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**Volume 53, Issue 6**, Pages 993-1001  
(December 2005)

◀ [previous](#) 19 of 62 [next](#) ▶

## Soft x-ray therapy for cutaneous basal cell and squamous cell carcinomas

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### Background

We have used a schedule for soft x-ray therapy of epithelial malignancies that takes into account the clinically diagnosed tumor involution under treatment.

### Objective

We sought to evaluate the effectiveness of this schedule in terms of cure rate and late ulcerations.

### Methods

Patients with 1267 consecutively irradiated (1988-1992) basal cell and squamous cell carcinomas were followed up (average 77 months).

### Results

The recurrence rate (5.1%) was related to tumor size and thickness and to the time-dose-fractionation factor. The frequency of ulcerations (6.3%) depended on field size, hardness of the x-rays, and in smaller fields (diameter up to 4 cm) on total dose, and time-dose-fractionation factor. Of all ulcerations, 82.5 % could be conservatively cured.

### Limitations

We have no evidence that our radiation schedule is superior to those published by other authors.

### Conclusion

These results verify the usefulness of soft x-ray therapy for cutaneous epithelial malignancies.

## Article Outline

- [Abstract](#)
- [Patients and methods](#)
- [Soft x-ray therapy](#)
- [Follow-up](#)
- [Statistical analysis](#)
- [Results](#)
- [Tumor involution under treatment](#)

ABSTRACT
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- [Recurrence rate](#)
- [Ulcerations in the irradiated field](#)
- [Changes with cosmetic relevance in irradiated fields](#)
- [Metastases](#)
- [Discussion](#)
- [Acknowledgment](#)
- [References](#)
- [Copyright](#)

Favorable risk/benefit ratios of radiotherapy for skin tumors have been reported by other authors,<sup>1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39</sup> even in recent years.<sup>7, 34, 35, 36, 37, 38, 39</sup> We have used a soft x-ray therapy schedule that takes into account the tumor involution under treatment. Basal cell carcinomas (BCCs) were irradiated with  $9 \times 5$  Gy and squamous cell carcinomas (SCCs) with  $12 \times 5$  Gy. If complete tumor involution and a beginning erosive reaction could not be clinically diagnosed after these doses, we continued our treatment one to two times per week. Our total doses are higher than those recommended by other authors. We report herein our retrospective experience with this schedule in terms of recurrence rates and frequency of late ulcerations.

## Patients and methods

 [return to article outline](#)

### *Soft x-ray therapy*

By definition, soft x-rays are produced by using tube voltages of 20 to 100 kV.<sup>40</sup> Their hardness is determined by the voltage and a filter of beryllium or aluminum. The penetration of the soft x-rays can be characterized by the half-value depth,<sup>40</sup> the distance from the skin surface to the point at which half of the surface dose has been absorbed. The half-value depth depends on the hardness of the x-rays, the size of the irradiated field, and the distance between x-ray tube and skin. Soft x-rays cannot penetrate cartilage or bone. Grenz rays are produced with 5 to 20 kV, superficial x-rays with 60 to 100 kV, and orthovoltage x-rays with 200 to 400 kV.

Treatments were performed with an RT-100 x-ray machine (10-100 kV) (Müller-Philips; Hamburg, Germany). Half-value depths resulting from the different combinations of cones, voltages, and filters of this unit range from 0.3 to 33 mm. The relation between tube voltages and half-value depth is illustrated by the following values for a round field with a diameter of 5 cm (distance between radiation tube and skin, 10 cm): 45 kV gives a half-value depth of 5.7 mm; 70 kV, 11.5 mm; and 100 kV, 15.7 mm.

Diagnoses were histologically or cytologically confirmed.<sup>41</sup> If the tumor margin was not visible, it was determined by several biopsies. The safety zone was always 1 cm irrespective of the size of the tumor. The irradiated field was exactly demarcated by a lead shield made for each case.

The tumor thickness was estimated either by palpation or determined histologically or by use of 20 MHz ultrasound. The exactly determined tumor thickness was usually lower than the estimated one. We therefore chose a half-value depth that was equal to the estimated tumor thickness or, if we calculated on the basis of an exactly determined thickness, a half-value depth that resulted in 80% of the surface dose at the bottom of the tumor.

