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ORIGINAL PAPER

High-resolution color-Doppler ultrasound for the study of skin growths

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Abstract High-resolution (17 MHz) color-Doppler ultrasound (US) is used in the evaluation of normal and pathological skin. To analyze retrospectively the sonographic pattern of healthy skin and of some skin lesions using Doppler US and to compare the results with dermoscopy examination and histology to identify specific patterns of ultrasound for differentiating benign from malignant lesions. To select among them the Melanomas to describe their US pattern, the presence and morphology of vascular signal and to compare their thickness at US with the Breslow index. After signing informed consent in accordance with the ethical standards laid down in the Declaration of Helsinki in 1964 and its subsequent amendments, 104 patients with skin lesions were retrospectively studied. Patients were evaluated with clinical dermatological examination and Doppler US, and underwent surgical excision with subsequent histological analysis. Statistical analysis: the difference between variables was analyzed with statistical Chi square test or Fisher's when appropriate. The strength of the relationship between variables was analyzed with Pearson's *r* coefficient. The sensitivity and specificity of US tests were also calculated. Sixty-five malignant lesions and 39 benign lesions were identified at Doppler US. In the 34 melanomas, typical US and vascular patterns were identified depending on the thickness of the lesion and a strong correlation between the latter and Breslow index was confirmed. Doppler US is a valuable diagnostic tool for the study of skin and for pre-excision characterization of skin lesions.

Keywords Skin ultrasound · Color Doppler · High-resolution ultrasound · Skin lesions · Melanoma · Breslow index

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Introduction

Early identification of the nature of an expansive lesion is the goal of most of the current research protocols. The superficial neoplasms often present a doubtful diagnostic orientation, although the integration of anamnesis with clinical dermatological examination and modern dermoscopy examination manages to provide a clear diagnostic identification most of the times. The integration with a simple ultrasound test may be a valuable aid in doubtful cases of malignancy. In recent years, diagnostic imaging procedures have undergone a profound transformation in parallel with the rapid evolution of technology and science. The development of ultrasound in the dermatological field is related to the availability of high-frequency transducers (>10 MHz), to the introduction of techniques that reduce the artifacts and optimize the power of resolution and to the possibility of studying the vascularity of expansive lesions of the skin and the formation of new vessels with color-Doppler US [2, 3, 5, 11, 13–15, 19–22, 24, 25, 28–32]. Alexander and Miller in 1979 [1] used for the first time ultrasound to study the skin, creating a one-dimensional scan with rudimentary equipment and with insufficient spatial resolution. The study of ultrasound pathology frequently regards lesions with a thickness <1 mm thus requiring high-frequency emission transducers. In the study of superficial organs, in particular in the field of dermatology, the depth of the region to be investigated is about 1–2 cm. Therefore, the use of high-frequency probes, allowing high-resolution imaging, is of paramount importance; nevertheless, currently used 5- to 17-MHz linear arrays probes also allow the visualization of deep layers up to 3.5 cm (depth), with an axial resolution of 0.090 mm, thus permitting to complete the study of superficial tissues. Using variable frequency probes it is possible to cover a depth of scan extended from 3.5 to 7 cm. High-resolution ultrasonography was also used for the study of common skin diseases such as psoriasis, scleroderma, erythema nodosum, sarcoidosis, lymphedema as well as for the evaluation of local complications due to the application of topical medications, of implantable materials for esthetic use and for the monitoring of burns [5, 15, 21, 23, 25, 31, 32]. The B-Mode technique has already been used in several studies for the characterization of skin growths but in a limited number of patients. Malignant neoplasms in these studies appeared mainly as hypoechoic lesions without the identification of specific sonographic features capable of differentiating the histological type [1, 3–9, 11, 13, 15, 20–22, 24, 25, 28–32]. The color Doppler was also used to study the vascularization of lesions such as melanomas, melanocytic nevi and basaliomas before surgical excision, with melanomas resulting more vascularized in particular in the central portion [3, 11, 13, 15, 19–21, 25, 28–32]. The correlation between the thickness of melanomas measured at US and histological examination (Breslow index) has been widely demonstrated in numerous studies showing to be significant when high-resolution probes have been used [11, 13–15, 19–22, 24, 25, 28–32]. In some studies, color Doppler has proved to be useful in differentiating pigmented lesions [3, 11, 13–15, 19–21, 25, 28–32] and in a study with a 5-year follow-up, the degree of vascularization was significantly related to the risk of metastasis [20].

