



# International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Operating Publisher  
SciFormat Publishing Inc.  
ISNI: 0000 0005 1449 8214

2734 17 Avenue SW,  
Calgary, Alberta, T3E0A7,  
Canada  
+15878858911  
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## ARTICLE TITLE

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CHEMOTHERAPY-INDUCED ALOPECIA - A LITERATURE REVIEW

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## DOI

[https://doi.org/10.31435/ijitss.1\(49\).2026.4950](https://doi.org/10.31435/ijitss.1(49).2026.4950)

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## RECEIVED

21 January 2026

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## ACCEPTED

18 March 2026

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## PUBLISHED

30 March 2026

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# THE EFFECTIVENESS OF CONTROLLED SCALP COOLING ON CHEMOTHERAPY-INDUCED ALOPECIA - A LITERATURE REVIEW

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## ABSTRACT

Chemotherapy-induced alopecia (CIA) constantly remains one of the most noticeable and stress-inducing side-effects of cancer therapy, despite new strategies and advances in therapeutic approaches. Even though usually reversible, hair loss carries serious psychological and social consequences that affect patients' comfort, social confidence and self-image, as well as adherence to oncological treatment. This review considers pathophysiological processes connected to CIA, focusing especially on anagen effluvium caused by cytotoxic nature of chemotherapeutic agents affecting proliferating hair follicle cells and underlines individual adaptation and susceptibility. Attention is focused particularly on controlled, mechanized scalp cooling method as an additional preventative intervention. Existing evidence from current studies clearly demonstrates that scalp cooling reduces the incidence and severity of CIA significantly, especially when it comes to taxane-based therapeutic regimens, with a range of 50% to 70% of hair preservation. In other types of therapies, like anthracycline-based, scalp cooling effectiveness is more limited but still shows meaningful reduction in severity and later onset of alopecia. Scalp cooling effectiveness reaches further than clinical outcomes. It contributes to an improved life quality, maintenance of privacy and identity and more positive patient-reported data. This review also takes global disparities, safety and ethical issues under consideration. Overall, innovative supportive strategies in medicine, like scalp cooling, integrate biological efficacy and psychological and social benefits and further underscore the importance of patient-focused approach in contemporary medicine, including oncological care.

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## KEYWORDS

Hair Loss, Scalp Cooling, Chemotherapy Side-Effects, Patient Quality of Life, Psychosocial Impact

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## CITATION

Dominik Ryszard Płaza, Jakub Chamier-Gliszczyński, Aleksandra Boba, Przemysław Siemiątkowski, Kacper Zima, Zuzanna Pietruk, Agnieszka Kiedik, Julia Kozłowska, Sylwia Skraińska. (2026) The Effectiveness of Controlled Scalp Cooling on Chemotherapy-Induced Alopecia - A Literature Review. *International Journal of Innovative Technologies in Social Science*. 1(49). doi: 10.31435/ijitss.1(49).2026.4950

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### 1. Methodology

This article is a narrative review focused on an interdisciplinary analysis of current literature that addresses the topic of chemotherapy-induced alopecia and scalp cooling method as a supportive intervention. The research for English-language literature was conducted using publicly accessible databases: PubMed, Scopus, Google Scholar. Search strategy included following terms: chemotherapy-induced alopecia AND scalp cooling AND life quality.

Observational studies, controlled trials and certain qualitative research were selected based on the accuracy and relevance to clinical effectiveness, biological mechanisms and patients-reported findings with social implications. The findings were introduced in such a way that biological evidence and psychosocial impact could be understood from a patient-centered approach in oncological care.

### 2. Introduction

Chemotherapy treatment is a fundamental baseline of oncological treatment nowadays and plays a key role in determining therapy outcomes for a variety of malignant tumors. Even though we have developed a wide range of targeted therapies as well as immunotherapy methods, the cytotoxic medicines are still commonly applied as a baseline treatment or as one of the modalities of multimodal therapies. Although the effectiveness of chemotherapy is incontrovertible, it is still commonly associated with a broad range of serious side effects that reach out much further than biological functions and it can significantly influence patients' psychological health and well-being with sociocultural extent [1].

Throughout all the adverse effects, one of the most unjustly stigmatizing and fear-inspiring is chemotherapy-induced alopecia (CIA), being very commonly associated with visible side-effects of cancer treatment. The time in which hair-loss is typically observed after starting chemotherapy is two to four weeks and most common medication groups that cause it are taxanes and anthracyclines [2]. Despite its usually

reversible nature, alopecia during treatment has a meaningful and almost immediate impact on patients. Due to hair-loss being a clear, externally visible sign of illness, it is a clear social stigma that almost instantly exposes patients' diagnosis, making those stricken with disease unable to control their privacy and intimacy concerning their health [3].

