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Sensor-controlled scalp cooling to prevent chemotherapy-induced alopecia in female cancer patients

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ABSTRACT

Background Scalp cooling has been used since the 1970s to prevent chemotherapy-induced alopecia, one of the most common and psychologically troubling side effects of chemotherapy. Currently available scalp cooling systems demonstrate varying results in terms of effectiveness and tolerability.

Methods For the present prospective study, 55 women receiving neoadjuvant, adjuvant, or palliative chemotherapy were enrolled. The aim was to assess the effectiveness of a sensor-controlled scalp cooling system (DigniCap: Sysmex Europe GmbH, Norderstedt, Germany) to prevent chemotherapy-induced alopecia in breast or gynecologic cancer patients receiving 1 of 7 regimens. Clinical assessments, satisfaction questionnaires, and alopecia evaluations [World Health Organization (WHO) grading for toxicity] were completed at baseline, at each cycle, and at completion of chemotherapy.

Results Of the 55 patients, 78% underwent scalp cooling until completion of chemotherapy. In multivariate analysis, younger women and those receiving paclitaxel weekly or paclitaxel–carboplatin experienced less alopecia. The compound successful outcome ("no head covering" plus "WHO grade 0/1") was observed in all patients 50 years of age and younger receiving 4 cycles of docetaxel–cyclophosphamide or 6 cycles of paclitaxel–carboplatin. Conversely, alopecia was experienced by all women receiving triplet polychemotherapy (6 cycles of docetaxel–doxorubicin–cyclophosphamide). For women receiving sequential polychemotherapy regimens (3 cycles of fluorouracil–epirubicin–cyclophosphamide followed by 3 cycles of docetaxel or 4 cycles of doxorubicin–cyclophosphamide followed by 4 cycles of docetaxel), the subgroup 50 years of age and younger experienced a 43% success rate compared with a 10% rate for the subgroup pf older women receiving the same regimens.

Conclusions The ability of scalp cooling to prevent chemotherapy-induced alopecia varies with the chemotherapy regimen and the age of the patient. Use of a compound endpoint with subjective and objective measures provides insightful and practical information when counselling patients.

Key Words Chemotherapy-induced alopecia, sensor-controlled scalp cooling, breast cancer, ovarian cancer

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INTRODUCTION

Scalp cooling has been used for approximately 40 years to prevent chemotherapy-induced hair loss[1]. Temporary chemotherapy-induced alopecia, one of the most common and distressing side effects of chemotherapy treatment, can lead to a negative body image, lower self-esteem, sexual impairment, severe depression, anxiety, and disturbances in social relationships[2]. Fear of hair loss and the associated distress can even result in refusal to undergo appropriate chemotherapy treatment[3].

The precise mechanism for mitigating alopecia remains unclear, and the scalp cooling systems currently on the market demonstrate varying results in terms of effectiveness and tolerability for the patients[4]. The potential risk of scalp cooling lies in the protection of scalp metastasis from the effects of chemotherapy. However, that potential risk has, to date, been proved in only 2 patients[5]. Both of those patients had hematologic malignancies which, based on the published report, are regarded as a contraindication to scalp cooling.

The aim of our study was to assess the effectiveness and tolerability of a feedback-controlled scalp cooling

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system regulated by direct measurement of the patient's individual scalp temperature (DigniCap scalp cooling system: Sysmex Europe GmbH, Norderstedt, Germany) with respect to preventing chemotherapy-induced alopecia in breast or gynecologic cancer patients receiving 1 of 7 chemotherapy regimens.

METHODS

For this prospective cohort study, 55 female patients were recruited from two cancer treatment centres in Germany and Switzerland starting in 2013 to the end of 2014. The study was approved by the corresponding ethics commission (reference no. 01.53.01).

All consecutive cancer patients 18 years of age and older who planned to undergo neoadjuvant or adjuvant chemotherapy for breast, endometrial, or ovarian cancer were assessed for enrolment in the study. A patient was not eligible if she had grade 2 or greater hair loss at the baseline assessment or if she was unwilling to extend the duration of the required standard chemotherapy for the pre- and post-treatment scalp cooling process. Of the 68 women assessed for inclusion in the study, 55 were eligible and gave written consent to be enrolled.

