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PICTORIAL REVIEW

Sonography in pathologies of scalp and hair

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ABSTRACT. Disorders of the scalp often result in severe cosmetic interference with quality of life, creating the need for optimal medical surveillance. We tested the latest generation of ultrasound machines in patients with scalp pathology and prepared a cross-sectional library encompassing a wide assortment of conditions. Normative data on the sonographic anatomy of scalp and human hair, and important methodological considerations, are also included.

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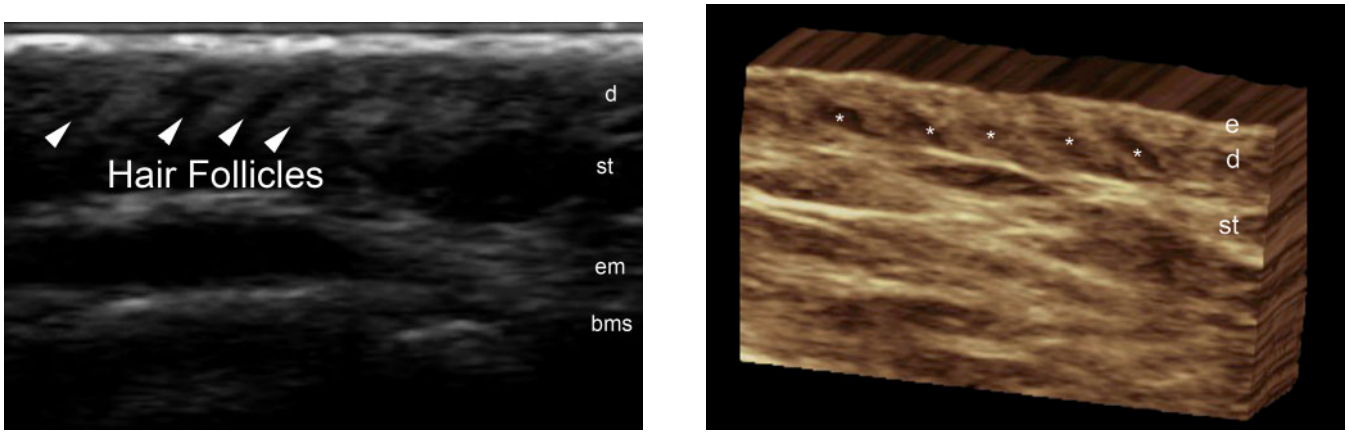
Scalp hair involvement in local pathology adversely affects self-image and quality of life by damaging a traditional conveyor of identity, ethnicity and health [1]. To improve the medical approach to diseases of the scalp, we evaluated colour Doppler ultrasound, a technique already applied to the study of localised lesions of the skin [2]. We screened 12 461 ultrasound examinations performed over the past 8 years at a national skin sonography referral centre, and selected 221 patients (168 male, 53 female) with scalp lesions. Sonograms were also performed on 33 healthy volunteers (31 male, 2 female). We then prepared a pictorial presentation highlighting sonographic characteristics of scalp skin, scalp hair and eyelashes, and archetypal scalp pathology



(a) (b)

Figure 1. (a) Ultrasound of normal scalp (transverse view) shows the typical echogenicity of the different skin layers; note the oblique orientation of the hair follicles. (b) Hair follicles on three-dimensional ultrasound (asterisk; 5 s sweep). bms, bony margin of the skull; d, dermis; e, epidermis; em, epicraneous muscle; st, subcutaneous tissue.

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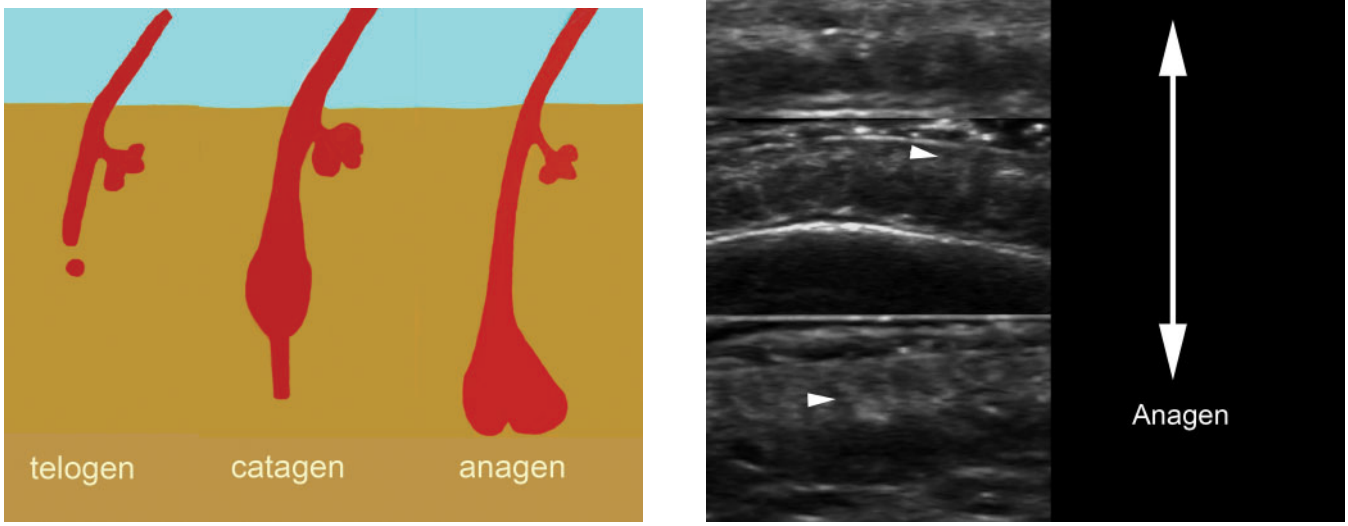


(a) (b)

Figure 2. Hair growth cycle. (a) Schematic representation. (b) Ultrasound; note the progressive dermal penetration of the hair follicle, from the telogen phase (inactive and resting phase with the hair bulb in a subepidermal location) to the anagen phase (active growth phase with the hair follicle reaching the bottom of the dermis).

(histologically confirmed). The Institutional Review Board of the Clinica Servet exempted this report from the requirement of informed consent.