In a social and cultural context, hair acts as a symbol of health, identity carrier, gender identity tool, general attractiveness indicator. Commonly in many cultures, hair is viewed and perceived as an indicator of self-expression and personal image along with its importance in social and cultural status. As a result, chemotherapy-linked alopecia may disrupt certain areas of life and lead to the feeling of vulnerability, worsened self-worth, loss of identity and control [4]. Such far-reaching effects have been acknowledged across several cultural contexts, which indicates that psychological and sociological significance of hair loss is much more severe than just an aesthetic inconvenience.

What is worth mentioning, is that the psychological effects of hair loss extend far beyond emotional burden. Some studies have suggested that the fear of hair loss may have an impact on the patients' attitude towards undergoing chemotherapy, for instance: the reluctance to begin the treatment, anxiety that accompanies the therapy, smaller motivation to stick to the prescribed routine [3, 5]. Taking all of this into consideration, chemotherapy related alopecia is not only connected to the severity of life quality imbalance but also a worrying barrier to adequate cancer treatment.

In the past, some common strategies that strived to mask the problem of chemotherapy-induced alopecia involved wearing wigs, scarves and other headwear but those solutions are only a mask for a more complex psychological problem that remains unsolved as a strong reminder of one's illness. Additionally, such temporary solutions can lead to additional emotional, practical and financial stress and discomfort [1].

Lately, a new trend can be observed aimed at oncological patients, which involves a patient-centered approach of not only striving to survive the process and mask the issues but also of taking care of their quality of life and general psychological well-being. Such strategic change also comes along with some new innovations in supportive technologies especially designed to help with treatment side effects which in return could enhance patients' living conditions during chemotherapy. Among such technologies, scalp cooling techniques have been developed and are now a promising step forward as a non-pharmacological mean to prevent chemotherapy-induced alopecia [5].

This technique focuses on applying a controlled hypothermia to the scalp skin peri-treatment with the aim of maintaining hair follicles from receiving damage from cytotoxic and cytostatic medications. An advancement around biomedical engineering has made it possible to automatize scalp cooling methods making them more precise and controlled when it comes to temperature regulation and therefore patient comfort and repeatability [6]. In result, scalp cooling technology has become a widely accepted addition to an oncological treatment rather than an experimental method.

Not only does scalp cooling have a promising biological effect, but also it represents a big step in technological advancement with important sociopsychological impact. The reduction or prevention of a noticeable sign of illness, scalp cooling preserves a sense of normalcy in everyday life and helps patients to maintain a feeling of control over their condition and how it is viewed by their surroundings. According to this idea, scalp cooling fits into a wider area of social innovations in medical care which combines a clinical benefit along with being valuable to the society.

This duality of values of scalp cooling makes it a meaningful contribution for interdisciplinary research and analysis that aim at both medical technology and social sciences. The goal of this review is to research, compare and analyze current existing evidence of clinical effectiveness, mechanisms, limitations and sociopsychological impact of controlled scalp hypothermia in patients treated with chemotherapy. Including scalp cooling in the broader context of innovations in both social and health sciences, this paper could contribute to still ongoing discussions on certain interventions enhancing the effectiveness and social impact of cancer treatment.

### **3. Pathophysiological mechanism of Chemotherapy-Induced Alopecia**

The process of hair growth is a complex combination of interactions between epithelial, mesenchymal and immunological compartments of hair follicle structure. Physiologically, the hair follicle goes under certain cyclical processes of growth, regression and pause, which are respectively called anagen, catagen and telogen. The anagen phase can be characterized by dynamic cell proliferation with high metabolic activity and vital melanogenesis. All of this makes the hair follicle one of the most intensely proliferating structures in the whole human body [7].

In healthy adults, around 80% to 90% of hair follicles are in the anagen state at a certain time, meanwhile the rest remains in catagen and telogen phases. Such intensity of proliferation among hair follicle cells makes those structures very vulnerable to circulating cytotoxic medications [2]. Chemotherapy-induced alopecia (CIA) is directly caused by antineoplastic medications that disrupt a natural hair cycle by premature cessation of proliferative anagen phase and leading into a dynamic shedding of hair.

#### **3.1 Pathomechanisms of Anagen Effluvium**

This existing balding process of CIA happens as a form of anagen effluvium, that is described as a direct damage to rapidly dividing matrix keratinocytes found in hair follicle [2]. The target of chemotherapeutic medications are actively proliferating malignant cells. Those medications interfere with DNA synthesis, the formation of mitotic spindle, regulation of cell cycle. The key is that those processes are not specific for cancerous cells and so normal, healthy cells that undergo rapid proliferation, like hair follicles, gastrointestinal epithelium and bone marrow, are also affected [8].