Of all tumors, 78.1% were treated with 5 Gy per fraction. Smaller doses per fraction were mainly used for thicker and larger tumors. Outpatients were irradiated 2 to 3 times per week and patients admitted to the clinic were irradiated 6 times per week.

From 1988 through 1992 we consecutively irradiated 560 men and 553 women with 1019 BCCs, 245 SCCs, and 3 patients with combinations of BCCs and SCCs. Fifteen patients with

BCCs, one case of SCC, and the 3 patients with combined malignancies had two or more tumors in close proximity. Five of these cases and 12 of the single tumors were treated with two adjacent fields. One BCC had been surgically removed before therapy so that only the safety margin had to be irradiated. The tumor (T) classification was done according to the system of the International Union against Cancer<sup>42</sup>: TX: cannot be assessed; T0: no evidence of tumor; Tis: in situ; T1:  $\leq 2$  cm; T2:  $>2$  cm and  $\leq 5$  cm; T3:  $>5$  cm; T4: invades deep extradermal structures. The distribution of T class (Tis or T1 vs T2 or T3) and tumor thickness (half-value depth) was significantly different ( $\chi^2$  test:  $P < .01$ ) between BCCs and SCCs: 38.7% of the treated BCCs were T2 or T3 tumors versus 61.9% of the SCCs. Of all thin tumors (treated with a half-value depth of  $\leq 7$  mm), 84.8% were BCCs versus 82.6% of tumors with intermediate thickness (half-value depth:  $>7$ -12 mm) and 31.6% of all thick tumors (half-value depth:  $>12$  mm). A significantly higher percentage of thicker BCCs and SCCs was treated in men compared with women; the difference was more pronounced for SCCs compared with BCCs: 75.0% of the thicker SCCs (half-value depth  $>12$  mm) were irradiated in male patients versus 54.2% of the thicker BCCs.

Fifty-five BCCs and 12 SCCs had been previously treated and they recurred before radiotherapy. All other malignancies in this study were previously untreated (primary) tumors.

Fifty-six of the irradiated 1113 patients (5.0%) were younger than 60 years of age, 284 (25.7%) were 60 to 69 years old, 438 (39.4%) were from 70 to 79 years old, 291 (26.2%) were 80 to 89 years old, and 44 (4.0%) were 90 years of age and older.

Ten tumors were treated twice weekly, 570 treated 3 times per week, and 687 treated 6 times per week with doses per fraction of 3.5 or 5 Gy, depending on the size of the tumor. If residual tumor was still visible or palpable or if no erosive reaction had developed after total doses of 45 Gy for BCCs and 60 Gy for SCCs, the treatment was continued; BCCs were irradiated twice weekly with 5 Gy up to 55 Gy and then once weekly with 5 Gy and SCCs irradiated once weekly with 5 Gy until we saw complete tumor involution and a beginning erosive reaction. Seventy-one tumors (5.6%) were irradiated with total doses of 35 to 45 Gy, 176 (13.9%) with more than 45-51 Gy, 493 (38.9%) with more than 51-60 Gy, 387 (30.5%) with more than 60-70 Gy, 99 (7.8%) with more than 70-80 Gy, and 41 (3.2%) with more than 80 Gy. The average total dose for BCCs was 61.0 Gy; for SCCs, 63.6 Gy; for tumors treated two or three times per week, 61.5 Gy; and for those irradiated 6 times per week, 61.4 Gy. Treatment was usually stopped after application of 85 Gy. If a partial tumor involution and a beginning erosive reaction could be recognized, we reduced the size of the irradiated field. If the reduced largest diameter was less than 1.5 cm, we continued the treatment even after application of 85 Gy. Nineteen fields (1.5%), which had been reduced to a size of less than 1.5 cm, were irradiated with a total dose of  $>85$ -101.5 Gy (average 92.6 Gy).