Technical considerations

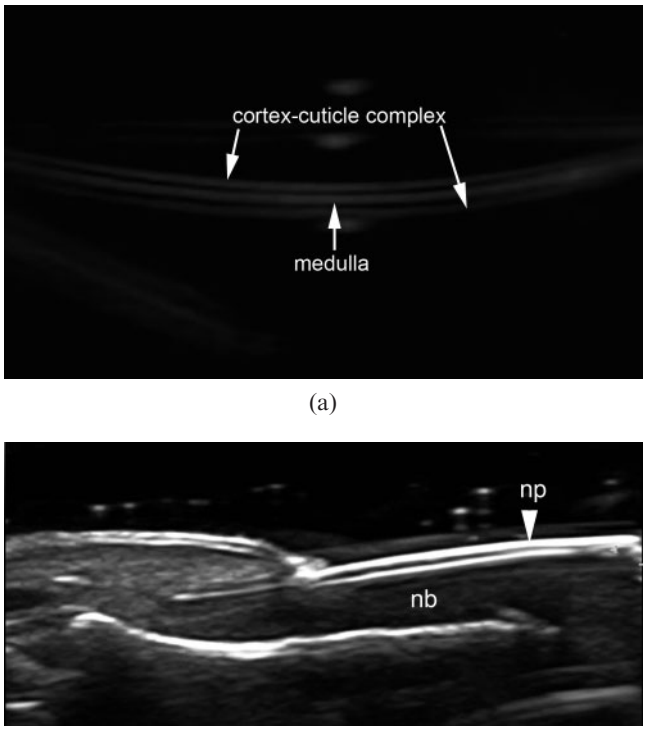
The ultrasound operator, placed facing the lesion site(s) on the supine patient, applied copious amounts of gel on the scalp surface and between the hairs. Sonography testing routinely included the lesion's transverse and longitudinal axes; hair follicles were followed along the main axis and two perpendicular views. The ultrasound equipment included the Philips HDI 5000 and IU 22 (Philips Healthcare, Eindhoven, Netherlands), and Esaote Gold MyLab 70 XVG and Twice (Esaote, Genoa, Italy) systems, with variable frequency probes (7–15 MHz or 6–18 MHz) and Doppler frequency of 7–14 MHz. Greyscale examination was routinely followed by colour Doppler ultrasound with spectral curve analysis of blood flow; stand-off pads or contrast medium were not needed.

Imaging findings

Normal scalp skin

Ultrasound of scalp skin confirmed the known histological differences in regional thickness, with frontal skin being thinner than occipital skin, clear separation between an epidermal hyperechoic line and a dermal hyperechoic band, and subcutaneous tissue as a hypoechoic band with hyperechoic septa between the fat lobules. At a deeper level a thin hypoechoic band corresponded to the galeal layer (epicraneous muscle and its aponeurosis), and a hyperechoic line marked the bony margin of the skull (Figure 1). The scalp blood supply runs along a centripetal network made up of large subcutaneous trunks [3].

Longitudinally the hair follicle contains the proximal dermal follicle bulb and the distal hair shaft, the relative position of which depends on the growth phase (hair



(a)

(b)

Figure 3. Ultrasound. (a) Normal scalp hair (longitudinal axis) showing the trilaminar organisation of the hyperechoic keratin component. (b) Nail (longitudinal axis) showing the bilaminar organisation of keratinised nail plates. nb, nail bed; np, nail plates.

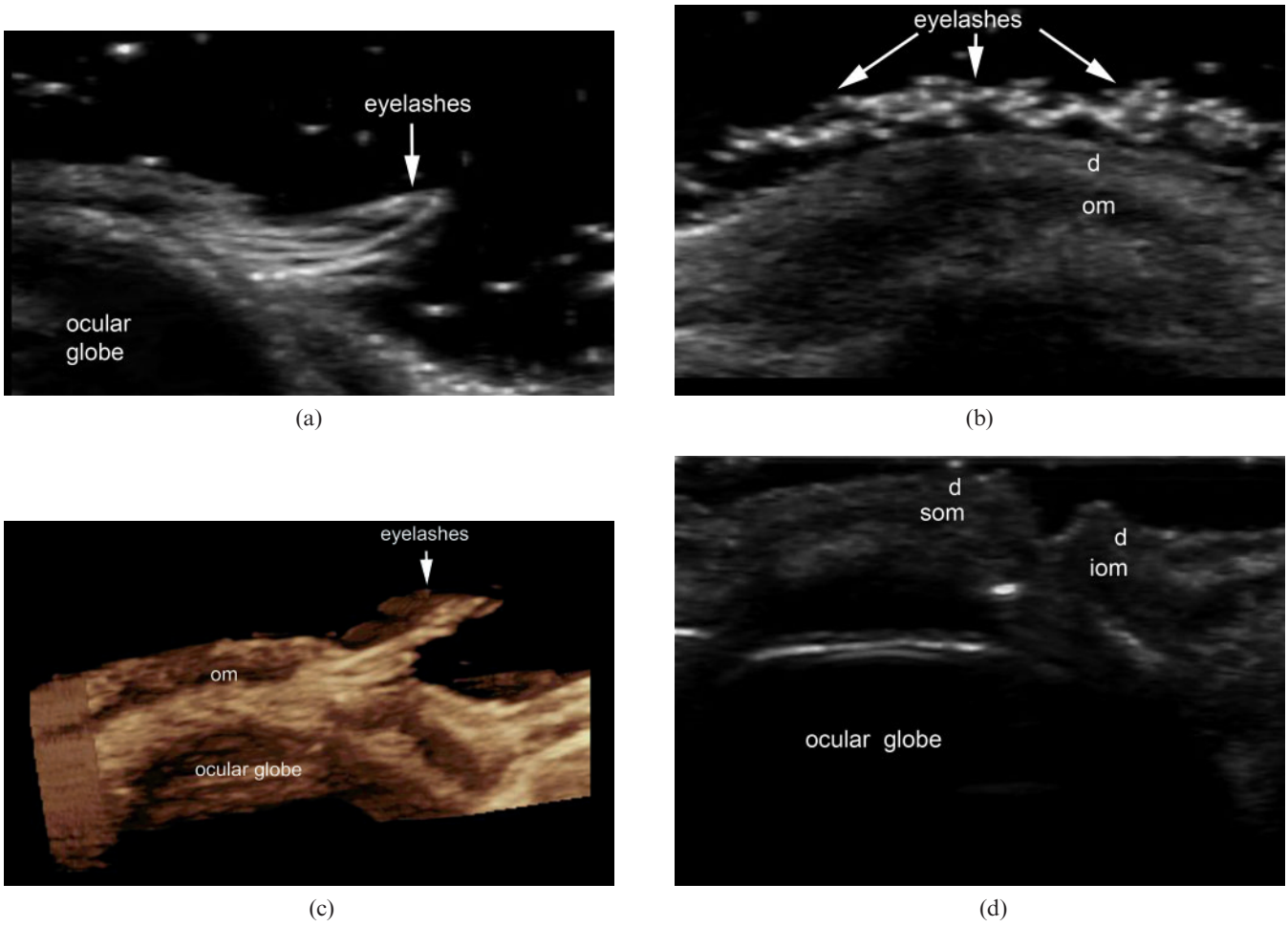


Figure 4. Eyelashes ultrasound. (a) Longitudinal view of normal eyelashes seen as hyperechoic lines arising from the upper eyelid. (b) Transverse view of normal eyelashes showing the ''crown-like'' image. (c) Three-dimensional longitudinal view (5 s sweep) of normal eyelashes. (d) Alopecia areata (longitudinal view): there is absence (loss) of the eyelashes. d, dermis; iom, inferior orbicular muscle; om, orbicular muscle; som, superior orbicular muscle.