Looking at the cellular level, cytotoxic chemotherapeutics cause a series of disruptions including DNA damage, mitochondrial dysfunction and oxidative stress in the hair follicle matrix. Those effects lead to apoptotic tendencies of affected cells that further promote the programmed cellular death and sudden hair shaft production inhibition [9]. Consequently, the hair shaft becomes weakened and structurally abnormal and prone to breakage and shedding. As a clinical result, visible and sudden diffuse hair loss occurs, typically within the first two weeks to a month after starting chemotherapy treatment [1].

Along with direct hair growth cessation, melanocytes in the hair follicle are also affected and highly sensitive to chemotherapeutics. That is why many patients experience changes in hair color, texture and general structure of hair once they regrow after the treatment finishes. Such proof further indicates how profoundly cytotoxic medications influence follicular biology.

#### **3.2 Influence of Chemotherapeutic medications and regimens**

It is important to note that the type of chemotherapeutic medications play a key role in the following severity and pattern of hair loss. Most cases of chemotherapy-induced alopecia are linked to using drugs such as anthracyclines (for instance, doxorubicin) or/and taxanes (for instance, paclitaxel) as they have a really potent effect on rapidly proliferating cells [9]. Moreover, combining multiple cytotoxic agents typically results in even more serious and advanced hair loss, in comparison to monotherapy.

One must remember about the critical role of dosage and therapy intensity. More advanced cumulative doses and shorter intervals of treatment administration as well as continuous infusions are typically associated with more severe alopecia incidence [2]. Following that thought, dose reduction and longer intervals may somewhat allow for better hair follicle recovery and less serious hair loss.

It is worth mentioning that there is also a big role of pharmacokinetic properties of chemotherapeutic medications on their influence on the distribution to the scalp. A more lipophilic structure or longer systemic circulation cause the substance to accumulate more in hair follicles and exercise a greater toxic effect [10].

#### **3.3 Susceptibility and Biological variability**

Even though patients receive identical, standardized treatments, not all of them experience chemotherapy-induced alopecia with the same intensity. Those differences between individuals reflect certain tendencies for varied susceptibility caused by a mix of genetic, hormonal and anatomical features [11].

Among different populations and even individual people, there are considerable variations in hair structure that include hair follicle density, hair shaft thickness and hair cycle timing dynamics. Follicular sensitivity to chemotherapeutics is also dependent on individual characteristics of genetic factors that affect drug metabolism, the repair capacity of DNA and pathways of apoptotic signaling [11]. Moreover, changes in hair follicle stem cells along with vascular supply to the hair follicle may also influence the severity of hair loss and play a role in the hair regrowth after treatment.

Individual features like psychological resistance, nutritional state, comorbid conditions may also influence the extent of hair loss during chemotherapy by altering immune responses and scalp skin homeostasis. Such factors underline the importance of multifactorial character of CIA and suggest that predicting and preventing hair loss severity may be difficult to generalize.

### **3.4 Temporary and reversible character of alopecia**

Chemotherapy-induced alopecia is commonly considered to be reversible and the hair regrowth usually begins after a few months after the treatment is finished. As mentioned before, hair regrowth often comes with the changes in hair structure and color, which suggests some persistent biological alterations to the hair follicle [7].

Sometimes, especially after a prolonged or high-dosage chemotherapy or stem cell transplant, permanent or elongated effects of hair loss have been observed. Despite it being quite rare, such outcome may seriously impact psychological health of the patients and demands further extensive focus on preventative strategies [9].

### **3.5 Implications for preventative interventions**

The key to the development and tailoring of the preventative strategies and solutions for hair loss, such as scalp cooling, requires deep understanding of biological mechanisms causing CIA. Aiming directly at vascular reactivity and metabolic reactions involved in hair follicle response to cytotoxic medicines, scalp cooling method acts directly on the pathophysiology of the processes responsible for anagen effluvium [10].

Looking from a broader point of view, studying CIA establishes a model for research on how medical side effects intersect with sociopsychological status and wellbeing of individuals stricken with illness. Keeping that in mind, innovations aimed at hair preservation during chemotherapy may benefit more areas than just biological preservation, but also enhancing patients' psychological resilience, social interactions and activity and enhance the adherence to the life-saving treatment.

## **4. Scalp cooling technology as medical and social innovation**

Controlled scalp cooling should not only be understood as an additional medical intervention but also as a clinical innovation which, when implemented, influences the structural and sociological change in healthcare systems. The popularity of scalp cooling is varied throughout different countries and even medical institutions which is largely caused by healthcare organizations, hospitals' policies and infrastructure [5, 10].