The types of chemotherapy received by the patients were these:

- Paclitaxel 175 mg/m^2 and carboplatin 6 AUC (area under the curve) for 6 three-week cycles [n = 12 (22%)]
- Doxorubicin 60 mg/m^2 and cyclophosphamide 600 mg/m^2 for 4 three-week cycles, followed by docetaxel 100 mg/m^2 for 4 three-week cycles [n = 11 (20%)]
- Epirubicin 90 mg/m^2 and cyclophosphamide 600 mg/m^2 for 4 three-week cycles, followed by paclitaxel 80 mg/m^2 weekly for 12 weeks [n = 10 (18%)]
- Paclitaxel 80 mg/m^2 weekly for 16 weeks [n = 8 (15%)]
- Docetaxel 75 mg/m^2 and cyclophosphamide 500 mg/m^2 for 4 three-week cycles [n = 6 (11%)]
- Fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, and cyclophosphamide 500 mg/m^2 for 3 three-week cycles, followed by docetaxel 100 mg/m^2 for 3 three-week cycles [n = 6 4 (7%)]
- Docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, and cyclophosphamide 500 mg/m^2 for 6 three-week cycles [n = 4 (7%)]

Patients underwent clinical assessments at baseline (pre-treatment), at the end of each therapy cycle, and at completion of the chemotherapy regimen. Assessments included photographs with a 10-megapixel digital camera (PowerShot A3000 IS: Canon, Melville, NY, U.S.A.) of the patient's head from 5 different views (frontal, right and left lateral, occipital, and crown). In addition, each patient completed a self-administered questionnaire at baseline and at the end of the entire chemotherapy regimen. The oncology nurses were trained to complete the case report form using the World Health Organization (WHO) grading of acute and subacute toxicity for alopecia[6], to take photographs in a standardized manner (consistent lighting, positioning, and distance), and to administer the scalp-cooling treatment.

Used in accordance with the manufacturer's instructions, the DigniCap scalp cooling system applies a consistent temperature to the patient's scalp before, during, and after each chemotherapy cycle. An individually sized silicone cap, applied together with a neoprene cap, ensures a proper fit for insulation. The patient's hair is moistened before the cap is placed on her head. A coolant is then circulated through the system and sensors regulate the temperature.

The temperature setting was determined according to the thickness of the patient's hair (default setting was 5°C, with 3°C used for thicker hair). Before the start of each chemotherapy cycle, the study patients underwent a pre-drug cooling phase of 30 minutes. The overall length of the cooling time varied according to the chemotherapy regimen and included a post-drug cooling phase lasting between 60 and 120 minutes. Specifically, the post-drug cooling phase was 120 minutes for epirubicin–cyclophosphamide, for fluorouracil–epirubicin–cyclophosphamide, and for docetaxel–doxorubicin–cyclophosphamide; 100 minutes for docetaxel and for paclitaxel–carboplatin; 90 minutes for doxorubicin–cyclophosphamide and for docetaxel–cyclophosphamide; and 60 minutes for weekly paclitaxel. In addition to standard patient monitoring during chemotherapy, the oncology nurse recorded technical complications and side effects experienced by the patients during the course of the cooling process.

To objectively determine the effectiveness of scalp cooling for preventing alopecia, the WHO recommendations for grading acute and subacute toxicity were used to assess the degree of hair loss:

- Grade 0: no hair loss
- Grade 1: minimal hair loss (>0% to 25%)
- Grade 2: moderate, patchy alopecia (>25%–75%)
- Grade 3: complete alopecia, but reversible (>75%)
- Grade 4: non-reversible alopecia (>75%)

Subjective assessment of the tolerability and efficacy of treatment used a patient satisfaction measure (scale of 0–100, and a question about whether the patient would recommend treatment to others) and head covering behavior (use of a wig or scarf to cover the head when outside the home).

