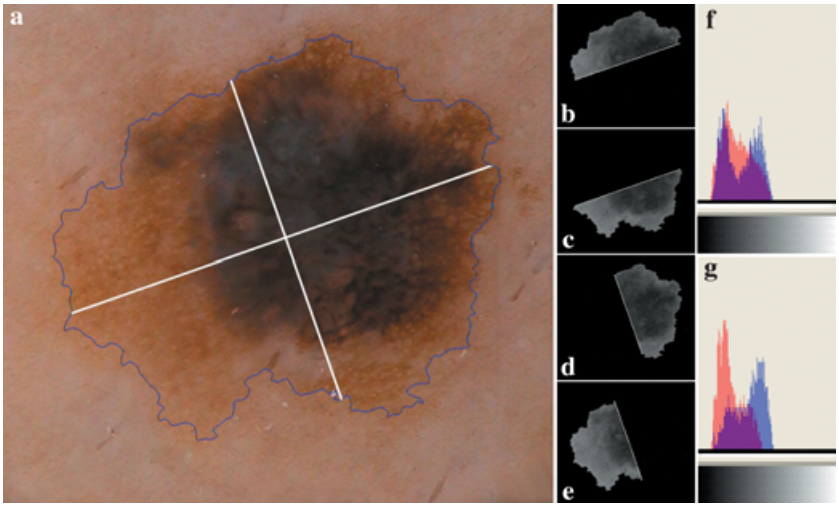

fig. 1 Image analysis of the pigment distribution asymmetry in a melanoma: (a) ×20 magnified image with highlighted border contour and the major and minor axes. (b), (c), (d) and (e): greyscale transformation of the halves of the lesion along the major and minor axes, respectively, and, (f) and (g), the corresponding grey-level histograms (in red the histogram of the half (b) and (d); in blue the histogram of the half (c) and (e) and in purple, the overlapping points). In this case, the difference of the mean lightness between the halves gave a result < 6 for the major axis (f), corresponding to a score of 0, and > 6 for the minor axis (g), corresponding to a score of 1, resulting in a total pigment distribution asymmetry score of 1.

For the evaluation of the number of border segments with a sharp margin, the lesion was again divided into eight sectors along the main axis and along directions 45° to the left and right of the axis. The border gradient was calculated by obtaining values of the gradient of lightness, measured along a 30-pixel segment. These measurements were carried out in a normal direction, i.e. from the inside to the outside of the lesion.[27] Subsequently, mean slope values in each sector were calculated and a value ≥ 3 corresponded to an abrupt border (score = 1), obtaining a score with values ranging from 0 and 8 for each lesion.

Statistics

For statistical analysis the SPSS statistical package (release 10.0.06, 1999; SPSS Inc., Chicago, IL, USA) was used. As basic statistics, frequency of shape asymmetry, pigment distribution asymmetry, overall asymmetry and number of border cut-offs obtained by computer evaluation and by consensus between the two clinicians were calculated both for melanomas and for benign melanocytic lesions. Statistical analysis of border cut-off evaluations was also performed, and evaluations were divided into three subgroups, 0–2, 3–5 or 6–8 abrupt cut-offs. Differences between nevus and melanoma values were evaluated using the chi-square test of independence (Fisher's exact test was applied if any expected cell value in the 2×2 table was less than 5). A *P*-value less than 0.05 was considered significant. To assess the validity of the criteria for the diagnosis of melanoma, odds ratio (OR) and 95% confidence interval (CI 95%) were calculated. OR was considered statistically significant if CI 95% did not include the unit. To evaluate the concordance between humans and computer, percentage of coincidental evaluations and Cohen's Kappa index for agreement were calculated for each descriptor. Kappa values range between 1 and 0. A Kappa value of 1 indicates full agreement beyond chance, values greater than 0.7 are generally considered excellent, values less than 0.4 poor and values between 0.4 and 0.7 fair to good. A *P*-value of < 0.05 was considered significant.

Results

Shape, pigment distribution and overall asymmetry along two axes were more frequently observed both by clinicians and the computer in melanomas than in nevi, with odds ratio values ranging from 6.199 to 42.381 (Table 1). No significant differences were observed by both clinicians and the computer for the number of abrupt border cut-offs between malignant and benign lesions.