In Western Europe and North America high-income healthcare systems, an increasing number of automated scalp cooling devices have been added to oncology units standard practice as a part of supportive care. This movement has been facilitated by a growing number of serious evidence for clinical effectiveness, more common access to the devices and increasing reports of patients' positive outcomes which indicate the treatment success [6, 12]. In comparison, in setting with limited resources, there is restricted access to scalp cooling which highlights constant inequalities concerning the availability of technologies focused on enhancing patients' quality of life.

From a perspective of innovation studies, scalp cooling technology is an example of a supportive treatment strategy therefore it is meant to mitigate the negative side-effects of proven life-saving therapies. Baseline medical treatments are usually only based on survival data, whereas supportive treatments tend to prioritize psychosocial benefits and patients' perception of their own dignity, simultaneously challenging traditional cost-effectiveness strategies. Further evaluations suggest that scalp-cooling may be more cost-effective longterm, limiting the need for wigs, psychological care and withdrawal from social and work life [10].

Implementation of the scalp-cooling method depends highly on the attitude of professionals and the culture of institutions. Successful adoption requires lots of coordination between oncologists, nursing personnel, technical workers and willingness of institutions to focus on patient-centered care. Nurses hold a particularly important role in admitting scalp-cooling treatment and successfully managing the patients' comfort and adherence to the delivered protocol. There is a strong indication that well-trained staff and proper organization significantly impact clinical outcomes and patient satisfaction [5].

A patient's decision on whether to undergo scalp-cooling is importantly shaped by social expectations and context as well as estimated benefit. Some patients can refuse scalp-cooling due to the prolonged treatment risk, situational discomfort and skeptical approach towards its effectiveness. On the other hand, other patients may perceive hair preservation prospect as crucial to save their identity and normal functioning in society.

Those perspectives determine the importance of individualization in care strategies and shared decision-making [3].

Innovative technologies like scalp cooling give rise to questions regarding their analysis of success in healthcare. Qualitative biomedical statistics may underestimate the value of scalp cooling, omitting the psychological value that is the most important to patients. Patient-reported outcomes should be incorporated into evaluation statistics to fully understand the impact of scalp cooling and other supportive strategies in healthcare.

### **5. An analysis of qualitative and quantitative data for the effectiveness of scalp cooling**

Scalp cooling clinical effectiveness in CIA prevention has been widely evaluated in the past twenty years thanks to randomized controlled trials, cohort studies and systematic reviews. Overall, these studies gather comprehensive evidence that there is a reduction in the severity and incidence of hair loss while using scalp cooling, compared to baseline chemotherapy alone, without any supportive strategies [10-13].

#### **5.1 The effectiveness of hair preservation goals.**

Dean's scale or the World Health Organization (WHO) scale are most commonly used as standardized alopecia grading scales in assessment of clinical effectiveness of scalp cooling, combined with patient reports. Among different studies, preservation of 50% of hair or more is considered a successful outcome of scalp cooling. Such a threshold is believed to significantly reduce the need for head coverings and wigs [12].

Clinically significant benefits have been demonstrated in randomized clinical trials published in high-impact journals. Rugo et al. states that 50.5% of patients that have received automated scalp cooling preserved enough hair without the need of head covering, whereas a control group scored at 0% at that criterion [10]. In the SCALP trial, hair preservation has been reported in 66.3% of patients that received scalp cooling, while almost all patients in the control, non-scalp cooling group have experienced a very serious alopecia [11].

Such findings were also corroborated in meta analyses and observational studies, with reports that hair preservation after scalp cooling estimates around 50% to 70%, depending on baseline chemotherapy scheme and scalp cooling protocol [12, 13]. In patients that did not receive treatment, the rate of alopecia remained consistent and exceeded 80%-90% [2].

#### **5.2 Distinction of chemotherapeutic regimens.**

Scalp cooling effectiveness is most importantly determined by the type of chemotherapy medication used. The highest rate of hair preservation using scalp cooling is observed while taxane-based therapy, sometimes exceeding 70% [9, 10].

On the other hand, anthracyclines-based regimens, using doxorubicin or epirubicin, for instance, show lower effectiveness of scalp cooling method. Anthracyclines demonstrate a long tissue distribution period and highly alopecigenic properties and so local scalp cooling may have a limited protective capacity [7]. According to Komen et al., better effects of scalp cooling were noticed when taxanes-based therapy was used, rather than application of anthracyclines therapy protocols [9].