The data collected were entered into an electronic database for subsequent analysis in the IBM SPSS Statistics for Windows software application (version 21.0: Armonk, NY, U.S.A.). In addition to generating descriptive statistics (central tendency and variance), inferential statistics using multivariate analyses were obtained to compare results according to chemotherapy regimen (logistic regression using backward likelihood ratio). Variables entered into the multivariate model were chemotherapy regimen, age, and duration (in minutes) of scalp cooling per chemotherapy cycle. A p value less than 0.05 was considered to indicate statistical significance.

RESULTS

Patient Characteristics and Treatment

The study enrolled 55 women [ethnicity: 52 white (95%), 3 Asian (5%)] who underwent chemotherapy between 2013

and 2014. Mean age at the time that chemotherapy commenced was 56 ± 12 years (range: 32–79 years). Most of the study participants (76%) were being treated for breast cancer (35 adjuvant, 5 palliative, 2 neoadjuvant); 12 patients (22%) were being treated for ovarian cancer, and 1 patient (1.8%), for endometrial cancer. The median duration of the scalp-cooling treatment was 3.5 hours, depending on the duration of chemotherapy and the post-drug cooling phase (interquartile range: 3–4.5 hours; range: 2.5–6 hours).

Of the 55 women, 43 (78%) completed the scalp-cooling treatment for the entirety of their chemotherapy regimen. Reasons for cessation of treatment in the remaining 12 patients were hair loss ($n = 7$), death ($n = 3$), change of treatment centre ($n = 1$), and doubts about study participation which resulted in withdrawal of consent within 30 minutes of initiation of the 1st cycle ($n = 1$). Of the women who terminated scalp-cooling treatment early, only patients who stopped because of "hair loss" (Table I) were included in the remaining analyses ($n = 50$).

Outcomes

Objective Assessments

According to the WHO alopecia grading system, the overall level of effectiveness of scalp-cooling treatment for preventing hair loss (grades 0–1) was 56% (28 of 50 patients), which includes the women who stopped treatment early. Table II presents the objectively measured degree of hair loss and treatment effectiveness according to chemotherapy regimen received.

Subjective Assessments

The median score for patient satisfaction with the effectiveness of treatment was 90% (interquartile range: 60%–100%; range: 10%–100%). A satisfaction score of 80% or better was reported by 64% of the women. Recommendation of the scalp-cooling treatment to other patients was endorsed by 36 women (72%); 10 (20%) said that they did not know; and 4 (8%) would not recommend scalp cooling. A head covering was worn at some point during the treatment period by 26 women (52%). Table III presents the key subjective results according to chemotherapy regimen received.

A combined successful outcome was defined using both the objective measure "alopecia WHO grade 0 or 1" and the subjective measure "no head covering." Table IV presents the combined objective and subjective indicators according to chemotherapy regimen and patient age. Using that strict definition for success, the statistically significant predictors of minimal hair loss in the multivariate model were younger age ($p = 0.019$) and the paclitaxel weekly ($p = 0.012$) and paclitaxel–carboplatin ($p = 0.023$) regimens. Figure 1 illustrates minimal hair loss in a 32-year-old breast cancer patient who underwent neoadjuvant chemotherapy.

Comparison of the objective and subjective alopecia assessment methods showed that no woman with a grade 0 assessment used a head covering. However, of the 18 patients with a WHO grade 1 assessment at the end of chemotherapy, 8 (44%) used a head covering when outside of their home, even though their result was objectively defined as a treatment success. With alopecia grade 2, the rate of head covering was 67% (8 of 12). All women with grade 3 hair loss used a head covering.

No technical difficulties or patient-reported complications were observed. Most patients reported being reasonably comfortable throughout treatment, with the cold sensation at a tolerable level. As previously mentioned, only 1 of the 55 participating patients (1.8%) could not tolerate scalp cooling and stopped treatment within the first 30 minutes.

