



SCALP COOLING FOR CHEMOTHERAPY-INDUCED ALOPECIA IN BREAST CANCER: A RECENT LITERATURE REVIEW

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ABSTRACT

Chemotherapy significantly improves the prognosis of breast cancer patients. However, its most disturbing side effect is alopecia, which significantly reduces patients' quality of life. Scalp cooling (SC) was developed to minimize hair loss during chemotherapy. Study objective: To analyze the effectiveness, success factors, technical parameters, and tolerability of SC in breast cancer patients. Study methods: A literature review using the PRISMA approach, including English and Indonesian studies from 2021 to 2026. Keyword combinations: "scalp cooling" and "chemotherapy-induced alopecia" were used to search the literature through PubMed, Scopus, Google Scholar, and DOAJ. Of the 1,744 articles identified, ten articles met the inclusion criteria and underwent further analysis. Results: Scalp cooling was 40%-90% effective in preventing hair loss. It was most effective with taxane-based regimens compared to anthracycline-based regimens. The effectiveness of SC was influenced by the type, dose, and duration of chemotherapy, as well as the cooling temperature. Hair characteristics had no effect. SC contributed to hair recovery and reduced alopecia. It was well tolerated, with mild side effects. However, treatment discontinuation rates were observed in some studies. Conclusion: SC is an effective and evidence-supported supportive intervention to reduce the severity of chemotherapy-induced alopecia in breast cancer survivors. Its success depends on the regimen and requires optimization of technical parameters and patient education to improve its sustainability in clinical practice.

Keywords: breast cancer; chemotherapy-induced alopecia; hair loss; prevention; scalp cooling

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INTRODUCTION

Breast cancer, also known as (carcinoma mammae), is a non-communicable disease that has become a global health issue due to its substantial impact on women's life quality (Usniyah et al., 2025). According to Global Cancer Observatory (GLOBOCAN) data from 2022, around 2,308,897 new cases of breast cancer were diagnosed worldwide that year. This represents 11.6% of all global cancer cases. The cases resulted in 665,684 deaths. Breast cancer is the second most prevalent form of cancer worldwide and the most prevalent among women (Ferlay et al., 2024).

A similar situation is occurring in Indonesia, where the burden of this disease continues to show an upward trend. GLOBOCAN data recorded the number of national cancer cases in 2020 at 396,914 with a fatality rate of 59.08% (234,511 deaths), which then increased in 2022 to 408,661 new cases and 242,998 deaths (Rosita et al., 2025). The latest report shows that breast cancer dominates the national cancer profile with 66,271 new cases or around 16.2% of the total cancer burden in Indonesia (Nurfadhilah et al., 2026). The escalation of this incidence linearly increases the need for chemotherapy as the primary modality in the management of breast cancer (Maryani et al., 2025). Chemotherapy is one of the therapeutic approaches used to suppress the proliferation of neoplastic cells through the use of cytotoxic agents (Amalia et al., 2025). However, although it is effective in inhibiting the spread of tumour cells, its non-selective nature towards rapidly dividing cells in areas such as the bone marrow, gastrointestinal tract and hair follicles causes various systemic side effects (Amjad et al., 2025).

Side effects commonly reported from chemotherapy include nausea, vomiting, pain, alopecia, fatigue, anemia, and neutropenia, with the severity influenced by the type of regimen and the patient's physiological condition (Fawwaza et al., 2025). A study conducted in Bangalore on 30 cancer patients undergoing chemotherapy showed that 80% of patients experienced hair loss (alopecia), 76.7% reported fatigue, and 73.3% experienced nausea and vomiting. Other symptoms such as pain, weakness, and numbness in the upper and lower extremities were reported by 66% of participants (Tamang et al., 2025).

Chemotherapy-induced alopecia (CIA) remains among the most prevalent side effects of chemotherapy and a significant concern for patients. In fact, more than 50% of patients view alopecia as the worst aspect of treatment, with around 8% reportedly refusing chemotherapy due to concerns about this condition (Eslami et al., 2023). In addition to the physical effects of treatment, breast cancer patients often experience psychological disturbances such as anxiety and stress, which can lead to a decline in life quality (Dewi et al., 2022). Recent research indicates that approximately 55% patients with breast cancer experience elevated levels of psychological distress due to chemotherapy-induced alopecia (CIA), which has been linked to an increased risk of depression, body image disturbances, and a decline in overall psychosocial well-being (Peera et al., 2024).