Aims

The aim of this study was

- To evaluate retrospectively the characteristics of normal skin by ultrasound examinations performed with a high-frequency transducer [5–17 MHz].
- To evaluate retrospectively the morphological aspects of some skin growths at ultrasound B-mode and color–power Doppler using a high-frequency transducer [5–17 MHz]; to correlate the results of ultrasound with dermoscopy examination and histological data to identify specific ultrasound patterns to differentiate benign from malignant lesions.
- To select melanomas among the malignant lesions, to describe their sonographic pattern, the presence and morphology of vascular signal and to compare their thickness at US with the histological Breslow index and check whether or not our data were combined with data already present in the literature.

Materials and methods

Study of normal skin

The study was performed retrospectively on the material and data available in the archive at the Radiology Department of AOUP Federico II (Naples) and has therefore been performed in accordance with the ethical standards laid down in the Declaration of Helsinki in 1964 and its subsequent amendments. Patients were informed and expressed their consent for the use of such material for cumulative and statistical studies.

The normal US pattern of the skin was studied using a Philips ultrasound machine (iU22) with 5- to 17-MHz transducer linear arrays.

For the study of normal skin, 20 healthy volunteers (5♂) with average age of 37.5 years (10–55) underwent ultrasound of the volar aspect of the forearm (Fig. 1).

Study of skin lesions

The study was performed retrospectively on the material and data available in the archive. Patients were informed

Fig. 1 5- to 17-MHz transducer, young skin. Sonographic anatomy of the skin, transverse view. *White arrow head* epidermis, *black arrow head* dermis, *black arrow* muscle fascia, *white arrow* subcutaneous adipose tissue

and expressed their consent for the use of such material for cumulative and statistical studies.

Over a period of time of 3 years (2006–2010), 104 skin neoplasms found in as many patients (46 ♂) with average age of 56.5 underwent US examination. Each patient was subjected to a general clinical examination, a dermatological examination and a dermoscopy examination of the skin lesion and consequently addressed to the Radiology Department to undergo a preoperative skin ultrasound examination. A generous amount of gel was used to form a bearing spacer and avoid compression of the lesions. No stand-off pad was ever used. The focal zone has been adapted in relation to the position of the lesion. The lesions were detected either as a simple thickening of the skin layers or as expansive formations. The transducer was oriented so that the maximum axial diameter of the lesion was parallel to the longitudinal axis of the probe; the maximum axial diameter and the antero-posterior diameter were measured for each lesion. The US structure (homogeneous–heterogeneous), the echogenicity (hyper–iso–hypoechoic), the margins (regular–irregular), the localization in the various skin layers and the maximum thickness of the lesion were evaluated. In addition, the skin growths were studied with color Doppler to test the ability of the method to detect a vascular pattern able to distinguish benign from malignant ones. The color and power Doppler parameters have been set for the study of low-speed blood flow (color Doppler: PRF 500 Hz, wall filter 27 Hz, gain 75 %, persistent media; power Doppler: PRF 350 Hz, wall filter 45 Hz, gain 85 %, low optimization). The presence of vascular signal inside and around the lesion was studied and the measurement of blood flow velocity (cm/s) and resistance index (systolic velocity − diastolic velocity/systolic velocity) was carried out with pulsed Doppler (Doppler frequency 7 MHz, sample volume size 1.5 mm, wall filter 40 Hz).

After surgical excision, the lesions were subjected to histological examination at the Department of Pathology, Faculty of Medicine and Surgery of the University of Naples Federico II. The lesion was removed, fixed in neutral buffered formalin, included in paraffin and then 4-μm-thick sections stained in hematoxylin and eosin