#### *Follow-up*

Irradiated fields were followed up for an average period of 77 months (range, 0-181 months; median, 82 months). Of all irradiated fields, 87.6% were followed up for at least 5 years or up to the death of the patient (last information  $<100$  days before the death). Of 1267 irradiated fields, 1042 (82.2%) were examined at least once in the follow-up period in our clinic; 98 of the remaining fields (7.8% of all treated tumors) were examined at least once by a local physician, for 90 fields (7.1%) we only have information from the patients themselves or their relatives, and for 37 fields (2.9%) we have no follow-up information. Twenty-two of the 37 tumors (59.5%) for which we have no follow-up information were from 13 patients, who died within 1 year after treatment. One to 2 years after treatment we had obtained 72.9% of the information by 478 examinations in the clinic, 18.8% by 123 reports from local physicians, and 8.4% by 55 letters or phone calls from the patients or their relatives. Nine to 10 years after treatment the corresponding percentages were 10.8%, 35.7%, and 53.5%, respectively.

#### *Statistical analysis*

Observed differences were statistically analyzed by the  $\chi^2$  test.<sup>43</sup> The raw recurrence rate is obtained by dividing the number of recurrences by the total number of treated tumors.<sup>22</sup> The cumulative recurrence rate is calculated by a modified life-table method including the calculation of an annual recurrence rate after adjusting for patients lost to follow-up.<sup>22</sup>

## **Results**

 [return to article outline](#)

#### *Tumor involution under treatment*

Nine hundred fifty-one BCCs (93.3%), 223 SCCs (91%), and two combinations of BCCs and SCCs had a clinically complete regression, 44 tumors (3.5%) had not, although 80 to 101.5 Gy had been applied in 26 of these cases. In 47 cases (3.7%) residual tumor could not be excluded at the end of the treatment.

#### Recurrence rate

Sixty-five tumors (5.1%) recurred: 46 BCCs (4.5%), 17 SCCs (6.9%) and two combinations of BCCs and SCCs (Table I). Four of these recurrences were only suspected, not proven. Twenty-five recurrences were found in the irradiated field (2.0% of treated tumors) and 31 (2.4 %) at its margin; for 9 recurrences no information regarding localization was available. Raw and cumulative recurrence rates<sup>22</sup> were higher for SCCs compared with BCCs, for malignancies with a higher T-class (except SCC Tis), and for tumors that had been treated and that recurred before radiotherapy compared with previously untreated tumors (Table I). Tumor thickness and time-dose fractionation factor (TDF)<sup>44</sup> were related to the recurrence rate of epithelial malignancies (combined evaluation of BCCs and SCCs; Table II). The influence of both parameters on the recurrence rate of BCCs compared with that of SCCs was different or could not be evaluated because the numbers were too low in some subgroups (Table II; Figs 1 and 2). Total dose, the number of treatments per week, gender, and age of the patient were not significantly related to the recurrence rate of BCCs and SCCs; the dose per fraction was not an independent factor (Table II). A significantly higher ( $\chi^2$  test:  $P < .01$ ) recurrence rate of T2 and T3 epithelial malignancies and of thicker ones was also observed when only recurrences in the irradiated field, not at its margin, were taken into account. Five recurrences (19%) were observed among the 26 tumors that had not completely regressed up to the end of the treatment despite total doses of 80 Gy or higher.

Table I. Raw and cumulative recurrence rates of BCCs and SCCs after soft x-ray therapy

Tumor	No.	Recurrence rates (%)			
		Raw*	Cumulative* after		
			5 y	10 y	15 y
BCCs and SCCs, total <sup>†</sup>	1267	5.1	4.7	6.9	7.4
BCCs, total	1019	4.5	4.2	6.1	6.1
T1 <sup>‡</sup>	615	2.4 <sup>§</sup>	3.9	4.7	4.7
T2 <sup>‡</sup>	366	5.2 <sup>§</sup>	4.2	8.6	8.6
T3 <sup>‡</sup>	22	9.1 <sup>§</sup>	11.4	11.4	
Previously untreated (primary)	964	4.4	4.2	5.7	5.7
Previously treated and recurrent	55	7.3	4.3	13.2	13.2
SCCs, total	245	6.9	6.0	10.5	12.8
Tis <sup>‡</sup>	13	7.7 <sup>  </sup>	11.1		
T1 <sup>‡</sup>	79	1.3 <sup>  </sup>	1.7	1.7	1.7
T2 <sup>‡</sup>	138	8.7 <sup>  </sup>	7.4	14.2	19.0
T3 <sup>‡</sup>	14	21.4 <sup>  </sup>	25.9	25.9	
Previously untreated (primary)	233	6.4	5.8	9.6	12.0
Previously treated and recurrent	12	16.7	30.0	30.0	

\*

Raw and cumulative recurrence rates were calculated according to method of Silverman et al.<sup>22</sup>

<sup>†</sup>

Including 3 patients with combinations of BCCs and SCCs.