Given the heavy psychological burden, the integration of alopecia management services into oncology care is crucial. Unfortunately, many oncology centers currently do not routinely provide specialized services for alopecia management beyond the use of wigs (Mokbel et al., 2024). Wigs and other hair prostheses are a minimally invasive and efficient method of concealing hair loss. They help individuals with alopecia regain lost sense of self-confidence and feel more secure about their looks. Nonetheless, the utilization of wigs has the potential to give rise to concerns regarding visibility and stability, heightened anxiety and stress, feelings of inauthenticity, and the potential for eschewing social activities involving movement (Courtney & C.su, 2024). Furthermore, some individuals struggle to find a suitable wig, and high costs can increase the family's financial burden. Moreover, information about wigs is frequently lacking, making it difficult for patients in remote areas to find the right options (Katayama et al., 2025).

This condition has prompted the exploration of various more comprehensive preventive approaches. Several methods have been developed to prevent or reduce the risk of CIA, such as scalp compression (tourniquet), the use of 2% topical minoxidil, and physiotherapy approaches. However, among these various methods, scalp cooling (SC) is the most widely used technique and has been applied since the 1970s. This method works through local cooling that causes vasoconstriction in the hair follicles, thereby reducing blood flow when the concentration of the chemotherapy drug reaches its peak, as well as decreasing the metabolic activity of the cells (Molina et al., 2023). In clinical practice, scalp cooling has become a widely used complementary method for preventing chemotherapy-induced alopecia (CIA) and has been approved by the U.S. Food and Drug Administration (FDA) as a supportive approach for cancer patients (Bandla et al., 2025).

Research on the use of scalp cooling to prevent chemotherapy-induced alopecia (CIA) in breast cancer patients has continued to grow in recent years at the global level. A previous literature review by (Cahyono & Irawaty, 2020) discussed the effectiveness of scalp cooling and its determining factors, but this review was compiled before the availability of a number of clinical studies and the latest real-world data that specifically evaluated the breast cancer population. Therefore, This review aims to analyze the latest evidence on the effectiveness of scalp cooling and its influencing factors, such as chemotherapy regimens, hair characteristics, cooling duration and temperature, and aspects of tolerability and patient experience in clinical practice. This study is expected to strengthen the scientific basis for the use of scalp cooling as an evidence-based

supportive intervention, while encouraging the development of similar research in Indonesia, given the limited national data on the implementation of this intervention in breast cancer patients.

METHOD

This article was compiled using a literature review method based on secondary data from previous studies. Articles were selected based on the PICOS framework (Population: Breast cancer patients receiving chemotherapy, Intervention: Use of scalp cooling during chemotherapy, Comparison: No scalp cooling or variations in cooling protocols, Outcome: Incidence or degree of chemotherapy-induced alopecia (CIA), success rate in maintaining hair, tolerability, and patient-reported outcomes, Study design: Randomized controlled trials, cohort studies, and observational studies). The literature search for this study was conducted using reputable electronic databases, including PubMed, Google Scholar, DOAJ, and Scopus. The search used a combination of keywords: Scalp cooling AND breast cancer AND Chemotherapy-induced alopecia AND Prevention. A total of 1,744 articles were identified from the databases. After the screening process and application of the inclusion criteria, 10 articles were included in the final analysis.

This study's inclusion criteria included original research articles published from 2021 to 2026 that were available in full text and written in Indonesian/English. The exclusion criteria were articles that could only be accessed in abstract form, single case reports, non-research articles, and studies that did not specifically evaluate the use of scalp cooling among breast cancer patients. Article searchers and selectors conducted the article search and selection process in stages. Initially, articles were screened based on whether their titles and abstracts were suitable for the predetermined inclusion criteria. Articles irrelevant to the research focus or that do not meet the combination of keywords used were excluded from the selection process. Then, articles meeting the inclusion criteria were evaluated for methodological quality with the Critical Appraisal Skills Program (CASP) tool, which assesses the validity, reliability, and feasibility of the research results for further analysis in this review.

