Assessment of Cutaneous Radiation Fibrosis by 20 MHz-Sonography

P. GOTTLÖBER[1], N. NADESHINA[2], O. BRAUN-FALCO[1], G. PLEWIG[1], M. KERSCHER[1], R.U. PETER[1]
[1]*Department of Dermatology, Ludwig-Maximilians-University, Munich, Germany*
[2]*Institute of Biophysics, Clinical Department, Moscow, Russia*

Abstract. Radiation fibrosis is the cardinal symptom of the chronicle stage of the cutaneous radiation syndrome. The degree of cutaneous fibrosis can clinically be estimated by palpation. High-frequency 20 MHz-sonography is an established, noninvasive procedure, which renders an exact determination of skin thickness and additionally densitometry is possible. We investigated 15 survivors of the Chernobyl accident in 1986, who developed symptoms of the chronical stage of the cutaneous radiation syndrome. We determined skin thickness and echogenicity of skin areas clinically suggestive of radiation fibrosis before, during and after treatment. 20 MHz-sonography showed a distinct enlargement of the echorich corium and a reduction of the subcutaneous fatty tissue in comparison with the unaffected, contralateral skin, here demonstrating typical features of radiation fibrosis, namely dermal fibrosis and reactive pseudoatrophy and fatty tissue. The histology presented an increase and swelling of the collagen fibers and atypical fibroblastic cells. The patients received treatment with low-dose interferon y (Polyferon ^{R}, 3 x 50 µg s.C., three times per week) up to 30 months. A marked reduction of skin thickness and echogenicity reaching nearly normal values could be observed. We conclude that 20 MHz-sonography is an easy to apply, noninvasive, well established procedure to quantify cutaneous radiation fibrosis and to assess therapeutic outcome.

1. Introduction

Cutaneous radiation fibrosis, a symptom of the chronicle stage of the cutaneous radiation syndrome [1,2], is caused by an increase of collagenous connective tissue.. It is of clinical importance as severe fibrosis can lead to functional impairment, contractures and secondary ulcerations [3]. The degree of cutaneous fibrosis can clinically only be estimated by palpation. Histologic examination is of limited applicability, as fibrotic skin has a decreased vascularization and does not heal easily.

Other procedures for determination of cutaneous radiation fibrosis like nuclear magnetic resonance tomography and positron emission tomography are time-consuming and expensive. Computer tomography is associated with an additional radiation load for the patients.

Therefore a noninvasive method which allows a quantitative determination of the extent of cutaneous radiation fibrosis after exposure to ionizing radiation is needed.

The 20 MHz-B-Scan-ultrasound is a well established procedure for three-dimensional imaging of morphology and topography of cutaneous structures, which proved to be highly reproducible in the hands of experienced examinators [4]. It has been used for skin thickness measurements in patients with localized and progressive systemic scleroderma [5] and for evaluation of drug effects on the skin [6]. Furthermore, sonometric measurements of tumor thickness in patients with basal cell carcinoma [7] and malignant melanoma [8] have been performed.

Here we report on the experience in the follow-up of survivors of the Chernobyl accident with severe radiation-induced skin damage by this diagnostic method.

2. Patients and methods

15 male survivors of the Chernobyl nuclear power plant accident in 1986, suffering from the chronical stage of the cutaneous radiation syndrome, were examined in our department in 1991 and during the following four years. Telangiectases, radiation keratoses, radiation ulcers, atrophy, hypo- and hyperpigmentation, hemangiomas and hematolymhangiomas were noted (2). Additionally, a marked induration on the exposed skin areas in 8 of the 15 survivors could be determined. According to the clinical investigation fibrotic skin areas were selected and examined by 20 MHz-B-scan-ultrasound before during and at the end of treatment with low-dose interferon y (Polyferon ^{R}, 3 x 50 µg per week). Furthermore, biopsies were taken of selected cutaneous areas at the beginning and the end of therapy.

Histologic examination revealed the typical histological signs of cutaneous radiation damage like orthohyperkeratosis, flattening of epidermis, i.e. loss of papillary folds and an increase of collagenous fibers with atypical fibroblastic cells. The collagenous fibers were swollen.