<sup>‡</sup>

Multiple (>1) tumors in the same irradiated field were excluded.

§

Differences of the raw recurrence rate of BCCs T1-T3 were statistically significant ( $\chi^2$ , 6.99;  $P < .05$ ).

||

Differences of the raw recurrence rate of SCCs Tis-T3 were statistically significant ( $\chi^2$ , 9.13;  $P < .05$ ).

Table II. Influence of different parameters on the recurrence rate of BCCs and SCCs

Parameter	BCCs and SCCs (n = 1267)*	BCCs (n = 1019)	SCCs (n = 245)
Localization†	NS‡	NS‡	Undecided§
Half-value depth (tumor thickness)	SS‡ ( $P < .01$ )	NS‡	SS‡ ( $P < .01$ ; Fig 1)
TDF factor¶	SS‡ ( $P < .01$ )	SS‡ ( $P < .01$ ; Fig 2)	Undecided§
Dose per fraction	SS‡,# ( $P < .01$ ); not independent**	SS‡,# ( $P < .01$ ); not independent††	Undecided§

NS, No statistical significance; SS, statistically significant.

\*

Including 3 combinations of BCC and SCC.

†

Seven subgroups as in Table V.

‡

$\chi^2$  test.

§

The number of cases in some subgroups was too low for evaluation by the  $\chi^2$  test.

||

Subgroups:  $\leq 7$  mm,  $>7$ -12 mm,  $>12$  mm.

¶

Subgroups:  $\leq 140$ ,  $>140$ .

#

The recurrence rate after  $\leq 3.5$  Gy/fraction was significantly higher compared

with 4-5 Gy/fraction.

\*\*

Thicker epithelial malignancies were significantly ( $\chi^2$  test:  $P < .05$ ) more frequently irradiated with  $\leq 3.5$  than with 4-5 Gy/fraction.

††

T2 and T3 BCCs compared with T1 BCCs were significantly ( $\chi^2$  test:  $P < .01$ ) more frequently treated with  $\leq 3.5$  than with 4-5 Gy/fraction.

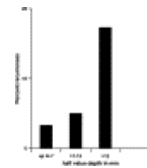


Fig 1. Recurrence rate of SCCs after soft x-ray therapy was significantly related to half-value depth of applied x-rays, which corresponded to half value depth ( $\chi^2$ , 11.2; degrees of freedom, 2;  $P < .01$ ; number of cases: tumor thickness  $\leq 7$  mm, 92;  $>7-12$  mm, 101;  $>12$  mm, 52).

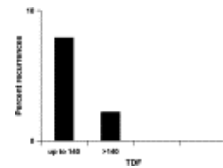


Fig 2. Recurrence rate of BCCs after soft x-ray therapy was significantly related to TDF ( $\chi^2$  18.27; degrees of freedom, 1;  $P < .01$ ; number of cases: TDF  $\leq 140$ , 393;  $>140$ , 626).

In addition, 5-year cure rates were calculated according to Mohs and Zitelli<sup>45</sup>: fields irradiated for 792 of 1267 epithelial tumors (669/1019 BCCs, 122/245 SCCs, and 1/3 mixed tumors) remained recurrence free within 5 years after therapy. Four hundred twenty-three cases after therapy of epithelial tumors (313 after treatment of BCCs, 110 after irradiation of SCCs) were indeterminate; patients either died (28.9 % of all epithelial tumors, 25.6% of BCCs, 42.9% of SCCs) or they were lost to follow-up within 5 years after therapy, but during their follow-up they were free of recurrences. Five-year cure rates (recurrence-free cases divided by all cases minus undetermined cases) were as follows: 93.8% (792/844) for all epithelial tumors, 94.8 % (669/706) for BCCs, and 90.4% (122/135) for SCCs.