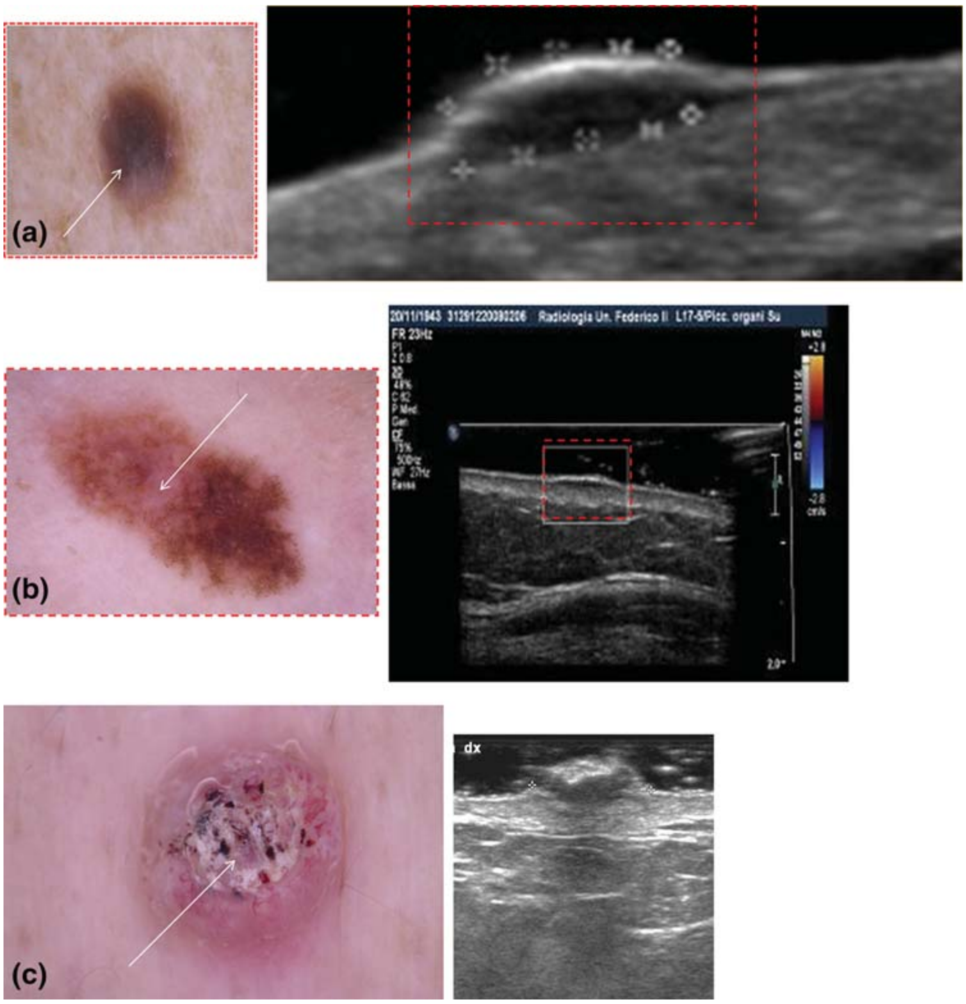

Fig. 2 Benign lesions. **a** Nevus nodular. Right arm, dermoscopic examination: the picture shows a pigmented lesion characterized by a double component: peripheral globular pattern and bluish central pigmentation; ultrasound examination: transverse view, homogeneous hypoechoic lesion, avascular. **b** Surface Nevo. Gluteus region, dermoscopic examination: the picture shows a large area with asymmetric pigmented lesion regression (>50 %) and eccentric hyperpigmentation; ultrasound examination: longitudinal view, slight thickening of the dermal–epidermal junction, avascular. **c** Keratoacanthoma. Torso, dermoscopic examination: the picture shows a lesion characterized by a vascular hairpin pattern and a central keratin plug with bluish areas along the periphery; ultrasound examination: transverse view. Expansive lesion occupying the entire dermis region with inhomogeneous echogenicity, predominantly hypoechoic, with very irregular superficial margins and epidermal thickening (*arrows*)