RESULT

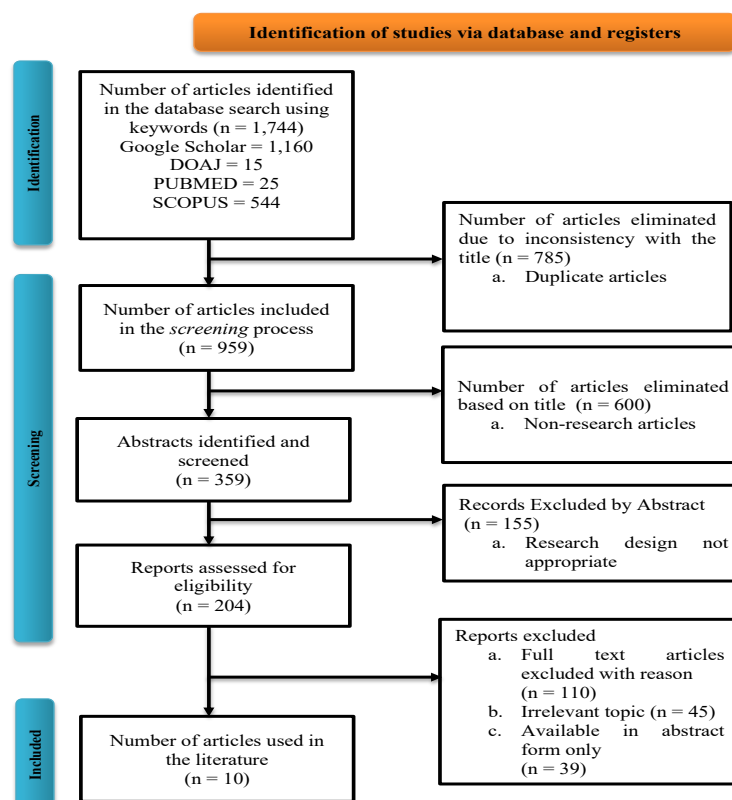


Figure 1. PRISMA flow diagram of the article selection process

The initial search yielded 1,744 articles. These articles were then sorted and adjusted according to a full-text assessment, resulting in a final selection of 10 articles.

Table 1.
Article Analysis

No	Topic and Author	Design	Objective	Sample Population	Research result
1	Hair safety study: Effects of scalp cooling on hair preservation and hair regrowth in breast cancer patients receiving chemotherapy - A prospective interventional study (Brunner et al., 2022)	Prospective interventional	Evaluating the efficacy of SC in diverse chemotherapy regimens and the recovery of hair during the monitoring period.	The study population included 128 patients with breast cancer.	The use of scalp cooling (SC) has been clinically proven to be effective in preserving hair, with experts assessing a 72% success rate (<50% hair loss) compared to 0% in the Non-Scalp Cooling (NCAP) group ($P \leq 0.001$). There was a significant discrepancy between the experts' objective assessment and the patients' self-assessment, with only 24% of patients rating their hair loss as grade 1.
2	Prospective Study Investigating the Efficacy and Safety of a Scalp Cooling Device for the Prevention of Alopecia in Women Undergoing (Neo) Adjuvant Chemotherapy for Breast Cancer (Carbognin et al., 2022)	Prospective observational	The present study will evaluate the effectiveness of scalp cooling in preventing hair loss. The evaluation will be based on the Dean alopecia scale, which is to be assessed by medical personnel.	178 breast cancer patients	The overall success rate was 68.0%. It was 100% for paclitaxel alone, 87.0% for docetaxel and cyclophosphamide, 59.5% for anthracycline and taxane, and 71.4% for the sequential regimen plus carboplatin. There was a significant difference between anthracycline- and taxane-based chemotherapy and taxane-based chemotherapy ($p \leq 0.001$).
3	PRO Hair Safe Study: The Patient's Perspective on the Effects of Scalp Cooling on Hair Preservation (Brunner et al., 2023)	Prospective observational	Assess PRO data on SC-induced alopecia and symptoms/functional health in BCP patients receiving taxane- or anthracycline-based chemo.	113 breast cancer patients	113 patients were enrolled: 75 received SC (average age 51.3, 52.7% premenopausal), and 38 received standard treatment (average age 55.6, 39.5% premenopausal). 53 discontinued SC; 70.7% cited hair loss. Patients used cooling caps 40.2% of the time (SD = 25.3%). The groups were similar during chemo in terms of hair loss ($p = 0.831$), overall quality of life, emotional/social function, and body image ($p = 0.627, 0.737, 0.635$, and 0.463 , respectively).
4	Prospective study of hair recovery after (neo)adjuvant chemotherapy with scalp cooling in Japanese breast cancer patients Shozo (Ohsumi et al., 2021)	Prospective study	Researchers evaluated hair recovery 1–13 months after chemotherapy. Two researchers assessed alopecia, and patients responded to a questionnaire.	117 Breast Cancer Patients.	Of the 117 patients, 75 in Group A completed scalp cooling during the planned cycle. 42 in Group B discontinued it after the first cycle. At 1 year and 4/7 months after chemo, Group A had better outcomes than Group B. Group A had faster hair recovery and fewer cases of hair loss when compared to Group B, especially in patients with an objective grade of 3 (hair loss >50%) in the initial month.