Development of recurrent tumor after therapy was as follows: 42 recurrences (65%) up to 3 years, 15 (23%)  $>3-6$  years, 5 (8%)  $>6-9$  years, and 3 (5%)  $>9-12$  years. We have attempted to classify the management of tumor recurrences with respect to the burden for the patients (Table III). Of the recurrent tumors, 27.7% were problematic, corresponding to 1.5% of the originally irradiated fields. They could not be treated at all or they could only be cured by means associated with a severe burden for the patients (Table III, class 3 and 4).

Table III. Management of tumor recurrences after radiation treatment, classified with respect to the burden for the patients (BCCs and SCCs)

	Cases	Cured

Class	Treatment	No.	%*	No.	%*
0	No treatment because of comorbidities or refusal of patient	7	10.8		
1	Surgery with patient under local anesthesia	21	32.3	20	30.8
2	Regional or free flaps and/or 2 operations and/or general anesthesia	25	38.5	23	35.4
3	Skin-muscle or tunnel flap or microsurgery or skin expander or >2 operations	6 <sup>†</sup>	9.2	3	4.6
4	Permanent defect after surgery, epithesis <sup>‡</sup>	5 <sup>§</sup>	7.7	4	6.2
	No information regarding treatment of recurrent tumor	1	1.5		
	Total	65	100.0	50	76.9

\*

Percentage of all recurrences.

<sup>†</sup>

No follow-up information after treatment for two cases.

<sup>‡</sup>

Epithesis: prosthetic replacement of an exterior part.

<sup>§</sup>

No follow-up information after treatment for one case.

<sup>||</sup>

Follow up of the 50 cured tumors: 44 days: 1; &gt;2-4 years: 8; &gt;4-8 years: 20; &gt;8-14 years: 21.

#### *Ulcerations in the irradiated field*

The acute radiation reaction usually regresses within 4 weeks. An ulceration or erosion was observed later than 8 weeks after the end of therapy in 80 irradiated fields (6.3%). Of all ulcerations, 82.5% could be cured by ointments (usually containing gentamicin) and moist compresses or they healed spontaneously (Table IV). Only 12 ulcerations corresponding to 0.9% of the originally irradiated fields were problematic because they recurred, had to be operated on with the patient under general anesthesia, or could not be cured at all. In all irradiated fields the frequency of ulcerations was significantly related ( $\chi^2$ :  $P < .01$ ) to the half-value depth (corresponding to the tumor thickness), the largest diameter of the irradiated field ( $\chi^2$ :  $P < .05$ ), the localization (scalp and lips, >10%; Table V), and in fields with the largest diameter of up to 4 cm subjected to total dose, and TDF ( $\chi^2$ :  $P < .01$ ). The localization had a significant influence after radiotherapy of BCCs and SCCs, although relative frequencies were different (Table V); a higher half-value depth (tumor thickness) was related to a higher frequency of ulceration after therapy of SCCs (Fig 3), but not after treatment of BCCs, whereas the largest diameter of the irradiated field was significant after therapy of BCCs (Fig 3), but not of SCCs. TDF and total dose were significant in larger fields after irradiation of BCCs (Fig 4). Both parameters could not be statistically evaluated after treatment of SCCs because numbers were too low in some subgroups. Age and dose per fraction were not related to the frequency of ulcerations. Gender was a significant, but not independent, factor after treatment of SCCs; a higher percentage of thicker SCCs had been irradiated in men than in women. Five ulcerations (12.2%) were observed in the 41 fields that had been treated with more than 80 Gy. One ulceration (1%) developed 2 months after therapy, 49 ulcerations (61%) 3 months up to 3 years, 20 (25%) more than 3 and up to 6 years, 7 (9%) more than 6 and up to 9 years, 1 (1%) more than 9 and up to 12 years, and 2 (2%) more than 12 and up to 15 years after therapy.

Table IV. Management and cure rates for ulcerations in irradiated fields\*

Class	Treatment	No. of cases	Cured No. % <sup>‡</sup>	Recurred No. % <sup>‡</sup>
0	No treatment (comorbidities)	5	—	—
1	Conservative treatment <sup>‡</sup>	66	66 5.24	0.3
2	Surgery with patient under local anesthesia	2	2 0.20	
3	Surgery with patient under general anesthesia	2	2 0.21	0.1
	No information	5	—	—
	Total	80	70§5.65	0.4

\*

Treatments were classified with respect to the burden for the patients.