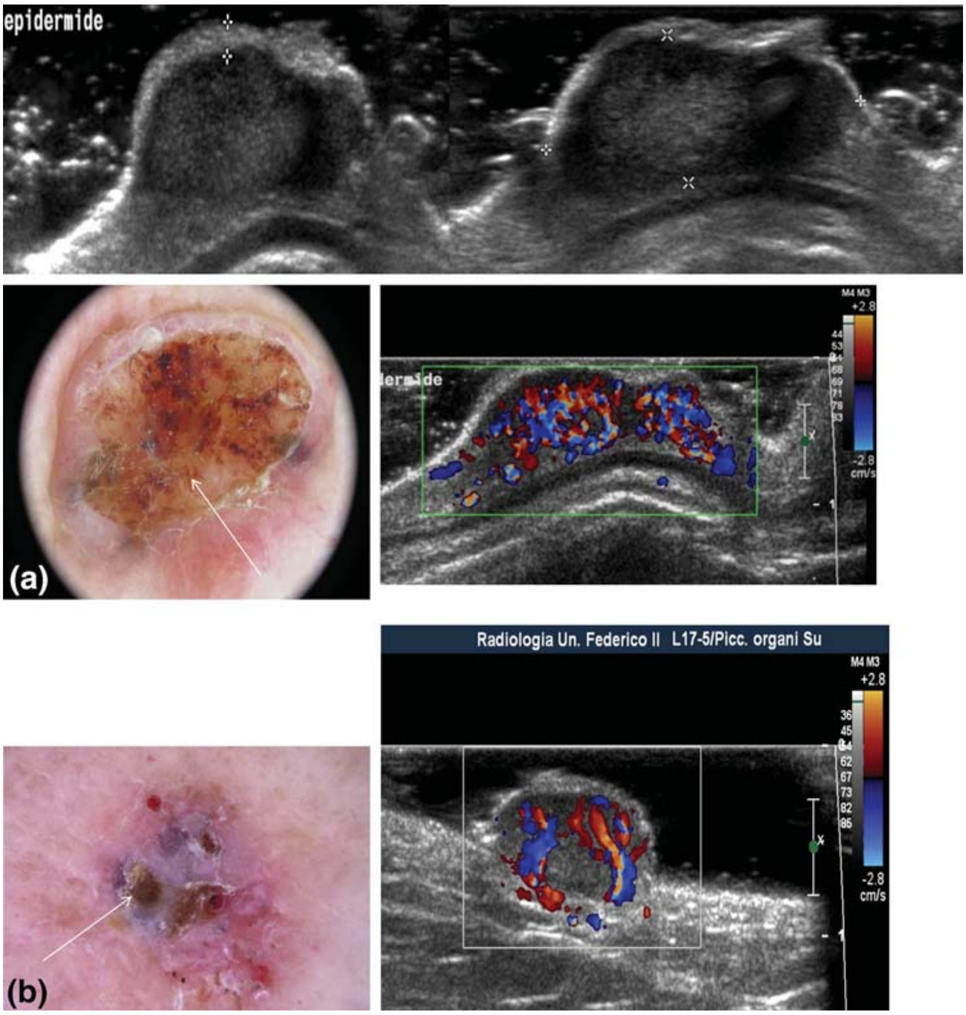

Fig. 3 Malignant lesions. **a** Squamous cell carcinoma. Right ear, dermoscopic examination: the picture shows a lesion characterized by crust and hairpin blood vessels in the periphery. Ultrasound examination: transverse, longitudinal view. Inhomogeneously hypoechoic lesion with irregular margins occupying the entire epidermis and dermis region, hypervascular. **b** Basal cell carcinoma. Right sub-scapular region, dermoscopic examination: the picture shows a lesion characterized by blue–gray ovoid areas and numerous telangiectasias. Ultrasound examination: transverse view. The hypoechoic and inhomogeneous lesion extends to the level of the epidermis and dermis, and shows regular margins, hypervascular signal

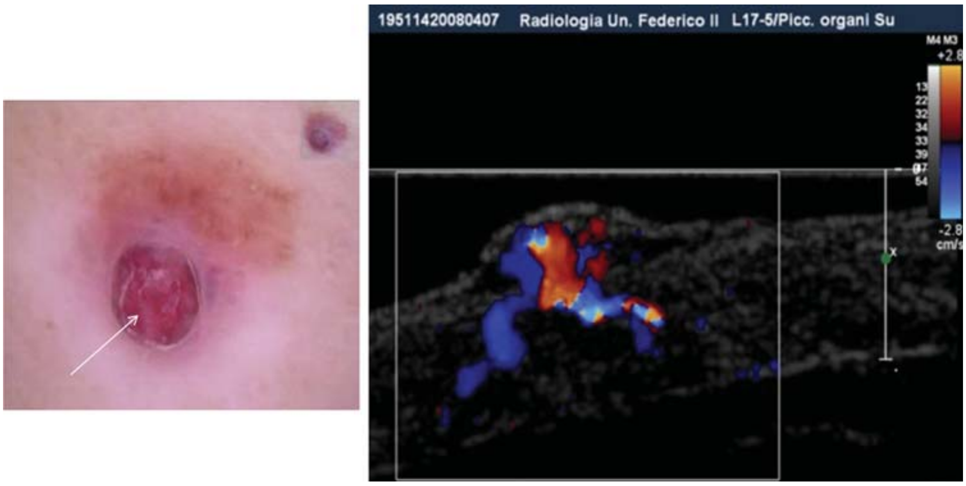

Fig. 4 Malignant lesions. **a** Melanoma. Torso, dermoscopic examination: the picture shows a lesion characterized by an asymmetric atypical vascular pattern, *blue–white* structures of regression and residual pigmentation. Ultrasound examination: transverse view, nodular hypoechoic lesion; solid nodular lesion, prevalently hypoechoic, raising from the dermo-epidermic junction. The lesion shows regular margins and is hypervascular

were set up. In the case of melanomas the histological index of Breslow was determined. And finally, the morphological pattern at US was correlated with the histological one.

Statistical analysis

The difference between the ultrasound parameters was analyzed with the Chi square statistical test. The strength of the relationship between variables was analyzed by Pearson's correlation coefficient *r*. The sensitivity and specificity of the various sonographic patterns were also calculated.

Results

Study of normal skin

The US appearance of healthy skin is a layer of variable thickness depending on the site, the age and the constitutional *habitus* of the patient and is characterized by the succession of bands with different echogenicities [12]. The distinction between the layers of the skin is important because different skin diseases can originate from different layers (Fig. 1).