DISCUSSION

Scalp hypothermia to prevent alopecia aims to reduce circulation to the scalp, leading to decreased perfusion of the hair follicles and, ultimately, to diminished intrafollicular drug uptake and metabolism[7]. The various methods for scalp cooling include use of frozen cryogel in the shape of a helmet and the circulation of cold air or cold liquid in a cap or helmet[8–12]. Drawbacks of those reported cooling methods include a lack of consistent scalp temperature

TABLE I Characteristics of the seven patients who terminated scalp cooling during chemotherapy because of hair loss

Cancer type	Therapy type	Age (years)	Chemotherapy regimen	Average cooling time per treatment (hours)	Cycles completed at cessation	Grade[a] of alopecia at cessation
Breast	Neoadjuvant	40	TAC×6	4.5	3	3
Breast	Adjuvant	50	TAC×6	4.5	1	2
Breast	Adjuvant	45	FEC×3→D×3	4.0	1	2
Breast	Adjuvant	46	AC×4→D×4	3.0	2	3
Breast	Adjuvant	47	AC×4→D×4	3.0	2	2
Breast	Adjuvant	76	Weekly paclitaxel×16	3.0	2	2
Ovarian		60	Paclitaxel–carboplatin×6	5.5	1	3

[a] World Health Organization grading: 0 = none; 1 = minimal hair loss (0% to 25%); 2 = moderate, patchy alopecia (>25% to 75%); 3 = complete alopecia, but reversible (>75%); 4 = non-reversible alopecia (>75%).

TAC = docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; FEC = fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; D = docetaxel 100 mg/m^2 every 3 weeks; AC = doxorubicin 60 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; weekly paclitaxel = 80 mg/m^2 weekly; paclitaxel–carboplatin = paclitaxel 175 mg/m^2 plus carboplatin 6 AUC (area under the curve) every 3 weeks.

TABLE II Objective assessment of the effectiveness of scalp cooling at the end of chemotherapy or at cessation of cooling treatment

Chemotherapy regimen	Patients (*n*) by grade[a] of alopecia					Effectiveness (grades 0 and 1)
	0	1	2	3	Total	
FEC×3→D×3 or AC×4→D×4 or EC×4→P×12	3	8	9	4	24	46%
Paclitaxel–carboplatin×6	3	5	1	2	11	73%
Weekly paclitaxel×16	2	2	1	0	5	80%
TC×4	2	2	1	1	6	67%
TAC×6	0	1	0	3	4	25%
TOTAL	10	18	12	10	50	56%

[a] World Health Organization grading: 0 = none; 1 = minimal hair loss (0% to 25%); 2 = moderate, patchy alopecia (>25% to 75%); 3 = complete alopecia, but reversible (>75%); 4 = non-reversible alopecia (>75%).
FEC = fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; D = docetaxel 100 mg/m^2 every 3 weeks; AC = doxorubicin 60 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; EC = epirubicin 90 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; P = paclitaxel 80 mg/m^2 weekly; paclitaxel–carboplatin = paclitaxel 175 mg/m^2 plus carboplatin 6 AUC (area under the curve) every 3 weeks; weekly paclitaxel = 80 mg/m^2 weekly; TC = docetaxel 75 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; TAC = docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks.

TABLE III Subjective indicators of alopecia and patient satisfaction by chemotherapy regimen

Chemotherapy regimen	Pts (*n*)	Indicator [*n* (%)]		
		≥80 Satisfaction with cooling treatment	Recommend to others	No head scarf or wig used
FEC×3→D×3 or AC×4→D×4 or EC×4→P×12	24	15 (63)	16 (67)	9 (38)
Paclitaxel–carboplatin×6	11	8 (73)	10 (91)	7 (64)
Weekly paclitaxel×16	5	4 (80)	3 (60)	4 (80)
TC×4	6	4 (67)	5 (83)	4 (67)
TAC×6	4	1 (25)	2 (50)	0 (0)
TOTAL	50	32 (64)	36 (72)	24 (48)

FEC = fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; D = docetaxel 100 mg/m^2 every 3 weeks; AC = doxorubicin 60 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; EC = epirubicin 90 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; P = paclitaxel 80 mg/m^2 weekly; paclitaxel–carboplatin = paclitaxel 175 mg/m^2 plus carboplatin 6 AUC (area under the curve) every 3 weeks; weekly paclitaxel = 80 mg/m^2 weekly; TC = docetaxel 75 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; TAC = docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks.