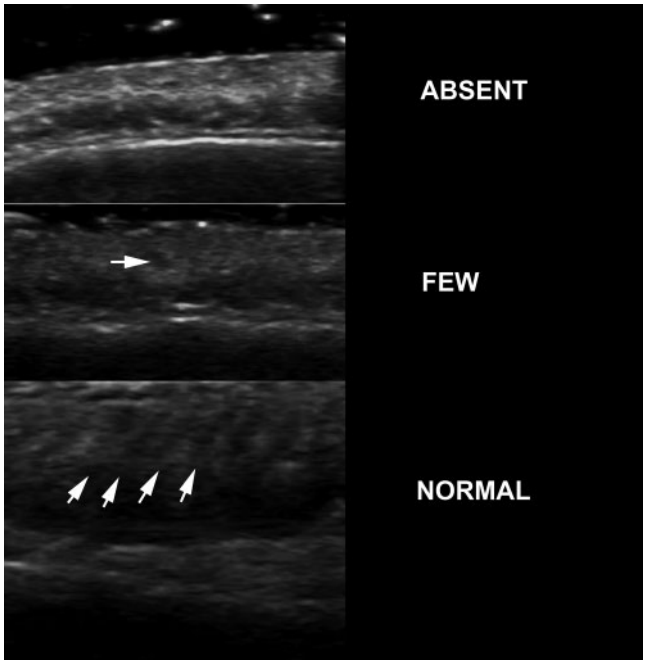
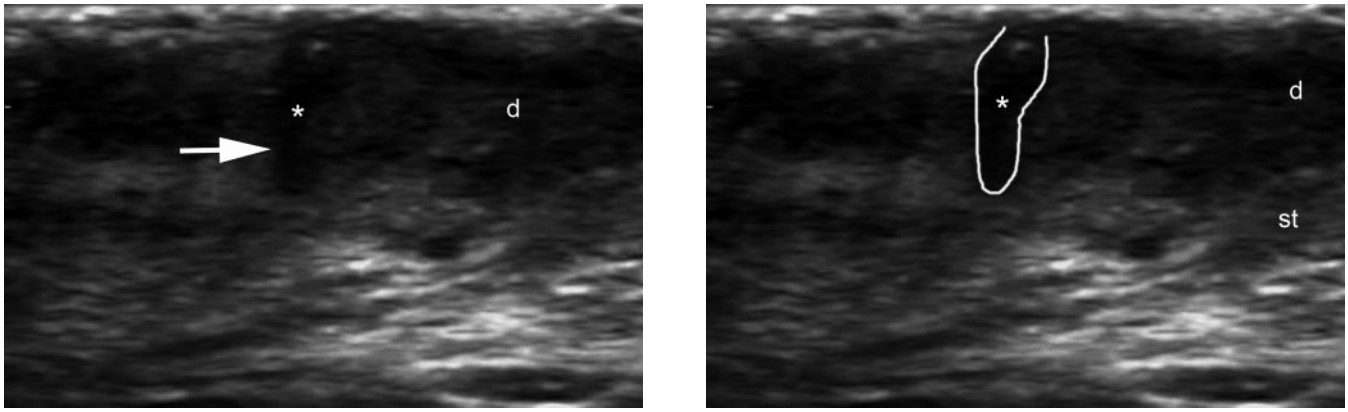


Figure 5. Estimation of scalp follicular population. Density-gradient ultrasound depicting variation in hair follicle number (arrows).

cycle clock): in the telogen or resting phase the hair bulb is in a superficial subdermal location, while in the anagen or active growth phase the hair bulb is almost in the subcutaneous tissue; in the catagen or transition phase it is found in an intermediate position [4] (Figure 2). In contrast to many animals, the human hair growth cycle is independent for each individual follicle; overall, 90% of scalp hairs are normally in the anagen phase, while the remaining 10% are in telogen or catagen phases.

Normal hair shaft

Hair shaft morphology (*i.e.* outer sheath, complex cuticle–cortex and inner central medulla) has been previously observed with experimental MRI systems [5]. Ultrasound provides additional details such as a characteristic trilaminar hyperechoic structure (Figure 3a), presumably reflecting the longitudinal arrangement of keratin chains. Interestingly, this arrangement resembles the bilaminar structure of the also keratinised ungual plaque of the nail (Figure 3b) [6]. Eyelashes are uniformly monolaminar (Figure 4), perhaps reflecting limitations in



(a) (b)

Figure 6. Inflamed hair follicle. (a) Ultrasound (transverse view): follicular enlargement and hypoechogenicity (asterisk, centre of the hair follicle; arrow, the base of the hair follicle); dermal echogenicity is also decreased. (b) Outline of hair follicle (asterisk, centre of the hair follicle). d, dermis; st, subcutaneous tissue.

the resolution of ultrasound machines (currently 0.1 mm), or microstructural specificities of the keratinous component.

Hair follicle density

Ultrasound not only detects abnormalities in the morphology of hair follicles but also provides qualitative estimation of the follicular population, from its total absence (alopecia) to reductions in follicle number (Figure 5). Since sonography can also detect hair cycle phase, it could have potential application in the monitoring of treatments against baldness.