The ultrasound image of the non-pathological skin is composed of three layers: epidermis, dermis, and subcutaneous tissue or hypodermis. The echostructure of the skin layers depends on its main components. In the case of the epidermis, its echogenicity is influenced by the presence of keratin, the dermis by its content of collagen, and last, the subcutaneous tissue by the amount of fat lobules. On sonography, the epidermis appears as a hyperechoic line in nonglabrous skin (i.e., not from the palmar and plantar regions) and as bilaminar hyperechoic and parallel lines in glabrous skin (palms of the hands and soles of the feet). The dermis appears as a hyperechoic band, usually less bright than the epidermis, and the subcutaneous tissue appears as a hypoechoic fatty layer with hyperecho fibrous septa in between [31, 32]

With high-frequency and multifrequency transducers, including the 17-MHz probe, a smooth distinction between the deep dermis and the superficial dermis begins to be possible, the latter being slightly more hypoechoic, especially in case of photoaged skin [23, 26, 27].

Study of skin growths

Of the 104 neoplasms examined, 39 were histologically benign and 65 malignant. The malignant had thickness between 0.47 and 11 mm, the benign between 0.6 and 15 mm (Table 1a). At the B-mode ultrasound examination (Table 1a) 39/65 malignant neoplasms showed prevalent heterogeneous echogenicity and 26/65 hypoechoic homogeneous echogenicity. In distinguishing neoplasms on the basis of the extension in the various skin layers into lesions with superficial location, if only the epidermal layer was interested, and deep lesions, in the case of involvement of two or more layers, it was observed that most of the growths showed surface localization, in particular 26/39 of benign growths and 42/65 malignant ones. The majority of the lesions presented regular margins, in particular 26/39 of benign and 37/65 of malignant (Fig. 2). The study with color Doppler showed internal vascular signal in 54/65 malignant neoplasms and in 10/39 benign lesions (Tables 1a).

The different vascular pattern showed by malignant and benign lesions (inner and irregular signal in the former case, regular and predominantly perilesional in the second case) has strengthened our hypothesis by which color-Doppler US added to B-mode US allows to better differentiate the nature of the lesion, constantly to be related to clinical information (Figs. 3, 4).

The 34 melanomas were also divided into three subgroups (Tables 2a, b, c = thickness ultrasound <1, >1, <3 and >3 mm); among the latter, 24/34 (Tables 2b, c) had intense vascular signal context.

Statistical analysis

The difference between the ultrasound parameters analyzed with the Chi square statistical test revealed a statistically significant difference only for the vascular signal parameter. The calculation of the sensitivity and specificity of the various sonographic patterns indicated that only the evaluation of the vascular signal with color and power Doppler showed good sensitivity and specificity in the identification of malignant lesions [sensitivity = 0.83 (83 %) confidence interval (95 % from 73.96 to 92.19 %) and a specificity = 0.74 (74 %) confidence interval (95 % from 60.65 to 88.6 %)]. Furthermore, an increase of the sensitivity (94 versus 83 %) of the ultrasound study in discerning between benign and malignant lesions was observed if the vascular pattern was associated with echostructural inhomogeneity of the lesion. However, a slight decrease of the specificity (73 versus 74 %) of the latter group was found. It has been observed also a significant correlation between the US-detected thickness and Breslow index in Melanomas ($r = 0.9845212$–0.9632), in accordance with recent data from the literature [11, 13–15, 19–22, 24, 25, 28–32].

Discussion

The use of high-frequency ultrasound transducers can be a non-invasive tool for in vivo pre-excisional characterization of the skin lesions [3, 10, 11, 13–15, 19–22, 24, 25, 28–32]. The increased spatial resolution achievable with the high-frequency transducers greatly improves the ability of imaging ultrasound in defining the margins and the depth of the skin growths [3, 10, 11, 13–15, 19–22, 24, 25, 28–32]. Of all the ultrasound parameters detectable, however, only the vascular pattern detected with color and power Doppler showed in our study a satisfying capacity in