There was a good concordance between humans and computer for the evaluation of shape asymmetry (coincidental evaluation = 89.4%; K index = 0.686), pigment distribution asymmetry (coincidental evaluation = 74.9%; K index = 0.446) and overall asymmetry A (coincidental evaluation = 68.3%; K index = 0.514). Furthermore, an excellent concordance was achieved for the determination of abrupt cut-offs, with an 89.5% coincidental evaluation (K index = 0.778). A good human–computer concordance was also obtained for evaluation of the overall number of segments with an abrupt border cut-off per lesion, corresponding to the 'B' parameter of the ABCD rule of dermoscopy (coincidental evaluation = 62.5%; K index = 0.541) (Table 2). Dividing into three subgroups, corresponding to lesions with 0–2, 3–5 or 6–8 abrupt cut-offs, an excellent concordance was obtained (coincidental evaluations = 87.9%; K index = 0.801).

Table 1 Frequency of shape-, pigment distribution- and overall asymmetry scores and border scores according to human and computer evaluation of 331 melanocytic lesion images

	Human			Computer		
	Nevi	**Melanomas**	**OR**	**Nevi**	**Melanomas**	**OR**
sA score						
0	182 (83.5%)	51 (45.1%)	0.163	168 (77.1%)	55 (48.7%)	0.282
1	27 (12.4%)	32 (28.3%)	2.795	39 (17.9%)	30 (26.5%)	–
2	9 (4.1%)	30 (26.5%)	8.394	11 (5%)	28 (24.8%)	6.199
pA score	**Nevi**	**Melanomas**	**OR**	**Nevi**	**Melanomas**	**OR**
0	153 (70.2%)	13 (11.5%)	0.055	147 (67.4%)	27 (23.9%)	0.152
1	56 (25.7%)	27 (23.9%)	–	59 (27.1%)	48 (42.5%)	1.990
2	9 (4.1%)	73 (64.6%)	42.381	12 (5.5%)	38 (33.6%)	8.698
A score	**Nevi**	**Melanomas**	**OR**	**Nevi**	**Melanomas**	**OR**
0	134 (61.5%)	10 (8.8%)	0.061	120 (55%)	20 (17.7%)	0.176
1	67 (30.7%)	28 (24.8%)	–	72 (33.0%)	32 (28.3%)	–
2	17 (7.8%)	75 (66.4%)	23.336	26 (11.9%)	61 (54.0%)	8.663
Total	218	113		218	113	
B score	**Nevi**	**Melanomas**	**OR**	**Nevi**	**Melanomas**	**OR**
0–2	122 (56%)	50 (44.2%)	–	118 (54.1%)	58 (51.3%)	–
3–5	39 (17.9%)	29 (25.7%)	–	41 (18.8%)	23 (20.4%)	–
6–8	57 (26.1%)	34 (30.1%)	–	59 (27.1%)	32 (28.3%)	–
Total	218	113		218	113	

sA, shape asymmetry; pA, pigment distribution asymmetry; A, overall asymmetry; B, abrupt border cut-offs; OR, odds ratio.

Discussion

Epiluminescence microscopy techniques improve diagnostic accuracy for melanoma when employed by experienced dermatologists.[28] In fact, pattern analysis of dermoscopic images requires specific training, long experience and frequent use of the method. Moreover, in spite of a reference terminology[29,30] recognition of characteristic patterns is influenced by unavoidable subjectivity and variability in the interpretation of dermoscopic images.[31] The ABCD rule for dermoscopy, first proposed by Stolz and Nachbar, significantly enhances diagnosis of melanocytic lesions in less experienced users[32] both by the simplicity in memorizing the features and by the efficacy in diagnosing melanomas. However, a poor interobserver reproducibility was observed during the consensus net meeting.[29] Thus, an automated system reproducing the clinical evaluation

Table 2 Comparison between human and computer evaluation of the number of abrupt border cut-offs (B) on 331 melanocytic lesion images

		Computer								
	B scores	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total**
Human	**0**	**94**	3	2	3		1				105
	1	22	**12**	5		2		2			43
	2	9	5	**10**	1			3			28
	3	2		1	**12**	3	1				19
	4	2		1	4	**14**	4	2		1	28
	5	1		2		6	**6**	1	1		17
	6				1	2	3	**4**	4	2	16
	7						3	2	**11**	5	21
	8			1		1	1	5	2	**44**	54
	Total	130	20	22	21	28	19	19	18	54	331

could be useful for the training and diagnostic support of novices. A simplified version of the ABCD rule for dermoscopy was recently introduced by Blum *et al*.[25] Owing to the relevance of parameter 'A' in diagnostic judgement, they evaluated separately the asymmetry for outer shape and differential structures inside the lesion. As we considered this distinction of the 'A' criterion useful for both diagnostic and learning purposes, we evaluated the two aspects separately.