5	Effectiveness of increasing the scalp cooling duration to prevent alopecia during adjuvant chemotherapy for breast cancer: a randomized pilot study (Carton et al., 2024)	Randomized Pilot Study	Determining whether extending the duration of scalp cooling can improve hair preservation.	37 breast cancer patients.	There was no statistically significant difference in success rates between the two groups after each of the three cycles (etoposide: Group A: 40%; Group B: 44%; paclitaxel: Group A: 50%; Group B: 36%; $p > 0.05$). Hair regeneration was higher in Group B at the eight-week follow-up, though not at the six-month follow-up. Patients in Group B reported head discomfort more frequently than those in Group A during the first session (94% vs. 62%, respectively; $p = 0.039$).
6	Scalp cooling therapy for chemotherapy-induced hair loss in Asian patients with breast or gynecological cancers – a tertiary institution experience (Lee et al., 2024)	Prospective observational, non-randomized study.	Reporting our tertiary institution's experience in implementing SCT in patients with breast cancer or gynecological cancer undergoing chemotherapy	83 Breast and Gynecologic Cancer Patients	A total of 83 people were studied over 18 months, and 510 scalp cooling cycles were performed. 94% of patients (78 out of 83) reported a discomfort score of 3 or higher, indicating comfort. The highest hair preservation rate (76.7%, 23 out of 30) was in patients receiving weekly paclitaxel, while a lower rate (50%, 2 out of 4) was seen in patients receiving paclitaxel every three weeks. Only 1 of the 19 patients receiving anthracycline and cyclophosphamide chemotherapy successfully preserved hair.
7	The Efficacy of Paxman Scalp Cooling System in Preventing Hair Loss in Breast Cancer Patients Receiving Chemotherapy in Western India – Multi-centre Retrospective Cohort Study (Mekha et al., 2024)	Retrospective-observational cohort study	To evaluate the effectiveness and tolerance of the Paxman scalp cooling system (PSCS) in Indian breast cancer patients undergoing chemotherapy in adjuvant or neoadjuvant settings.	91 female patients with breast cancer	81% showed prevention of alopecia (grades 0 and 1), while 16.48% of patients experienced grade 2 hair loss (50%+ loss) after treatment. CIA was significantly higher for patients receiving anthracyclines and with cooling time >150 minutes. The incidence of grade 2 alopecia (>50% hair loss) was 81.3% in patients <6 weeks and 18.8% in those >6 weeks since chemotherapy began ($P < 0.0001$). No side effects were reported in 71.4% of patients, and headaches were most common (18.7%).
8	Effectiveness of Scalp-cooling Therapy for Preventing Chemotherapy-induced Alopecia in Patients With Breast Cancer: A Prospective Observational Study Focusing on Scalp, Eyebrow, and Eyelash Hair Loss	Prospective Observational Study	To assess the efficacy of scalp cooling in thwarting the development of unwanted hair growth in various anatomical locations, including the eyebrows and eyelashes.	154 patients with BC.	The use of scalp cooling led to a substantial decrease in the occurrence of severe hair loss (score 4–5) on the scalp ($p < 0.001$). While the disparities in eyebrow and eyelash hair loss proved to be non-significant ($p = 0.095$ and $p = 0.199$, respectively), a tendency towards diminished severe hair loss was discerned. The protective effect for body hair was not significant ($p = 0.446$).