Ultrasound measurements including A-scans, sum A-scans and B-scans were performed by the DUB 20 S, a digital ultrasound imaging system (tpm, Lüneburg, Germany) The 20 MHz-scanner with an axial resolution of about 80 µm and a lateral resolution of 200 µm is suitable to investigate epidermis, corium and subcutaneous fat tissue up to a depth of about 10 mm. All fibrotic areas of the examined patients were sonographically compared with contralateral, nonaffected sites. Skin thickness was determined as distance extending from the entry echo to the output echo representing the border between the deepest coral region and the subcutaneous fat tissue.

3. Results

The sonographic image of the involved skin showed under the entry echo a very echorich, corium considerable increased thickness. Furthermore, some isles of echorich spots were seen in the subcutaneous fat tissue, presenting enhanced collagenous septs. Additionally the echolucent space between the echo of the corium and echo of the muscle fascia was markedly reduced, presenting pseudoatrophy of fatty tissue caused by proliferative coral fibrosis.

Ultrasound B-mode images of radiation fibrosis revealed increased thickness of the corium from 27 % to 98 % in comparison with the uninvolved skin before treatment . The skin density was increased to 40 % of the normal value.

In two patients who didn't tolerate the therapy and topped the treatment after the first injection, a progression of cutaneous radiation fibrosis from 67 % to 200 % could be determined sonographically during 30 months. In these patients treated with interferon y there was a reduction of skin thickness during therapy and an approximation to the normal skin thickness. The values decreased from 26 % to 64 % compared with initial thickness before treatment after 30 months of therapy. Furthermore, there was a normalization of the skin density. The details of the therapeutic experience are published elsewhere (Peter et al submitted).

Conclusion

Radiation fibrosis develops after exposure to ionizing radiation in various tissues and is of eminent clinical significance, as the extent and progression of radiation fibrosis determines the clinical outcome [9].

Information about changes of the corium, subcutis and muscle fascia represent important data with regard to quality and quantity of the fibrotic process which has not been available until now. The 20 MHz-B-scan-ultrasound is an available, noninvasive and well reproducible procedure for determining the thickness and density of the fibrotic skin. There is a good agreement of the sonometrically and histometrically obtained skin thickness values. The 20 MHz-B-scan-ultrasound should be considered in the routine follow-up procedures for determination of the clinical course of cutaneous radiation damage. Furthermore, it should be used to assess the clinical course and to evaluate the therapeutic results.

References

[1] R.U. Peter, Klinische Aspekte des kutanen Strahlensyndroms nach Strahlenunfällen-Erfahrungen nach Goiania und Tschernobyl, Akt Dermatol 19 (1993), pp. 364-367.

[2] R.U. Peter, O. Braun-Falco, A. Birioukov, N. Hacker, M. Kerscher, U. Petersheim, T. Ruzicka, B. Konz, G. Plewig, Chronic cutaneous damage after accidental exposure to ionizing radiation: The Chernobyl experience, J Am Acad Dermatol 30 (1994), pp. 719-723.

[3] O. Braun-Falco, G. Plewig, H.H. Wolff, R.K. Winkelmann, Dermatology. Berlin, Springer, 1991.

[4] M.J. Stiller, J. Driller, J.L. Shupack, C.G. Gropper, M.C. Rorke, F.L. Lizzi, Three-dimensional imaging for diagnostic ultrasound in dermatology, J Am Acad Dermatol 29 (1993), pp.171-175.

[5] K. Hoffmann, U. Gerbaulet, S. el Gammal, P. Atlmeyer, 20 MHz-B-mode ultrasound in monitoring the course of localized scleroderma (morphea), Acta Derm Venereol 164 (1991), pp. 3-16.

[6] M. Kerscher, H.C. Korting, Topical glucocorticoids of the non-fluorinated double-ester type: Lack of atrophogenicity in normal skin as assessed by high-frequenced ultrasound, Acta Derm Venereol 72 (1992), pp. 214-216.

[7] K. Hoffmann, K. Winkler, S. el Gammal, P. Altmeyer, A wound healing model with sonographic monitoring, Clinical and Experimental Dermatology 18 (1993), pp. 217-225.

[8] K. Hoffmann, J. Jung, S. el Gammal, P. Altmeyer, Malignant melanoma in 20 MHz-B scan sonography, Dermatology 185 (1992), pp. 49-55.

[9] E. Scherer, C. Streffer, R. Trott: Radiopathology of organs and tissues. Berlin, Springer, 1990.