Human and computer concordance was good for shape asymmetry. From a mathematical point of view, calculation of the geometrical asymmetry is very simple, and the human concept, based on the comparison of two halves, can easily be reproduced. For melanoma diagnosis, the pigment distribution asymmetry along two axes appeared the most striking parameter for both clinician and the computer (Table 1). The human–computer concordance for pigment distribution asymmetry was lower than that observed for shape symmetry. In fact, our method evaluates only the difference in luminance values. Therefore, human and computer procedures are not directly comparable, as chromatic differences and pattern asymmetry are not taken into account. This methodological difference influences the OR values calculated by the computer and the clinician for pigment distribution asymmetry along two axes (8.698 and 42.381, respectively).

An excellent concordance for border cut-off evaluation was obtained by our method. As shown in Table 2, the computer 'B' score does not diverge greatly from the clinical one in the majority of cases. Only in two cases was a completely discordant evaluation made (human = 8, computer = 0) due to tanning of the surrounding skin. However, in contrast with previous results,[5,6] evaluation of the number of borders with an abrupt cut-off did not seem useful in distinguishing between benign and malignant lesions. This was probably because our cases were selected on the basis of clinical or dermoscopic equivocal aspects and because of the consequent exclusion of clearly benign lesions, usually characterized by shading borders.

Although selected thresholds for score attributions used in this study were applied to melanocytic lesions acquired with the same instrument and technique only, the method employed for evaluation of asymmetry and border cut-offs makes this system adaptable to images generated by different acquisition methods.

Acknowledgements

This study was partially supported by MIUR (Ministero dell'Istruzione dell'Università e della Ricerca), grant number 2004063811.

The authors have no conflict of interest to disclose.

References

1 Mayer J. Systematic review of the diagnostic accuracy of dermatoscopy in detecting malignant melanoma. *Med J Aust* 1997; **167**: 206–210.
2 Bufounta ML, Beauchet A, Aegerter P, Saiag P. Is dermoscopy (epiluminescence microscopy) useful for the diagnosis of melanoma? *Arch Dermatol* 2001; **137**: 1343–1350.
3 Kittler H, Pehamberger H, Wolff K, Binder M. Diagnostic accuracy of dermoscopy. *Lancet Oncol* 2002; **3**: 159–165.
4 Pehamberger H, Steiner A, Wolff K. In vivo epiluminescence microscopy of pigmented skin lesions. I. Pattern analysis of pigmented skin lesions. *J Am Acad Dermatol* 1987; **17**: 571–583.
5 Stolz W, Riemann A, Cognetta AB *et al.* ABCD rule of dermoscopy: a new practical method for early recognition of malignant melanoma. *Eur J Dermatol* 1994; **4**: 521–527.
6 Nachbar F, Stolz W, Merkle T *et al.* The ABCD rule of dermatoscopy. *J Am Acad Dermatol* 1994; **30**: 551–559.
7 Green AC, Martin NG, Pfitzner J, O'Rourke M, Knight N. Computer image analysis in the diagnosis of melanoma. *J Am Acad Dermatol* 1994; **31**: 958–964.
8 Hall PN, Claridge E, Morris Smith JD. Computer screening for early detection of melanoma. Is there a future? *Br J Dermatol* 1995; **132**: 325–338.
9 Gutkowicz-Krusin D, Elbaum M, Szwaykowski P, Kopf AW. Can early malignant melanoma be differentiated from atypical melanocytic nevus by in vivo techniques? Part II. Automatic machine vision classification. *Skin Res Technol* 1997; **3**: 15–22.
10 Seidenari S, Pellacani G, Pepe P. Digital videomicroscopy improves diagnostic accuracy for melanoma. *J Am Acad Dermatol* 1998; **39**: 175–181.
11 Binder M, Kittler H, Seeber A *et al.* Epiluminescence microscopy-based classification of pigmented skin lesions using computerized image analysis and an artificial neural network. *Melanoma Res* 1998; **8**: 261–266.
12 Seidenari S, Pellacani G, Giannetti A. Digital videomicroscopy and image analysis with automatic classification for detection of thin melanomas. *Melanoma Res* 1999; **9**: 163–171.
13 Andreassi L, Perotti R, Rubegni P *et al.* Digital dermoscopy analysis for the differentiation of atypical nevi and early melanoma. *Arch Dermatol* 1999; **135**: 1459–1465.
14 Pellacani G, Martini M, Seidenari S. Digital videomicroscopy with image analysis and automatic classification as an aid for diagnosis of Spitz nevus. *Skin Res Technol* 1999; **5**: 266–272.
15 Ganster H, Pinz A, Rohrer R *et al.* Automated melanoma recognition. *IEEE Trans Med Imaging* 2001; **20**: 233–239.
16 Day GR. How blurry is that border? An investigation into algorithmic reproduction of skin lesion border cut-off. *Computerized Med Imaging Graphics* 2000; **24**: 69–72.
17 Seidenari S, Pellacani G, Grana C. Computer description of colours in dermoscopic melanocytic lesion images