(Fujii et al., 2025)						
9	Does hair curl variation influence the efficacy of scalp cooling in the prevention of chemotherapy-induced alopecia in breast cancer patients? A randomized pilot trial (Obuseng et al., 2021)	A randomized pilot trial	Researchers aim to determine if scalp cooling is less effective on curly hair than on straight hair. They also aim to verify previous findings that scalp cooling reduces the impact of chemotherapy-induced alopecia (CIA).	48 Breast cancer (17 SC vs. 20 control)	Of the 77 patients, 48 were randomized, and 3 withdrew prior to the first visit. The 3-month ICC was 0.94 (95% CI: 0.85–0.97), indicating good agreement on the overall severity of alopecia. Cooling reduced CIA (37.29 ± 20.52 ; $p = 0.0167$), but not alopecia. CIA was similar in those with straight and curly hair ($p = 0.0740$).	
10	Retrospective evaluation of Penguin Cold Caps for chemotherapy-induced alopecia (Weaver et al., 2024)	Retrospective cohort	We evaluated data routinely recorded during the cold capping process to determine its tolerability and effectiveness. We also sought to determine whether CIA varied according to chemotherapy regimen or patient/hair characteristics.	100 Cancer Patients	During the study, 100 patients started cold capping therapy and most finished. Most patients had good results. On average, 75% of the hair was preserved, and 82 out of 89 patients had satisfactory results. A patient's chemotherapy regimen was a factor associated with a good response. Fewer patients receiving doxorubicin successfully retained their hair compared to those receiving other types of chemotherapy. There were no differences in success based on patient characteristics.	

DISCUSSION

Based on all the articles reviewed, scalp cooling intervention has been proven to preserve hair and prevent CIA in the majority of breast cancer patients undergoing chemotherapy. The reported range of effectiveness varies from 40% to over 90%, with most studies showing success in the range of 50–81% in preserving hair in breast cancer patients (Carbognin et al., 2022; Mekha et al., 2024). This effectiveness can be biologically explained through the mechanism of vasoconstriction of the scalp blood vessels, which reduces local perfusion, thereby decreasing the distribution of cytotoxic agents to the hair follicles. Additionally, hypothermia reduces the metabolic activity of hair matrix cells, thereby decreasing follicle sensitivity to chemotherapy-induced damage (Brunner et al., 2022; Fujii et al., 2025). Overall, these findings indicate that scalp cooling is a consistently effective supportive intervention in reducing the severity of CIA in breast cancer patients, although its success rate varies across studies.

Scalp cooling has been proven to not only play a role in preventing alopecia during chemotherapy, but also significantly contribute to accelerating post-treatment hair recovery. Ohsumi et al., 2021, shows that hair regrowth occurs progressively during the follow-up period, with an increase in the proportion of patients achieving full recovery over time. Patients who underwent consistent scalp cooling throughout the chemotherapy cycle showed a milder degree of hair loss and a lower incidence of persistent alopecia compared to the group that did not continue the intervention. These findings indicate that the scalp cooling mechanism likely provides a protective effect on hair

follicles from damage caused by chemotherapy agents, thereby supporting the hair regeneration process after therapy is completed and reducing the risk of persistent alopecia. However, the effectiveness of scalp cooling is not always the same for every patient. One of the most consistently reported factors affecting the effectiveness of this intervention is the type of chemotherapy regimen received by the patient (Brook et al., 2024).

Chemotherapy regimens emerge as the primary independent predictor significantly determining the success of scalp cooling (SC). Findings by Lee et al., 2024 confirm that the effectiveness of this intervention is far more optimal in non-anthracycline regimens compared to anthracycline-based ones. This correlates with the more aggressive cytotoxic profile of anthracyclines toward hair follicles, where protection failure is often observed from the early phases (cycle 1 or 2). Conversely, the use of taxane-based regimens shows significantly superior success rates (Brook et al., 2024). This difference in efficacy indicates that despite advances in scalp cooling technology, the pharmacodynamic profile of chemotherapy agents remains a limiting factor in follicle protection thresholds. These findings are consistent with a study by Carbognin et al., 2022, which confirmed that the effectiveness of scalp cooling after a full cycle of chemotherapy is significantly higher with taxane-based regimens. Data show a success rate of 100% with single-agent paclitaxel and 87.0% with the docetaxel–cyclophosphamide combination. Conversely, success rates decreased dramatically in sequential or anthracycline and taxane combination regimens (with or without carboplatin), at 59.5% and 71.4%, respectively (Carbognin et al., 2022). In addition to the type of regimen, dose size is also a key determinant.