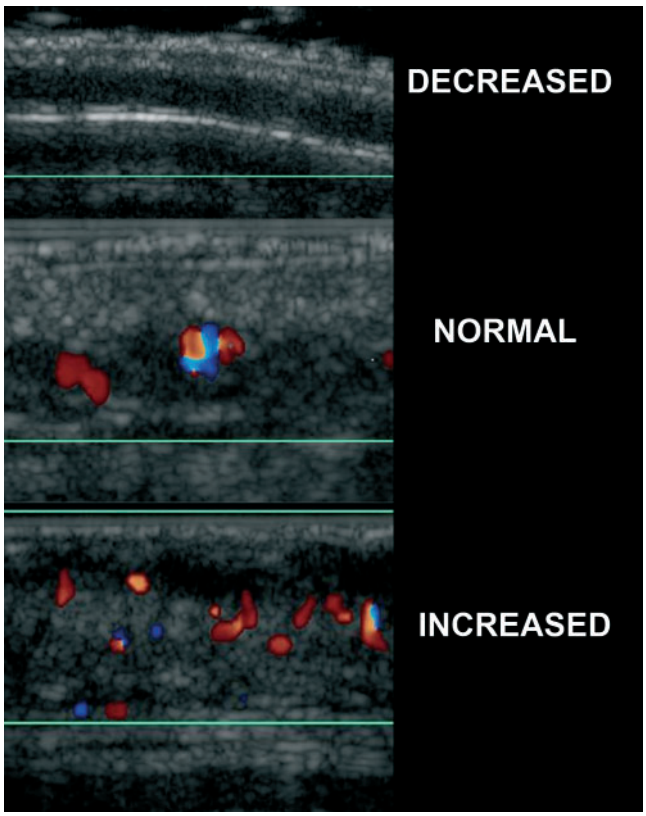


Figure 7. Scalp blood flow. Grading of scalp vascularity with colour Doppler ultrasound.

Hair follicle inflammation

Active inflammation is suggested by hair follicle alterations in diameter and/or echogenicity, appearing swollen and markedly hypoechoic (Figure 6); colour Doppler ultrasound may add a pathognomonic increase in blood flow (Figure 7).

Disorders of scalp skin and scalp hair

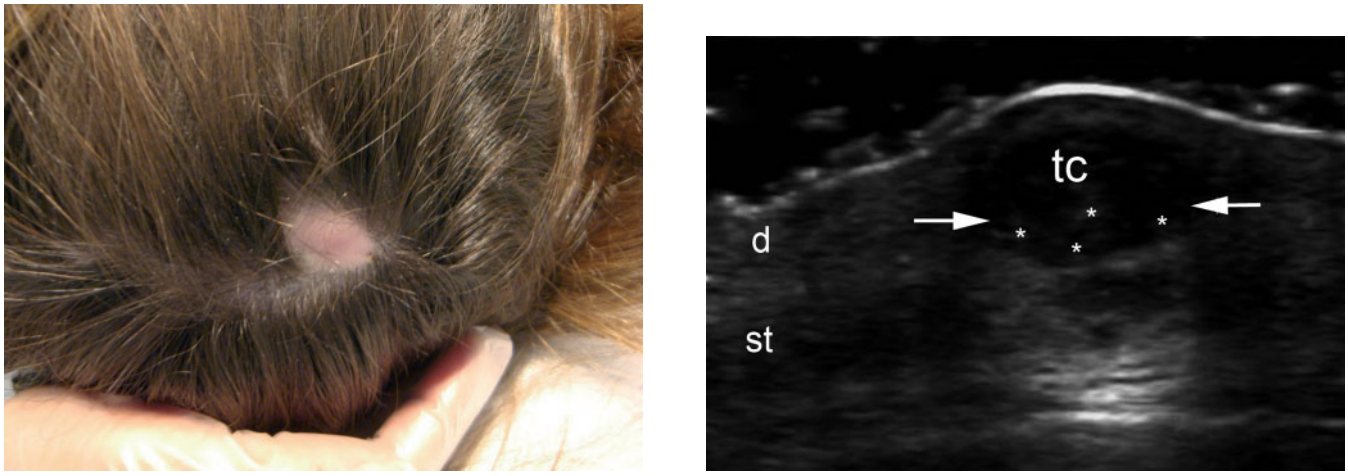
Benign

Trichilemmal cysts

These are cystic structures of the follicular isthmus (between the bulb and shaft), derived from the trichilemma (*i.e.* outer root sheath of the hair follicle) and located most commonly in the scalp (78%) or trunk (13%). Trichilemmal cysts present as smooth, firm nodules, often accompanied by hair loss: the cystic wall is devoid of any granular layer, showing instead abrupt transition between the epidermal stratum spinosum and the hair keratin; the cysts contain keratinous debris or cholesterol crystals, and occasional focal calcifications [7]. Sonography shows dermal and subcutaneous round or oval-shaped structures, generally anechoic but with detectable echoes from keratinous and dense cholesterol cystic elements, and with absence of connecting tracts (Figure 8).

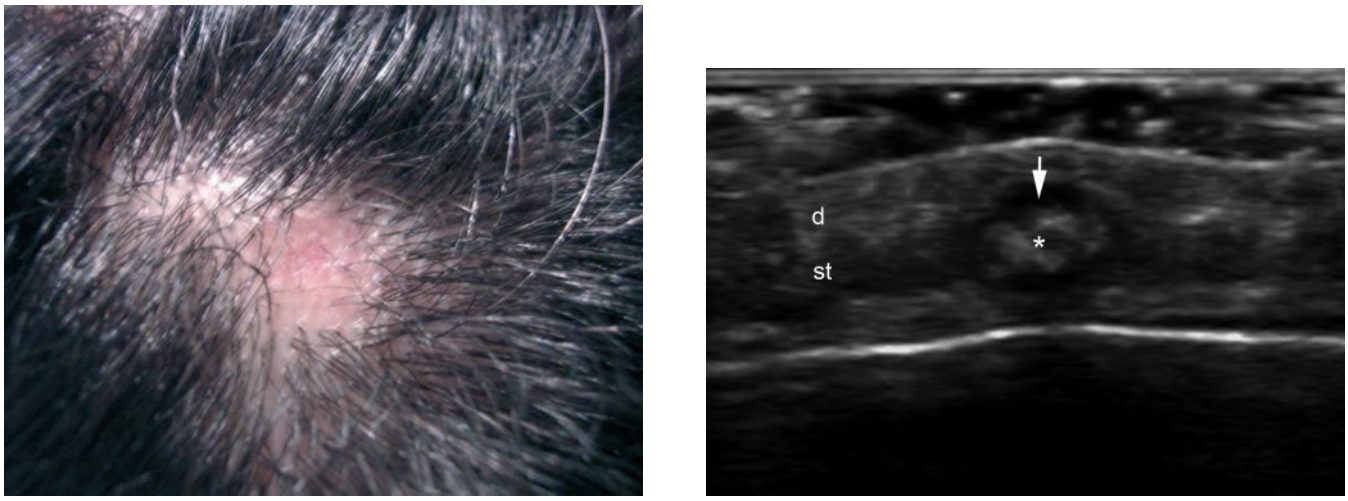
Pilomatrixoma

Also called pilomatricomas or calcifying epitheliomas of Malherbe, there are most frequent in the head and