TABLE IV Effectiveness based on combined subjective and objective indicators, by chemotherapy regimen and age

Chemotherapy regimen	"No head covering" and grade 0 or 1[a] alopecia [*n*/*N* (%)]		
	Overall	≤50 Years	>50 Years
FEC×3→D×3 or AC×4→D×4 or EC×4→P×12	7/24 (30)	6/14 (43)	1/10 (10)
Paclitaxel–carboplatin×6	7/11 (64)	4/4 (100)	3/7 (43)
Weekly paclitaxel×16	3/5 (60)	0/0 (0)	3/5 (60)
TC×4	3/6 (50)	1/1 (100)	2/5 (40)
TAC×6	0/4 (0)	0/3 (0)	0/1 (0)
TOTAL	20/50 (40)	11/22 (50)	9/28 (32)

[a] World Health Organization grading: 0 = none; 1 = minimal hair loss (0% to 25%).
FEC = fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; D = docetaxel 100 mg/m^2 every 3 weeks; AC = doxorubicin 60 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; EC = epirubicin 90 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; P = paclitaxel 80 mg/m^2 weekly; paclitaxel–carboplatin = paclitaxel 175 mg/m^2 plus carboplatin 6 AUC (area under the curve) every 3 weeks; weekly paclitaxel = 80 mg/m^2 weekly; TC = docetaxel 75 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; TAC = docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks.

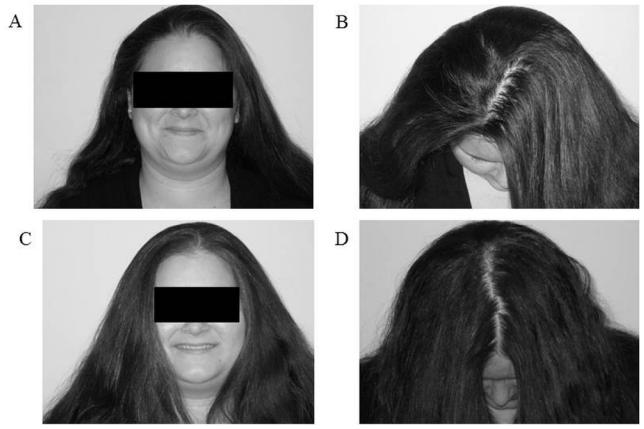

FIGURE 1 (A,B) Before and (C,D) after images of a 32-year-old breast cancer patient who underwent sensor-controlled scalp cooling (DigniCap: Sysmex Europe GmbH, Norderstedt, Germany) while receiving neoadjuvant chemotherapy consisting of 4 cycles of doxorubicin 60 mg/m^2 and cyclophosphamide 600 mg/m^2 every 3 weeks, followed by 4 cycles of docetaxel 100 mg/m^2 every 3 weeks.

control, loosely fitted caps, weight of the cap, and high workload for the nursing staff to change the frozen cryogel cap every 30 minutes.

The modern scalp cooling system used in the present study includes tight-fitting, light, soft silicone caps not covering the ears and forehead. Lowering of the temperature is stepwise and slow, and the temperature of the scalp is measured by 3 different sensors to maintain constant hypothermia of the skin surface[13]. This sensor-controlled scalp cooling system showed high efficacy in preventing chemotherapy-induced alopecia in certain modern chemotherapy regimens (assessed using subjective and objective measurements). With a combined subjective and objective success rate exceeding 50%, we believe that scalp cooling can be recommended for regimens such as paclitaxel weekly and the combination regimens of docetaxel–cyclophosphamide and paclitaxel–carboplatin. The combined success rate was significantly higher in the paclitaxel weekly and paclitaxel–carboplatin regimens than in the other regimens examined. Conversely, with the triplet regimen docetaxel–doxorubicin–cyclophosphamide, hair loss could not be prevented and should not be recommended. For the sequential polychemotherapy regimens fluorouracil–epirubicin–cyclophosphamide followed by docetaxel or doxorubicin–cyclophosphamide followed by docetaxel, the success rate of the scalp cooling system was 30%; cooling can therefore be considered for younger patients because age was a multivariate prognostic factor for a lower level of hair loss.