Table 1 a. Study of skin lesions

Histological examination		Ultrasound Features							
		B-MODE						Color Doppler	
Type	Number	Echostructure		Margins		Site		Vasculature	
		Homogeneous	Inhomogeneous	Regular	Irregular	Surface	Deep	Present	Absent
Benign lesions									
Not melanocytic									
Angioma	6	3	3	4	2	2	4	6	0
Keratoacanthoma	4	1	3	1	3	3	1	2	2
Actinic Keratoses	1	1	0	1	0	1	0	0	1
Sebaceous cysts	3	0	3	1	2	1	2	0	3
Fibrohistiocitoma	2	0	2	2	0	1	1	0	2
Granulomas	1	0	1	0	1	1	0	0	1
Pilomatrixoma	1	0	1	1	0	0	1	0	1
Scleroderma	1	0	1	1	0	0	1	0	1
Melanocytic									
Blue Nevi	3	2	1	2	1	1	2	0	3
Spitz Nevi	2	2	0	2	0	2	0	1	1
Dermal Nevi	4	3	1	3	1	3	1	0	4
Dysplastic Nevi	10	7	3	6	14	10	0	1	9
Sebaceous Nevi	1	1	0	1	0	1	0	0	1
Total Benign lesions	39	20	19	25	14	26	13	10	29
Malignant lesions									
Not melanomas									
Basal cell carcinoma	20	6	14	12	8	9	11	19	1
Squamous cell carcinoma	10	1	9	2	8	1	9	10	0
Liposarcoma	1	0	1	1	0	0	1	1	0
Melanomas									
Melanomas	34	19	15	23	11	32	2	24	10
Total malignant lesions	65	26	39	38	27	42	23	54	11

b. Frequency of echographic characteristics

	Number	Inhomogeneous echostructure (%)	Homogeneous echostructure (%)	Regular margins (%)	Irregular margins (%)	Site surface (%)	Site deep (%)	Vascular signal (+) (%)	Vascular signal (−) (%)
Benign	39	48.00	51.00	64.00	35.00	66.66	33.00	25.64	74.00
Malignant	65	60.00	40.00	60.00	40.00	64.00	35.00	83.00	16.90

the differentiation between malignant and benign lesions [3, 10, 11, 13, 15, 19–21, 25, 28–32].

In the evaluation of 34 melanomas we detected the presence of the vascular signal in 24/34 lesions, all of a thickness greater than 1 mm, and analyzing the morphology of the vascular signal we found a majority of regular signal type with one or two afferent vessels to the lesion. Only 3/34 lesions with anterior–posterior thickness greater than 1 mm showed no vascular signal but showed greater echostructural inhomogeneity. This is in agreement with literature data that have amply demonstrated that the vascular density detected within the tumor by color Doppler directly correlates with the metastatic potential. Indeed, in particular in the case of melanomas, the histopathologically measured thickness (Breslow index), which is the most important prognostic factor [4], can be accurately and non-invasively measured using ultrasound [1, 6, 9–11, 13–32]. Lassau et al. have indeed reported that the thickness of the tumor indicated by the Breslow index, as well as the vascular density of the tumor identified by color Doppler, is significantly correlated with metastatic potential and dissemination of melanomas [19, 20]. Serrone et al. [28] have confirmed this and added that for melanomas of thickness greater than 0.75 mm, the correlation between the

Table 2 Pattern at vascular ultrasound in <1 mm thickness melanomas

Thickness (mm)	Vascular signal	Number afferents	Distribution
a. Pattern at vascular ultrasound in <1 mm thickness melanomas			
0.60	0		
0.90	0		
0.80	0		
0.55	0		
0.45	0		
0.20	0		
1.00	1	1	II
0.70	0		
b. Pattern at vascular ultrasound in <1 mm, >3 mm thickness melanomas			
1.30	1	1	I
1.50	1	2	II
1.65	1	1	I
1.10	1	1	I
1.10	1	1	I
1.30	1	1	II
1.30	1	1	II
1.15	1	1	II
1.15	1	1	II
1.25	0		
2.80	1	1	II
2.30	1	1	III
2.45	1	1	III
2.20	1	1	III
3.00	1	2	III
2.00	0		
c. Pattern at vascular ultrasound in >3 mm thickness melanomas			
3.35	1	2	III
5.80	1	1	III
4.70	1	1	II
7.60	1	2	III
4.75	1	1	III
3.40	1	1	III
9.00	1	2	III
3.10	0		
3.50	1	1	I
3.50	1	1	III

Vascular Signal 0 = absent, 1 = present; Number of afferents detected; Distribution I = widespread, II = peripheral, III = radial

thickness at ultrasound and the histological thickness was significantly high; Catalano et al. [9] also demonstrated that the intralesional Color Doppler signal correlates with the Breslow index and with patient survival.

However, the detection of vascular signal at color Doppler within a skin lesion should not be considered as an absolute marker of malignity, as several benign lesions can show vascular signal too, among which angiomas are the most common because of their histological configuration. In these cases, the color-Doppler findings should always be related to the clinical examination.