The incidence of chemotherapy-induced alopecia is dose-dependent and tends to increase significantly in patients receiving dual or multiple agents, Carton et al., 2024 providing concrete evidence of the effect of dose escalation on the effectiveness of scalp cooling. The study noted that with a dose of 90 mg/m² of epirubicin, 52% of patients were able to retain their hair without the need for head coverings. However, this success rate dropped dramatically to only 33% when the dose was increased to 100 mg/m². Furthermore, in the EC (Epirubicin-Cyclophosphamide) regimen with a dose of 100 mg/m², the reported hair preservation rate was even lower, at only 29%. This trend indicates a negative correlation between increased anthracycline dose and scalp cooling efficacy, where patients receiving lower doses tend to achieve more optimal protective outcomes (Brook et al., 2024). Thus, regimen characteristics and dose magnitude are the primary determinants of intervention success, which are also influenced by technical parameters such as cooling duration and temperature.

Technical parameters, particularly cooling duration and temperature stability, play a crucial role in distributing the effects of hypothermia on the scalp and determining the response of follicles to cytotoxic exposure. To date, no standard has been established for the optimal duration; recommendations for post-infusion cooling time (PICT) are generally empirical and vary between institutions. Current clinical practice generally involves pre-cooling for approximately 30 minutes with post-cooling durations ranging from 15 minutes to 4 hours (Mekha et al., 2024). However, extending these durations does not always correlate with increased effectiveness. Carton et al., 2024 reported that extending cooling to 2 hours post-infusion did not provide significant benefits in hair preservation compared to the standard protocol, and even risked increasing patient discomfort and the incidence of side effects due to cold intolerance.

This finding is reinforced by a randomized controlled trial by Lugtenberg et al., 2022, which shows that shortening the post-infusion cooling time (PICT) to 20 minutes in patients receiving weekly paclitaxel still provides a comparable success rate to longer durations. The success rate for hair preservation was recorded at 75% in the 45-minute group and 82% in the 20-minute group, compared to 85% in the standard 90-minute group, with no statistically significant differences. Theoretically, the duration of post-infusion cooling should be related to the pharmacokinetic profile

of chemotherapy drugs, including half-life and plasma distribution patterns ((Lugtenberg et al., 2022). Therefore, simply extending the cooling duration without considering the pharmacokinetic characteristics of the drug does not always increase the effectiveness of hair follicle protection. In addition to duration, temperature control is another technical parameter that needs to be considered in the implementation of scalp cooling.

Scalp temperature control is one of the technical factors that play a role in determining the effectiveness of scalp cooling. Most studies recommend a temperature range of 16°C–20°C to maintain adequate vasoconstriction without compromising patient comfort (Brunner et al., 2022). However, a more aggressive approach was reported by Mekha et al., 2024 which maintained scalp temperature at 3°C using an automatic sensor-based cooling system. The study noted a significant success rate of 81% in preventing CIA (grade 0–1). Interestingly, even though the temperature used was well below the general standard, this intervention was reported to be well tolerated by 71.4% of participants without any significant side effects (Mekha et al., 2024). Although these success rates are relatively high, these findings do not necessarily indicate that lower temperatures consistently provide better results than the standard temperature range. Patient tolerance to cold also needs to be considered to ensure comfort during the intervention, as discomfort due to side effects can increase the risk of treatment discontinuation (Castro et al., 2023). This indicates that the technical settings for scalp cooling should be individualized, taking into account the type of chemotherapy drug used and the patient's tolerance or resistance to cold.

Hair characteristics, including thickness, texture, and density, are often assumed to influence the effectiveness of scalp cooling through their effect on temperature distribution on the scalp. However, recent literature evidence suggests that these physical factors do not play a significant role in determining the success of the intervention. Weaver et al., 2024 reported that the only variable significantly associated with the success of hair preservation was the type of chemotherapy regimen; no meaningful differences were found based on age, race, or hair characteristics such as thickness, coarseness, type, and length. Similar findings were confirmed by Obuseng et al., 2021, through a comparison of effectiveness in curly and straight hair, where statistical analysis showed no significant difference in the severity of CIA between the two groups. Although the control group with curly hair showed a tendency toward more severe alopecia, cooling intervention still provided equivalent protection across hair textures. Overall, these data indicate that hair physical structure is not the primary determinant of success, but rather the pharmacological profile of the chemotherapy regimen remains the most dominant factor in efficacy.