reproducing clinical assessment. *Br J Dermatol* 2003; **149**: 523–259.
18 Pellacani G, Grana C, Cucchiara R, Seidenari S. Automated extraction and description of dark areas in surface microscopy melanocytic lesion images. *Dermatology* 2004; **208**: 21–26.
19 Pellacani G, Grana C, Seidenari S. Automated description of colours on surface microscopic images of melanocytic lesions. *Melanoma Res* 2004; **14**: 125–130.
20 Seidenari S, Pellacani G, Grana C. Colors in atypical nevi: a computer description reproducing clinical assessment. *Skin Res Technol* 2005; **11**: 36–41.
21 Seidenari S, Pellacani G, Grana C. Pigment distribution in melanocytic lesion images: a digital parameter to be employed for computer-aided diagnosis. *Skin Res Technol* 2005; **11**: 236–241.
22 Haeghen YV, Naeyaert JMAD, Lemahieu I. An imaging system with calibrated color image acquisition for use in dermatology. *IEEE Trans Med Imaging* 2000; **19**: 722–730.
23 Grana C, Pellacani G, Seidenari S. Practical color calibration for dermoscopy, applied to a digital epiluminescence microscope. *Skin Res Technol* 2005; **11**: 242–247.
24 Blum A, Rassner G, Garbe C. Modified ABC-point list of dermoscopy: a simplified and highly accurate dermoscopic algorithm for the diagnosis of cutaneous melanocytic lesions. *J Am Acad Dermatol* 2003; **48**: 672–678.
25 Menzies SW, Ingvar C, McCarthy WH. A sensitivity and specificity analysis of the surface microscopy features of invasive melanoma. *Melanoma Res* 1996; **6**: 55–62.
26 Grana C. Pellacani G, Cucchiara R, Seidenari S. A new algorithm for border description of polarized light surface microscopic images of pigmented skin lesions. *IEEE Trans Med Imaging* 2003; **22**: 959–964.
27 Binder M, Schwarz M, Winkler A *et al.* A useful tool for the diagnosis of pigmented skin lesions for formally trained dermatologists. *Arch Dermatol* 1995; **131**: 286–291.
28 Argenziano G, Soyer HP, Chimenti S *et al.* Dermoscopy of pigmented skin lesions: results of a consensus meeting via the Internet. *J Am Acad Dermatol* 2003; **48**: 679–693.
29 Bahmer FA, Fritsch P, Kreusch J *et al.* Terminology in surface microscopy. *J Am Acad Dermatol* 1990; **23**: 1159–1162.
30 Stanganelli I, Burroni M, Rafanelli S, Bucchi L. Intraobserver agreement in interpretation of digital epiluminescence microscopy. *J Am Acad Dermatol* 1995; **33**: 584–589.
31 Binder M, Kittler H, Steiner A *et al.* Reevaluation of the ABCD rule for epiluminescence microscopy. *J Am Acad Dermatol* 1999; **40**: 171–176.