Limitations One of our limits was to have not performed an integration with the administration of contrast medium, which surely would have been beneficial to the study of the vascularity of neoplasms, but unfortunately, being ours a retrospective study, at the time of the survey such an integration was still not expected. Furthermore, in the literature the use of contrast medium for the study of melanomas and skin lesions was then, and is still now, widely described for the assessment of lymph node metastatic lesions prevalently with 12-MHz transducers, so there were not enough data to state a correct setting of the ultrasound systems and 17-MHz transducer for a contrast media study, and thus it would have been necessary to use 12-MHz transducers, with lower resolution in the view of the uppermost layers [7–9, 16–18, 23–25, 28–32]. However, given the results of more recent studies [16–18] and the technological developments of the transducers and ultrasound systems, our group has also begun to evaluate the tumor neovasculature with contrast-enhanced ultrasound.

The use of high-performing ultrasound systems, high-resolution transducers, abundant quantity of gel, very low pressure of the probe on the skin by the operator, and the setting of color and power Doppler for the study of slow and superficial flows was done in an attempt to minimize the number of false-negative neoplasms at the vascular study, which unfortunately seem to affect, as widely reported in the literature, lesions of thickness less than 1 mm and in particular 0.75 mm according to some authors [28]. On the other hand, it has been amply demonstrated in the literature that lesions with these small thickness have a reduced risk of metastasis [7–9, 19–22, 24, 25, 28–32].

The evaluation of margins can also be of great help to the surgeon who will remove the lesion. Basal cell carcinomas and squamous cell carcinomas even more, in fact, have a high probability of local recurrence after surgical excision [13–15, 19–21, 25, 31, 32]. It would also be useful to apply routine ultrasound study of the surgical scar, allowing for early detection of any recurrence.

Conclusions

In conclusion, the use of high-frequency ultrasound transducers (17 MHz) can therefore be a non-invasive tool for in vivo pre-excisional characterization of the skin lesions. The use of vascular signal and the US thickness in melanomas allows a valid indication to surgical excision, in agreement with the most recent literature [3, 6–9, 11, 13, 14, 19–22, 24, 28–32]. Sonography may provide reliable support in a wide range of common dermatologic conditions. It allows reasonable discrimination between diseased tissue and healthy skin tissue, of dermatologic and non-dermatologic origins, hypovascular and hypervascular lesions. It can also show critical information otherwise invisible to the naked eye of a clinician, including, for example, depth and activity of skin lesions [15, 22, 31, 32]. Therefore, it is clear that ultrasound examinations of the skin should be performed and interpreted by a radiologist with a high level of expertise and training in skin ultrasound, with a standardized technique to avoid diagnostic errors.

Conflict of interest The authors declare that they have no conflict of interest related to the publication of this article.