The effectiveness of scalp cooling is not uniformly distributed across the entire body. A prospective study conducted by Fujii et al., 2025 confirmed that although this intervention significantly reduced the incidence of severe alopecia on the scalp, the same results were not observed in the eyebrows, eyelashes, or other body hair. Data show that in the scalp cooling group, severe alopecia on the head occurred in 58.8% of patients compared to 98.5% in the control group. However, in the eyebrow and eyelash areas, only a trend toward reduction was seen without statistically significant results. Biologically, this efficacy depends on the mechanism of local vasoconstriction and suppression of metabolic activity in hair follicles precisely in the cooled area. Scalp hair follicles tend to be more responsive because the majority are in the active anagen phase when exposed to cytotoxic agents. In contrast, the eyebrow and eyelash areas do not receive direct exposure to cold temperatures, so the protective effect is very limited, possibly only through minimal regional conduction or local vascular connections (Fujii et al., 2025). These findings confirm that the benefits of scalp cooling are anatomically specific, where areas outside the direct cooling range will not receive optimal protection from chemotherapy toxicity.

Tolerability is an important component in the evaluation of supportive interventions such as scalp cooling. In general, SC shows a good safety profile with mild side effects that are tolerable by most

patients. The most commonly reported side effects are headache, cold intolerance, and mild nausea (Lee et al., 2024; Mekha et al., 2024). However, good physical tolerability does not always translate to continued use of the intervention until the end of the chemotherapy cycle. This indicates that factors other than physical side effects also play a role in determining patient acceptance of the intervention. Several studies show that some patients discontinue scalp cooling early in therapy, even before clinical alopecia appears. This condition indicates that the decision to continue or discontinue the intervention is not only influenced by tolerability aspects but also by other factors such as cost considerations and patients' perceptions of the expected effectiveness of hair protection (Ohsumi et al., 2021).

In addition to economic factors, patients' subjective perceptions of hair loss levels also influence the evaluation of the success of scalp cooling interventions. Several studies have shown differences between patients' assessments and objective evaluations by experts regarding the degree of alopecia that occurs. Patients tend to assess their hair loss as more severe than clinical assessments, which show that some hair can still be retained (Brunner et al., 2022). This difference in perception indicates that patients' subjective experiences play an important role in determining their satisfaction with the intervention provided. In clinical practice, this perception can also influence the continuation of scalp cooling use, as patients who feel the results obtained do not meet their expectations tend to discontinue therapy earlier (Brunner et al., 2023). Thus, the success of scalp cooling implementation depends not only on its physiological effectiveness in reducing alopecia, but also on the alignment between the results obtained and patients' expectations, as well as their understanding of the intervention's objectives and limitations.

Collectively, the reviewed literature shows that the success of scalp cooling is the result of a multidimensional interaction between biological factors, chemotherapy regimens, technical parameters, and patients' psychosocial factors. Although clinical effectiveness is fairly consistent in reducing the degree of alopecia on the scalp, variations in response between patients and high rates of treatment discontinuation indicate that individualized approaches and patient education are important components in optimizing the benefits of this intervention.

CONCLUSION

A synthesis of the ten reviewed articles reveals that scalp cooling is an effective supportive approach for reducing chemotherapy-induced alopecia (CIA) among breast cancer patients undergoing chemotherapy. Reported hair preservation success rates range from 40% to over 90%, with most studies showing success rates between 50% and 81%. The effectiveness of scalp cooling is influenced by several factors, particularly the type and dose of the chemotherapy regimen. Taxane-based regimens tend to provide better hair preservation rates than anthracycline regimens. Technical parameters, such as cooling duration and scalp temperature, also influence the intervention's effectiveness, though protocol variations do not always result in significant outcome differences. Conversely, hair characteristics, such as texture or thickness, have not been shown to significantly affect therapy success. Overall, scalp cooling has a favorable safety profile with mild side effects. However, success in clinical practice is influenced by tolerability, patient perception of results, and adherence to the procedure throughout the entire chemotherapy cycle.

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