‡

Percentage of irradiated fields.

‡

Included 3 cases that probably healed spontaneously.

§

Forty-six of the 65 cured ulcers without recurrence were followed up: 10 for 0.3-3 years, 17 for >3-6 years, and 19 for >6-10 years.

Table V. Frequency of ulcerations in irradiated fields in relation to localization\*

Localization	Treated tumors					
	BCCs and SCCs <sup>‡,‡</sup>		BCCs <sup>§</sup>		SCCs <sup>  </sup>	
	No. ¶	%#	No. ¶	%#	No. ¶	%#
Scalp	48	14.6	29	20.7	19	5.3
Lips	96	10.4	41	0	55	18.2
Ears**	121	9.1	76	6.6	45	13.3
Forehead and temple	207	8.2	155	9.0	52	5.8
Nose	489	5.3	452	5.1	36	8.3
Cheek and chin	154	3.9	126	4.0	28	3.6
Periorbital region	144	2.1	133	2.3	10	0
Total	1259	6.4	1012	5.5	245	9.8

\*

Six larger irradiated fields of the face and two fields of the neck not included.

‡

Including two combinations of BCCs and SCCs.

‡

The differences were statistically significant ( $\chi^2: 17.71$ ;  $P < .01$ ).

§

The differences were statistically significant ( $\chi^2: 22.43$ ;  $P < .01$ ).

||

The difference between nose, lips, and ears (combined values) and all other localizations was statistically significant ( $\chi^2: 6.03$ ;  $P < .05$ ); localizations could not be separately evaluated because numbers were too low in some subgroups.

¶

Number of irradiated fields.

#

Percentage of irradiated fields with ulceration.

\*\*

Including retroauricular lesions.

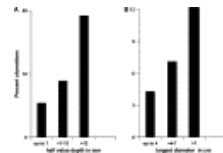


Fig 3. Percentage of ulcerations after soft x-ray therapy was significantly related (**A**) in fields after treatment of SCCs to half-value depth of applied x-rays ( $\chi^2, 7.31$ ;  $P < .05$ ), which corresponded to tumor thickness ( $\leq 7$  mm, 92 [number of cases];  $> 7$ -12 mm, 101;  $> 12$  mm, 52) and (**B**) in fields after treatment of BCCs to largest diameter of irradiated area ( $\chi^2, 10.76$ ;  $P < .05$ ;  $\leq 4$  cm, 680;  $> 4$ -7 cm, 309;  $> 7$  cm, 30).

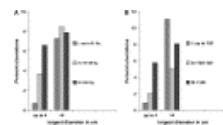


Fig 4. Percentage of ulcerations in follow-up period in relation to (**A**) total dose and (**B**) TDF in irradiated fields of different size after treatment of BCCs. Influence of applied total dose and TDF was statistically significant in irradiation fields with largest diameter of up to 4 cm (columns at left: **A**,  $\chi^2, 8.8$ ;  $P < .05$ ; **B**,  $\chi^2, 7.26$ ;  $P < .05$ ), but not in fields with largest diameter of more than 4 cm (columns at right in **A** and **B**). Number of cases: **A**:  $\leq 4$  cm: I, 151; II, 241; III, 288;  $> 4$  cm: I, 82; II 117; III, 140. **B**:  $\leq 4$  cm: I, 111; II, 141; III, 428;  $> 4$  cm: I, 63; II, 78; III, 198.


#### Changes with cosmetic relevance in irradiated fields

Hypopigmentation was observed at least once in the follow-up period in 72.7% of 1013 irradiated fields, telangiectases in 51.5%, erythema in 44.5%, and hyperpigmentation in 23.4%. We do not know whether the observed hypopigmentation was temporary or permanent.

### Metastases

In 10 of the 231 patients (4.3%) irradiated for SCCs, metastases developed. The 10 primary tumors were localized on the lower lip (n = 2), the forehead (n = 2), the auricle (n = 1), the upper lip (n = 1), the cheek (n = 1), the nose (n = 1), the temple (n = 1), and behind the auricle (n = 1). Five patients died of their metastases (7, 17, 27, 28, and 29 months after the end of therapy).