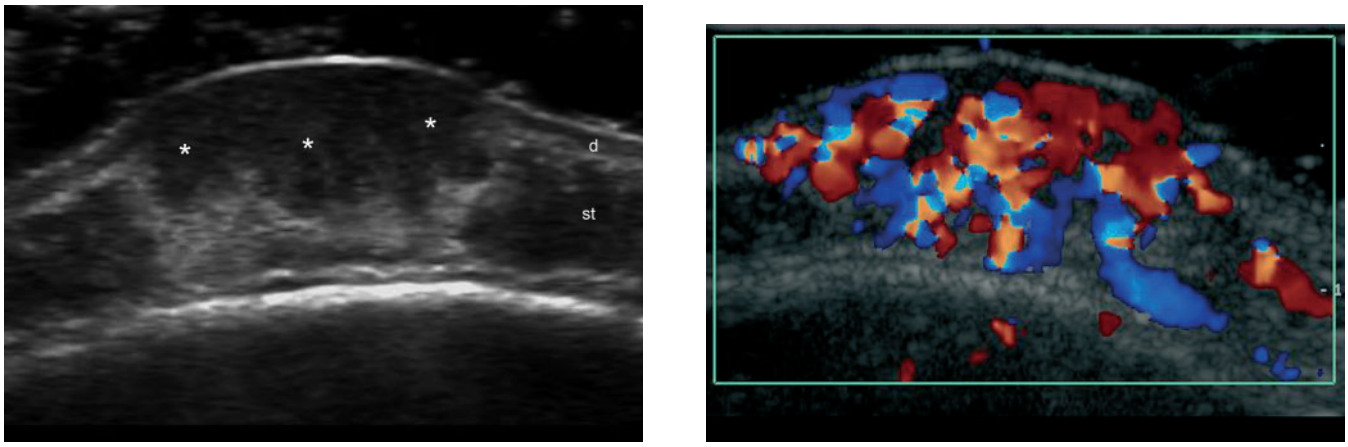
(a) (b)

Figure 8. Trichilemmal cyst. (a) Clinical: focal alopecia. (b) Ultrasound (transverse view) shows round dermal anechoic cyst (tc, arrows). Echoes within the cyst (asterisks) correspond to dense keratinous and oily debris. d, dermis; st, subcutaneous tissue.



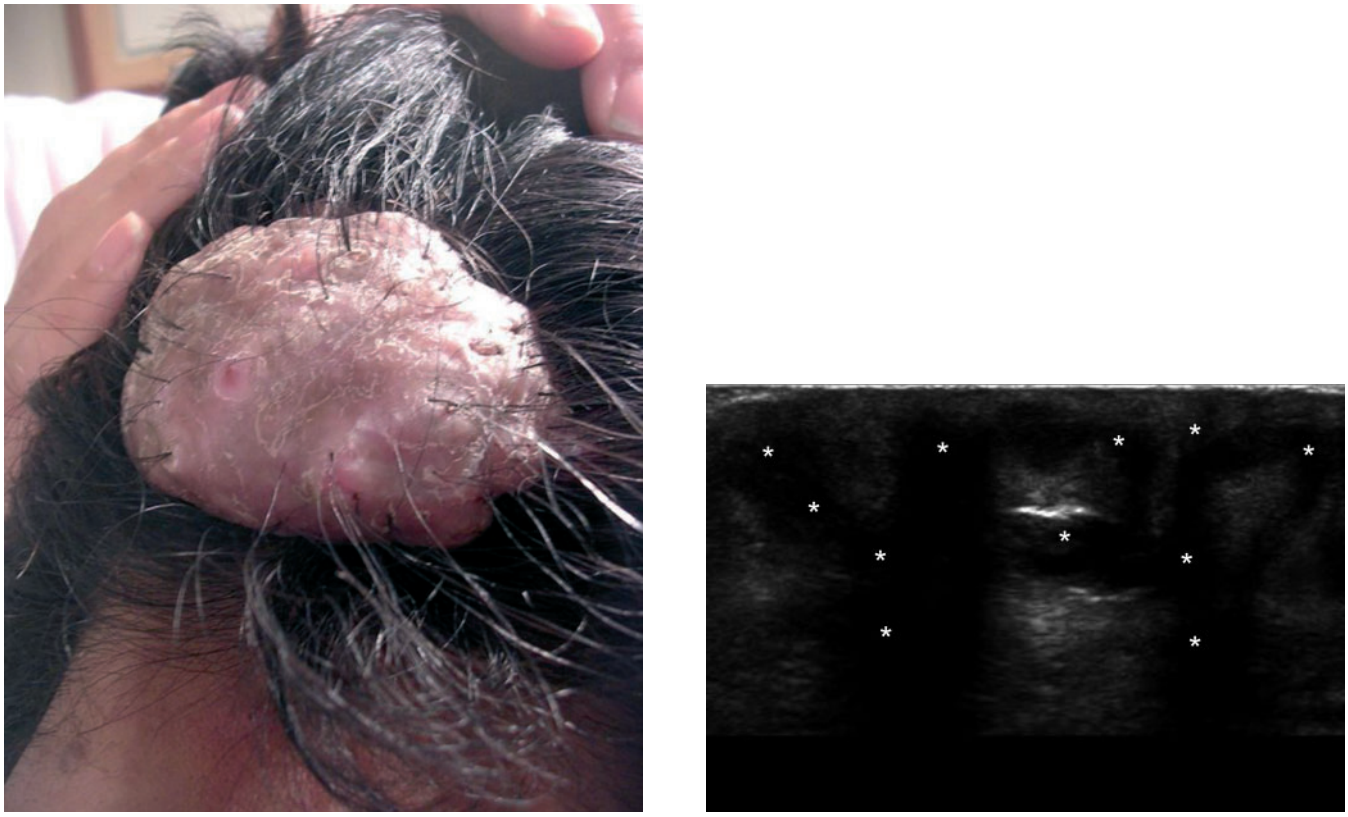
(a) (b)

Figure 9. Pilomatrixoma. (a) Clinical: slightly erythematous focal alopecia. (b) Ultrasound (transverse view) shows space-occupying target lesion of the dermis and subcutaneous tissue; solid nodule with hypoechoic rim (arrow) and hyperechoic centre (asterisk). d, dermis; st, subcutaneous tissue.