Our data compare favourably with the alopecia rates published for the same regimens without scalp cooling (Table v). For weekly paclitaxel, complete alopecia was reported to be 93.2%[14], and for 6 cycles of docetaxel monotherapy, the alopecia rate was reported to be 100%[15]. Accordingly, 6 cycles of polychemotherapy using docetaxel–doxorubicin–cyclophosphamide or fluorouracil–doxorubicin–cyclophosphamide had an alopecia rate higher than 97.8%[16]. For the sequential regimen of fluorouracil–epirubicin–cyclophosphamide followed by docetaxel, alopecia grade 3 or 4 has been reported to be 92.6%[17].

Our data confirm findings reported by other researchers using the same scalp-cooling device. Schaffrin-Nabe *et al.*[18] found alopecia grades 0–1 in 68.4% of 76 breast cancer patients after 4 cycles of epirubicin–cyclophosphamide followed by 12 weeks of weekly paclitaxel. Our rate of objective grades 0–1 with similar regimens was 46%, with 38% of the patients reporting no use of a wig or scarf to cover the head. Schaffrin-Nabe *et al.* also found that premenopausal status was associated with a higher success rate of scalp cooling. Similarly, we found that younger age was a multivariate predictive factor for less hair loss.

Using another scalp-cooling device (Paxman PSC1 and PSC2: Paxman Coolers, Huddersfield, U.K.), van den Hurk *et al.*[19] reported similar results: only 8% of their patients receiving docetaxel–doxorubicin–cyclophosphamide chemotherapy, 48% receiving fluorouracil–epirubicin–cyclophosphamide followed by docetaxel, and 81% receiving weekly paclitaxel used no head covering at the last cycle of chemotherapy. However, they found that only 38% of their 52 patients receiving paclitaxel–carboplatin used no head covering at the last cycle, whereas 64% of our patients did not use a head covering and had alopecia grade 0 or 1 after 6 cycles of the same chemotherapy.

In our study, the low drop-out rate of 1.8% because of intolerance (1 of 55 patients) reflects the high acceptability of this sensor-controlled cooling cap and is similar to the rate reported by Ridderheim *et al.*[13]. Using another scalp cooling device (Paxman), intolerance to cooling was reported to be 3%[19]. A recent randomized study showed that the scalp cooling duration could be shortened without a reduction in efficacy, which might make scalp cooling even more acceptable to patients[20].

Because the silicone caps of the DigniCap scalp cooling system are reusable, most of the cost is incurred with the initial purchase of the system and with maintenance. In our health care system, the time spent at the outpatient clinic for administration of chemotherapy is covered by health insurance. Given the increased time spent in the clinic by patients having scalp cooling, the initial investment is eventually repaid according to case load.

A limitation of our study was that a control arm without scalp cooling was absent. Given the success rates for alopecia prevention by this scalp cooling system in the literature (which was communicated to patients), a control arm without scalp cooling was believed to be unethical, and a randomized study was therefore not feasible.

Comparing objective and subjective alopecia assessment methods revealed unexpected results. Although 18 patients were classified as having WHO alopecia grade 1 at the end of their chemotherapy, 8 (44%) used a head covering when leaving home. That finding highlights the importance of both objective and subjective assessments of hair loss rather than a reliance on one indicator of treatment success. We therefore believe that a compound endpoint including both the subjective need to wear a head covering and an objective alopecia grade is a more valid way to measure the outcome of a scalp cooling system.