References

1. Alexander H, Miller DL (1979) Determining skin thickness with pulsed ultrasound. J Invest Dermatol 72(1):17–19
2. Aspres N, Egerton IB, Lim AC, Shumack SP (2003) Imaging the skin. Australas J Dermatol 44(1):19–27
3. Bessoud B, Lassau N, Koscielny S, Longvert C, Avril MF, Duvillard P, Rouffiac V, Leclère J, Roche A (2003) High-frequency sonography and color Doppler in the management of pigmented skin lesions. Ultrasound Med Biol 29(6):875–879
4. Breslow A (1970) Thickness, cross-sectional areas and depth of invasion in the prognosis of cutaneous melanoma. Ann Surg 172:902–908
5. Cammarota T, Pinto F, Magliaro A, Sarno A (1998) A current uses of diagnostic high-frequency US in dermatology. Eur J Radiol 27(Suppl 2):215–223
6. Catalano O, Siani A (2010) Cutaneous melanoma: role of ultrasound in the assessment of locoregional spread. Curr Probl Diagn Radiol 39:30–36
7. Catalano O, Voit C, Sandomenico F, Mandato Y, Petrillo M, Franco R, Botti G, Caracò C, Mozzillo N, D'Errico AG (2011) Previously reported sonographic appearances of regional melanoma metastases are not likely due to necrosis. J Ultrasound Med 30(8):1041–1049
8. Catalano O (2011) Critical analysis of the ultrasonographic criteria for diagnosing lymph node metastasis in patients with cutaneous melanoma: a Systematic review. J Ultrasound Med 30:547–560
9. Catalano O, Caraco C, Mozzillo N, Siani A (2010) Locoregional spread of cutaneous melanoma: sonography findings. AJR Am J Roentgenol 194:735–745
10. Choo HJ, Lee SJ, Lee YH (2010) Pilomatricomas: the diagnostic value of ultrasound. Skeletal Radiol 39:243–250
11. Clément A, Hoeffel C, Fayet P, Benkanoun S, Sahut D'izarn J, Oudjit A, Legmann P, Gorin I, Escande J, Bonnin A (2001) Value of high frequency (20 MHz) and Doppler ultrasound in the diagnosis of pigmented cutaneous tumors. J Radiol 82(5):563–571
12. Crisan D, Lupsor M, Boca A, Crisan M, Badea R (2012) Ultrasonographic assessment of skin structure according to age. Indian J Dermatol Venereol Leprol 78(4):519
13. Giovagnorio F, Andreoli C, De Cicco ML (1999) Color Doppler sonography of focal lesions of the skin and subcutaneous tissue. J Ultrasound Med 18(2):89–93
14. Harland CC, Bamber JC, Gusterson BA, Mortimer PS (1993) High frequency, high resolution ultrasound in the assessment of skin tumours. Br J Dermatol 128(5):525–532
15. Kleinerman R, Whang TB, Bard RL, Marmur ES (2012) Review ultrasound in dermatology: principles and applications. J Am Acad Dermatol 67(3):478–487
16. Lassau N, Chami L, Benatsou B, Peronneau P, Roche A (2007) Dynamic contrast-enhanced ultrasonography (DCE-US) with quantification of tumor perfusion: a new diagnostic tool to evaluate the early effects of antiangiogenic treatment. Eur Radiol 17(6):89–98
17. Lassau N, Chapotot L, Benatsou B, Vilgrain V, Kind M, Lacroix J, Cuinet M, Taieb S, Aziza R, Sarran A, Labbe C, Gallix B, Lucidarme O, Ptak Y, Rocher L, Caquot LM, Chagnon S, Marion D, Luciani A, Uzan-Augui J, Koscielny S (2012) Standardization of dynamic contrast-enhanced ultrasound for the evaluation of antiangiogenic therapies: the French multicenter Support for I Innovative and Expensive Techniques Study. Invest Radiol 47(12):711–716
18. Lassau N, Chebil M, Chami L, Bidault S, Girard E, Roche A (2010) Dynamic contrast-enhanced ultrasonography (DCE-US): a new tool for the early evaluation of antiangiogenic treatment. Target Oncol 5(1):53–58
19. Lassau N, Spatz A, Avril MF, Tardivon A, Margulis A, Mamelle G, Vanel D, Leclere J (1997) Value of high-frequency US for preoperative assessment of skin tumors. Radiographics 17(6):1559–1565
20. Lassau N, Lamuraglia M (2006) Prognostic value of angiogenesis evaluated with high frequency and colour Doppler sonography for preoperative assessment of primary cutaneous melanomas: correlation with recurrence after a 5 year follow-up period. Cancer Imaging 25(6):24–29
21. Mandava A, Ravuri PR, Konathan R (2013) High-resolution ultrasound imaging of cutaneous lesions. Indian J Radiol Imaging 23(3):269–277
22. Pellacani G, Seidenari S (2003) Preoperative melanoma thickness determination by 20-MHz sonography and digital videomicroscopy in combination. Arch Dermatol 139(3):293–300
23. Polańska A, Aleksandra Dańczak-Pazdrowska A, Silny W, Jenerowicz D, Olek-Hrab K, Osmola- Mańkowska A (2013) Nonlesional skin in atopic dermatitis is seemingly healthy skin—observations using noninvasive methods. Videosurgery Miniinv 8(3):192–199
24. Pupelli G, Longo C (2013) Small diameter melanocytic lesions: morphological analysis by means of in vivo confocal microscopy. Br J Dermatol 168(5):1027–1033
25. Rallan D, Harland CC (2003) Ultrasound in dermatology—basic principles and applications. Clin Exp Dermatol 28:632–638
26. Sandby-Moller J, Wulf HC (2004) Ultrasonographic subepidermal low-echogenic band, dependence of age and body site. Skin Res Technol 10(1):57–63
27. Sandby-Møller J, Thieden E, Philipsen PA, Schmidt G, Wulf HC (2004) Dermal echogenicity: a biological indicator of individual cumulative UVR exposure. Arch Dermatol Res 295(11):498–504
28. Serrone L, Solivetti F, Thorel M, Eibenschuntz L, Donati P, Catricalà C (2002) High frequency ultrasound in the preoperative staging of primary melanoma: a statistical analysis. Melanoma Res 12:287–290
29. Srivastava A, Woodcock JP, Mansel RE, Webster DJ, Laidler P, Hughes LE, Dwivedi A (2012) Doppler ultrasound flowmetry predicts 15 year outcome in patients with skin melanoma. Indian J Surg 74(4):278–283
30. Ulrich J, Petereit S, Gollnick H (1999) Preoperative sonographic diagnosis of melanoma—comparison of 7,5- and 20 MHz sonography. Ultrashall Med 20(5):197–200
31. Wortsman X, Wortsman J (2010) Clinical usefulness of variable-frequency ultrasound in localized lesions of the skin. J Am Acad Dermatol 62:247–256
32. Wortsman X (2012) Common applications of dermatologic sonography. J Ultrasound Med 31(1):97–111