## Discussion


 [return to article outline](#)

Vascularity and oxygen supply differ even between tumors of the same histologic type.<sup>46</sup> This can influence the response to radiotherapy. Less radiosensitive tumors may be insufficiently irradiated. We try to avoid this problem by varying the total dose according to the observed involution of the tumor undergoing therapy and the development of an erosive reaction. The characteristics of our treatment schedule have been published.<sup>6, 11, 47, 48</sup> Herein we report the results of 1267 consecutively treated cases. Some authors use fractionation schedules with definite total doses; others vary the total dose.<sup>8, 9, 32, 34</sup> The tumor regression under treatment<sup>15</sup> or the development of erythema<sup>23</sup> is taken into account. Some drawbacks of our approach have to be admitted; we cannot monitor the complete degeneration of the tumor under treatment with exact precision. A scar or other more solid tissue cannot be unequivocally differentiated from residual tumor by inspection and palpation. A slow tumor regression after a sufficient treatment cannot be excluded. Do we achieve higher cure rates with our approach? Published overall cure rates vary between 71% and 99%\*; most studies report higher than 90%. Our cure rates at 5 years<sup>45</sup> (94.8% for BCCs and 90.4% for SCCs) are within this relatively wide range. Published cumulative 5 year recurrence rates for subgroups agree with our results.<sup>23</sup> Our findings confirm results of earlier studies: higher cure rates of BCCs compared with SCCs,<sup>8, 9, 15, 18, 36</sup> of previously untreated tumors compared with previously treated and recurrent ones,<sup>8, 9, 15, 23, 34, 35, 36</sup> and of smaller malignancies or those with a lower T-class or stage.<sup>†</sup> Tumor thickness (half-value depth) and field size had a different influence on recurrences and ulcerations after treatment of BCCs compared with SCCs. The higher tumor thickness and the lower number of SCCs in our series may be responsible for these differences.

Of all treated tumors, 2.4% recurred at the margin of the irradiated field. This percentage is not high enough to generally recommend a safety zone broader than 1 cm. However, additional biopsies should be performed to better define the tumor border if it cannot be unequivocally recognized by inspection and palpation. Moreover, biopsies may be useful for tumors with a larger subclinical extension, for example, fibrosing BCCs with a diameter greater than 20 mm<sup>49</sup> and SCCs with a diameter greater than 20 mm on the scalp, ears, eyelids, and lips.<sup>50</sup>


Compared with other investigators,<sup>8, 17, 25</sup> our total doses are often higher. Does this result in a higher frequency of ulcerations in the irradiated fields during the follow up period? The ulceration frequency reported in previous studies ranges from 0.35% to 9.4%<sup>1, 12, 15, 29, 30, 51</sup>; we observed an ulceration frequency of 6.3%. In our study 77.5% of the ulcerations could be permanently cured by ointments and moist compresses or they healed spontaneously. In only 0.9% of the irradiated fields did problematic ulcerations develop that recurred, could not be treated at all, or had to be surgically treated with the use of general anesthesia. Ulcerations in the irradiated field are combined injuries<sup>52, 53, 54</sup>; in addition to the irradiation, other factors, such as sunlight exposure, allergies, or insect stings, play a role. We have therefore observed ulcerations occurring after irradiation with total doses as low as 51 Gy or less and with a TDF of 105 or less.

We conclude that our results, especially the relatively high cure rates, demonstrate the efficacy of soft x-ray therapy for cutaneous BCCs and SCCs. Our data do not indicate that our radiation schedule is superior to those published by other groups. Similar results might be obtained with a randomized trial.

 [return to article outline](#)

We thank Dr Klaus Ernst for performing part of the soft x-ray treatments; Ms Anne Allkämper, Ms Maria Middendorf, and Ms Barbara Setter for technical assistance; and Mr Graham Wilson, BEd, MA, Englisches Seminar der Universität Münster, for reviewing the manuscript with respect to style and grammar.

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 [return to article outline](#)

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From Fachklinik Hornheide.

Funding sources: None.

Conflict of interest: None identified.

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PII: S0190-9622(05)02325-X

doi:10.1016/j.jaad.2005.07.045

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