(a) (b)

Figure 10. Haemangioma of the scalp. (a) Ultrasound (transverse view) shows areas of heterogeneous echogenicity in the dermis and subcutaneous tissue; areas where tumour is proliferating most actively appear hypoechoic (asterisks). (b) Colour Doppler ultrasound (transverse view) shows markedly increased blood flow within the lesion.



(a) (b)

Figure 11. Acne keloidalis nuchae. (a) Clinical: large exophitic mass on the scalp. (b) Ultrasound (transverse view): large anechoic fistulous tracts (asterisks) transconnecting within the lesion.

neck of children and young adults (scalp: 9%); they present as painless and slowly enlarging firm to hard nodules arising from the follicular matrix. Sonography classically shows target-like lesions with a hyperechoic centre, hypoechoic rim and, often, with internal hyperechoic dots corresponding to calcium deposits (Figure 9) [8].

Haemangioma

This is the most common benign tumour of infancy, appearing as discrete soft, reddish masses in the head or neck, or as segmental but diffuse lesions. Haemangioma echogenicity is variable (hypoechoic or combined hyper–hypoechoic), with prominent arterial and venous vessels or arteriovenous shunts and occasional extension to the galeal layer and bony margin of the skull (Figure 10) [9].

Scarring alopecias

This group is complex and has inflammation and scarring as common components. Sonography shows dermal and subcutaneous inflammation (seen as hypoechogenicity for the dermis and hyperechogenicity for the subcutaneous tissue), frequently with increased blood flow in the affected areas.

Acne keloidalis nuchae

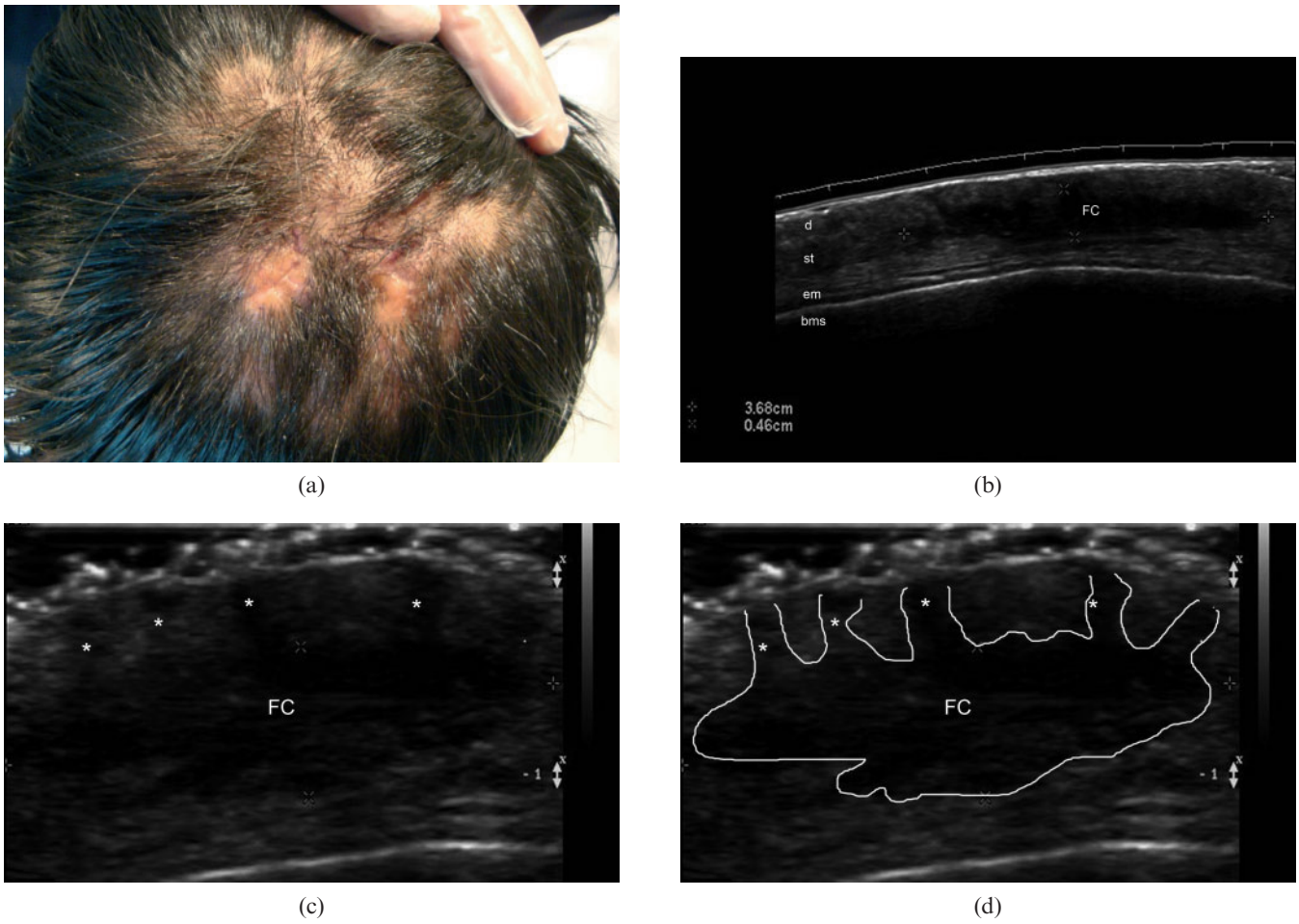
Acne keloidalis nuchae (AKN), an infrequent but deforming disorder of mostly young males, is a chronic scarring folliculitis expressed as papules and pustules, or plaques and nodules on the nape of the neck [10]. Similar to acne conglobata and hidradenitis suppurativa, it is thought to result from episodes of follicular occlusion. Sonography shows full-thickness cutaneous inflammation, hypoechoic connecting fistulous tracts and follicular enlargement (Figure 11).

Perifolliculitis capitis abscedens et suffodiens

Perifolliculitis capitis abscedens et suffodiens (PCAS), a rare and severe progressive dissecting cellulitis or folliculitis of the scalp, presents with purulent-draining painful nodules, burrowing connecting tracts and cicatricial alopecia [11]. PCAS may affect large areas or even the whole scalp, producing multiple areas of baldness; sonography shows debris-filled fluid collections and/or abscesses with multiple interconnecting hypoechoic fistulous tracts that reach the hair bulb, causing follicular swelling (Figure 12).