TABLE V Comparative subjective and objective hair retention rates

Cooling system		Patients by chemotherapy regimen [% (*n/N*)]							
Reference	**Endpoints examined**	**Weekly paclitaxel ×16**	**Paclitaxel–carboplatin or docetaxel–carboplatin ×6**	**Paclitaxel–carboplatin ×12**	**EC×4 →D×4 or AC×4 →D×4**	**EC or AC ×4 →P ×12**	**FEC×3 →D×3**	**TC×4**	**TAC×6**
DigniCap[a]									
Ridderheim *et al.*,2003[13]									
	No use of wig	—	63 (19/30)	—	—	—	—	—	—
Friedrichs *et al.*, 2014[21]									
	Alopecia grade 0 or 1[b]	—	—	—	54.8 (17/31)	—	28.6 (2/7)	—	—
Schaffrin-Nabe *et al.*, 2015[18]									
	No visible alopecia at last cycle	—	42.9 (3/7)	100 (2/2)	50 (3/6)	68.4 (52/76)	58.3 (7/12)	100 (1/1)	29% (2/7)
Current study									
	No head covering and alopecia grade 0 or 1[b] after last cycle	60 (3/5)	64 (7/11)	—	55 (6/11)	11 (1/9)	0 (0/4)	50 (3/6)	0% (0/4)
	Alopecia grade 0 or 1[b] after last cycle	80 (4/5)	73 (8/11)	—	64 (7/11)	22 (2/9)	50 (2/4)	67 (4/6)	25% (1/4)
CAP610 hypothermia cap[c]									
Auvinen *et al.*,2010[22]									
	Alopecia grade 0-1* after final cycle	—	—	—	—	—	81.80 (18/22)	—	—
Paxman[d]									
Van den Hurk *et al.*, 2012[19]									
	No head covering	81 (34/42)	38 (20/52)	75 (9/12)	63 (10/16)	48 (14/29)	48 (22/46)	—	8% (5/66)
No scalp cooling									
	Alopecia grade < 3[b]	6.80 (Sato *et al.*, 2003[14])	5.5 (Pignata *et al.*, 2011[23])	5.5	3 (Fisher *et al.*, 1990[24])	3	7.40 (Roché *et al.*, 2006[17])	18 (Chevallier *et al.*, 1995[15])	2.20% (Martin *et al.*, 2005[16])

[a] Sysmex Europe GmbH, Norderstedt, Germany.
[b] World Health Organization grading: 0 = none; 1 = minimal hair loss (0% to 25%); 2 = moderate, patchy alopecia (>25% to 75%); 3 = complete alopecia, but reversible (>75%); 4 = non-reversible alopecia (>75%).
[c] Southwest Technologies, North Kansas City, MO, U.S.A.
[d] Paxman Coolers, Huddersfield, U.K.

Weekly paclitaxel = 80 mg/m^2 weekly; paclitaxel–carboplatin = paclitaxel 175 mg/m^2 plus carboplatin 6 AUC (area under the curve) every 3 weeks; docetaxel–carboplatin = docetaxel 100 mg/m^2 plus carboplatin 6 AUC every 3 weeks; EC = epirubicin 90 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; D = docetaxel 100 mg/m^2 every 3 weeks; AC = doxorubicin 60 mg/m^2, cyclophosphamide 600 mg/m^2 every 3 weeks; P = paclitaxel 80 mg/m^2 weekly; FEC = fluorouracil 500 mg/m^2, epirubicin 100 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; TC = docetaxel 75 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks; TAC = docetaxel 75 mg/m^2, doxorubicin 50 mg/m^2, cyclophosphamide 500 mg/m^2 every 3 weeks.

CONCLUSIONS

Results from studies of the array of scalp cooling systems designed to prevent chemotherapy-induced alopecia, a common and psychologically troubling side effect for cancer patients, have varied. Our research showed that the effectiveness of DigniCap, a sensor-controlled scalp cooling system, depends on the chemotherapy regimen and the patient's age. Because subjective and objective indicators of success often differ, we recommend the use of a compound endpoint to gain more insightful and practical information to use in counselling patients.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood *Current Oncology*'s policy on disclosing conflicts of interest, and we declare that we have none.

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