Folliculitis decalvans

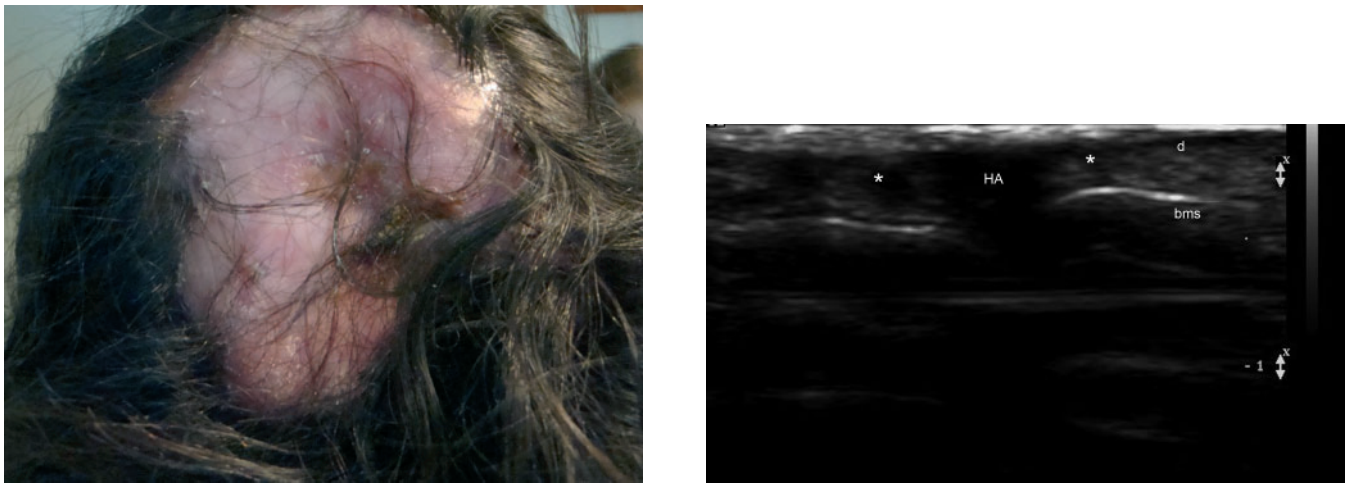
This also rare and recurrent purulent inflammation of the hair follicles of middle-aged adults typically affects the vertex and occipital areas, and presents with follicular pustules without external opening (ostia), late scarring and alopecia. Both *Staphylococcus aureus* infection and immunodeficiencies may be pathogenic factors [12]. Sonography shows multilayer inflammation, absence of fistulae and local follicular thickening (Figure 13).



(a) (b)

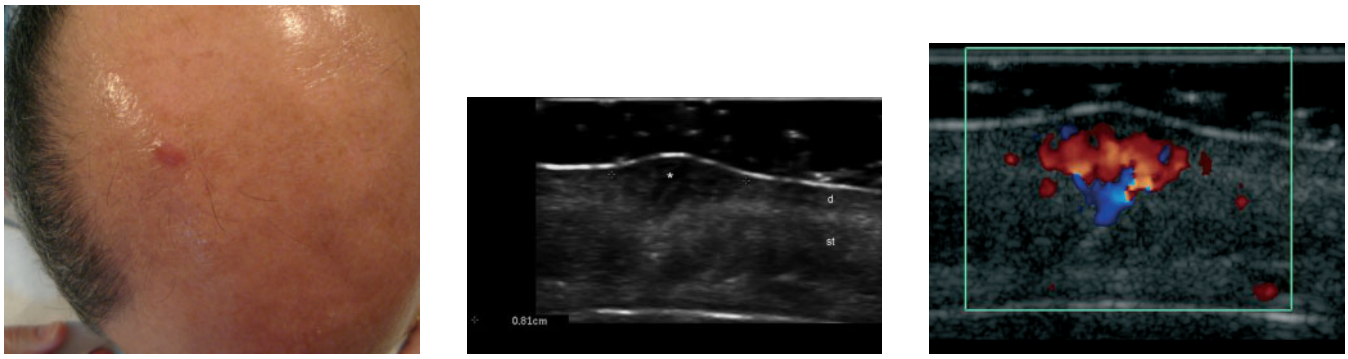
(c) (d)

Figure 12. Perifolliculitis abscedens et suffodiens. (a) Clinical: plaques of alopecia throughout the scalp. (b) Ultrasound (transverse extended field of view) anechoic fluid collection in the subcutaneous tissue connecting to hair follicles. (c) Ultrasound (transverse view): enlarged hair follicles (asterisks) connected to the fluid collection. (d) Outline of the fluid collection and involved hair follicles. bms, bony margin of the skull; d, dermis; em, epicraneous muscle; FC, fluid collection; st, subcutaneous tissue.



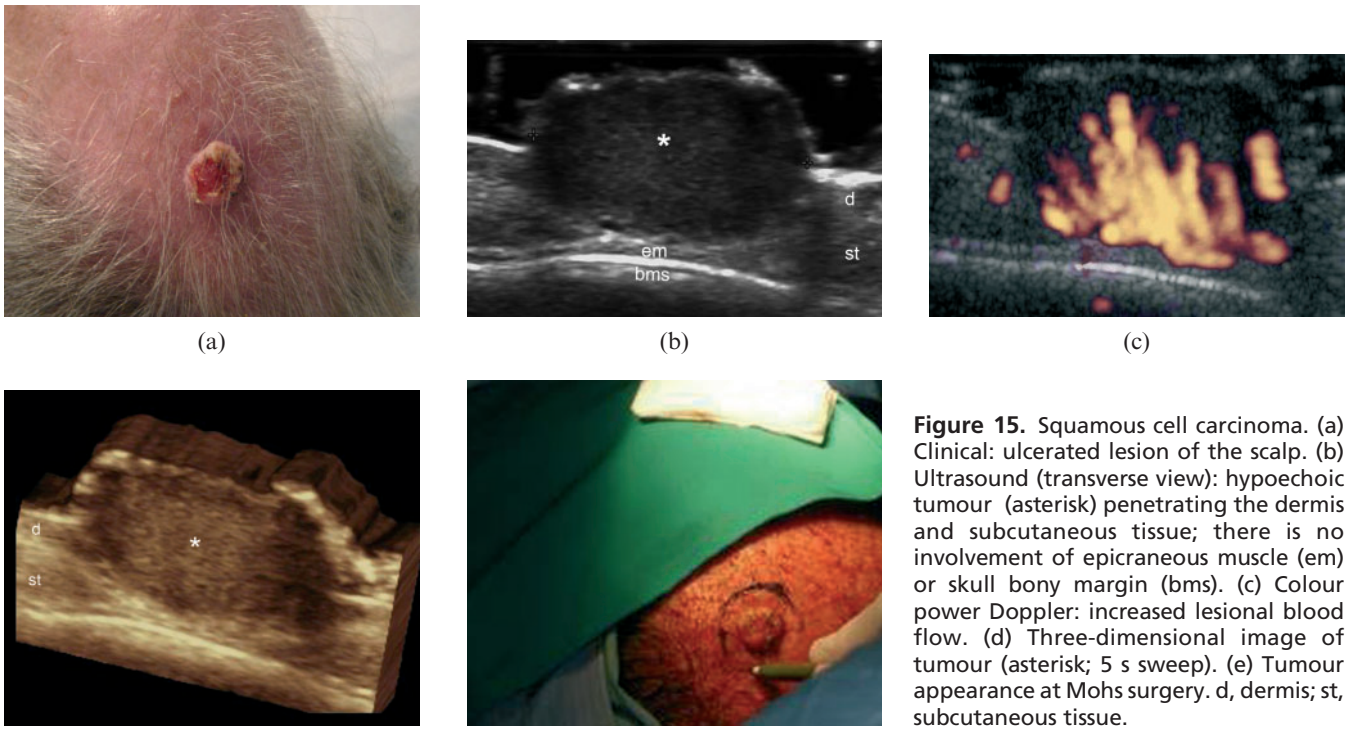
(a) (b)

Figure 13. Folliculitis decalvans. (a) Clinical: alopecia after neurosurgery and radiotherapy performed 10 years previously. (b) Ultrasound (transverse view): scarce and enlarged hair follicles (asterisks); hypoechoic area (HA) corresponds to post-surgical scarring. bms, bony margin of the skull; d, dermis.



(a) (b) (c)

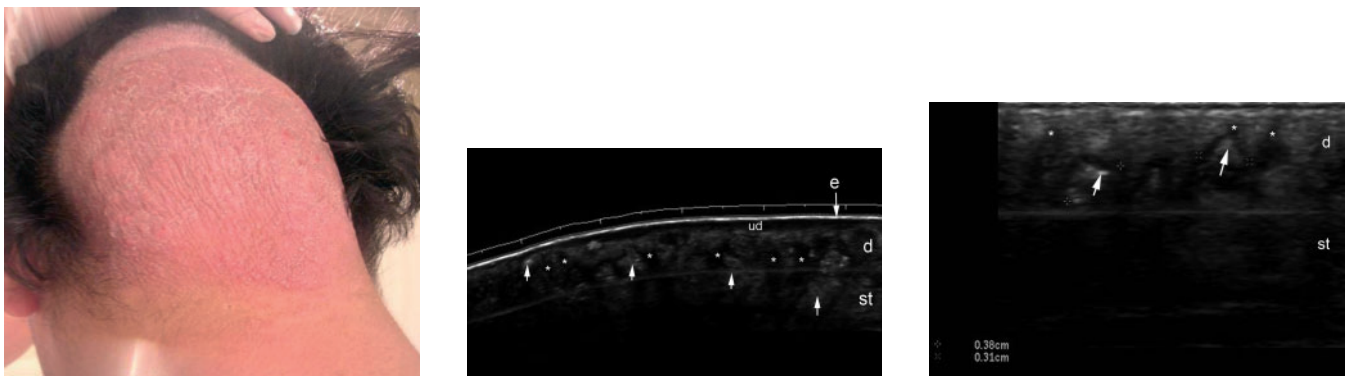
Figure 14. Pseudolymphoma. (a) Clinical: right frontal erythematous swelling. (b) Ultrasound (transverse view) increased dermal thickness and hypoechogenicity (asterisk), with subcutaneous hyperechogenicity. (C) Colour Doppler ultrasound (transverse view): increased blood flow. d, dermis; st, subcutaneous tissue.



(a) (b) (c)

(d) (e)

Figure 15. Squamous cell carcinoma. (a) Clinical: ulcerated lesion of the scalp. (b) Ultrasound (transverse view): hypoechoic tumour (asterisk) penetrating the dermis and subcutaneous tissue; there is no involvement of epicraneous muscle (em) or skull bony margin (bms). (c) Colour power Doppler: increased lesional blood flow. (d) Three-dimensional image of tumour (asterisk; 5 s sweep). (e) Tumour appearance at Mohs surgery. d, dermis; st, subcutaneous tissue.



(a) (b) (c)

Figure 16. Folliculotropic mycosis fungoides. (a) Clinical: large erythematous plaque of occipital baldness. (b) Ultrasound (extended field of view along the transverse axis): prominent hypoechoic band within the upper dermis (ud) corresponding to lymphocytic infiltrates; because of mucin degeneration some infiltrates have become hyperechoic (arrows), as seen around the hair follicles (asterisks). (c) Ultrasound (transverse axis): close up view of (b). bms, bony margin of the skull; d, dermis; e, epidermis; st subcutaneous tissue.

Pseudolymphomas

This heterogeneous group of lymphoproliferative disorders, with dermal infiltrates made of reactive T- or B-lymphocytes, tends to regress over time [13]. Importantly, pseudolymphomas may simulate cutaneous lymphomas both clinically and histologically. Sonography shows focal thickening and hypoechogenicy of the dermis, with moderate increase in vascularity (Figure 14).

Malignant

Skin cancer

Cancers of the scalp represent approximately 2% of all skin cancers, with basal cell carcinoma being most frequent in females and squamous cell carcinoma in males. Alopecia favours the development of skin cancer in males by increasing scalp exposure to solar radiation. Cancer recurrences are associated with large tumour size and immunosuppression; there is little resistance to tumour spread beneath the galeal plane and significant extension may be present at diagnosis, particularly after penetration of the periosteum. Sonography shows hypoechoic solid lesions of generally increased vascularity. Basal cell carcinoma may also present hyperechoic spots within the tumour (Figure 15) [14].

Folliculotropic mycosis fungoides

Folliculotropic mycosis fungoides (FMF), the commonest cutaneous T-cell lymphoma, presents with patches, plaques, acneiform lesions, palpable tumours and/or erythroderma, a clinical constellation that makes diagnosis difficult. Since neoplastic T-lymphocytes display tropism towards follicular epithelium, the head and neck are frequently involved, with alopecia a common sequela [15]. Sonography shows skin thickening, hypoechogenicity of the upper dermis and hair follicles with large surrounding hyperechoic deposits (Figure 16).

Conclusion

Colour Doppler ultrasound is a useful non-invasive tool for the evaluation of complex pathologies of the scalp and hair. This imaging tool also provides a new window into the pathogenesis of these highly multifaceted and distressing disorders of the skin.

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