Even though less effective, scalp cooling could still provide certain benefit in patients treated with anthracyclines. Typically, in such treatment regimens, scalp cooling may help with a later onset of hair loss and lesser severity overall in comparison with control groups. This suggests that scalp cooling may at least help with, yet not prevent, severe hair loss during certain types of chemotherapy [12].

#### **5.3 Comparison of scalp cooling population with standard care**

Explicit comparison between groups of patients that underwent scalp cooling and those that received traditional baseline treatment, show clear differences in medical outcomes. Those that did not receive scalp cooling experience hair loss almost universally, it occurs early from the treatment onset and often requires the patients to use head coverings or wigs [10,11].

Scalp cooling, by contrast, helps the patients to avoid experiencing moderate or severe hair loss (grade 2 to 3 alopecia). Despite the scalp cooling method, some degree of hair loss may still occur but final results still seem to be more acceptable enough to allow the patients to function in society without the fear of clear visual signs of illness [13].

Among different studies, the scalp cooling method provided a relative risk reduction for severe CIA ranging from about 40% to more than 60%, considering chemotherapeutics used for the regimen and a selected population [12]. Overall, studies suggest that scalp cooling is one of the most effective supportive treatments that help manage chemotherapy-induced alopecia.

#### **5.4 Gender and Tumor-Type Considerations**

When it comes to the studies on the effectiveness of scalp cooling, most significant evidence comes from the populations treated for breast cancer which reflects a high utilization of chemotherapy as well as the extent of psychological burden of hair loss in this particular group. Scalp cooling has demonstrated repeatable efficacy in observational and randomized studies in breast cancer patients group [10-12].

There are limited studies involving treatment of other types of tumors and male patients population but there seems to be a similar and comparable physiological effectiveness for more or less the same types of regimens of chemotherapeutic strategy. Existing data indicate that patients' gender does not influence the outcomes in a significant way, more likely the treatment type, dosage and intensity itself play a more crucial role in the determined efficacy [13].

More varied chemotherapy protocols, like the ones used in gynecological tumors and selected lymphomas provide more heterogeneous outcomes. Nonetheless, the scalp cooling method generates a measurable beneficial difference when compared to no supportive intervention. This supports its further applicability beyond populations treated for breast cancer [12].

#### **5.5 The importance of patient-reported outcomes**

Objective clinical grading scales provide general measures for hair preservation, while the essential insight into real life effectiveness comes from patients' reports. A greater confidence in appearance, meaningful confidence in social situations and reduced emotional burden are consistently reported by the patients that underwent scalp cooling [3, 13].

What is worth mentioning, is that patients' subjective perception of preserving hair seems to be as important as an objective hair retention. Preserving even a partial amount of hair is connected to substantial reduction of the psychosocial burden of chemotherapy treatment which reduces the need for head covering strategies and allowing for daily routine preservation [4].

Patients' individual experience also helps to spread the popularity and information about scalp cooling. Individuals' satisfaction correlates with the willingness to make recommendations to other patients as well and for those individuals to undergo such supportive treatment again, if necessary. This observation underscores the perceived value and wide acceptability for technological innovations in medicine [12].

#### **5.6 Socioeconomic considerations for wigs and head coverings**

One of the most economic and psychosocial benefits of scalp cooling is the reduced need for wigs and other head coverings. Control groups showed a greater need for wigs during and after treatment compared to those who underwent scalp cooling during chemotherapy [10].

This outcome implicates both psychological and economic burden. Dedicated head coverings and wigs may bring financial stress, lack of comfort and emotional distress as a constant and inherent reminder of illness. The reduction in need for those accessories may directly contribute to the improvement of life quality and expenses associated with treatment [3].

#### **5.7 Estimation of available evidence**

Attention needs to be brought to certain limitations of scalp cooling, in spite of strong supporting evidence. Different cooling protocols have been used in available studies, outcome measures and follow-up timeline complicate precise and direct comparison. Selection bias also has to be taken under consideration, as it may noticeably influence the results, as there may be important differences in patients that choose scalp cooling and those who decline it [12].

The predominance of breast cancer study groups also limit the generalization of findings. Future research and study strategies should focus on standardized outcomes with an inclusion of other cancer types and longer follow-up period. Such strategy could help with proper characterization of clinical and psychosocial outcomes of the automated scalp cooling method.

## 6. Limitations, safety, and ethical Considerations

It is important to note that scalp cooling is not a universal protective method against CIA. Its effectiveness varies among different chemotherapy regimens, intensity and individual traits of the treated populations [9, 12]. Even with optimal cooling of the scalp, some patients may notice non-satisfactory hair preservation results while receiving medical agents with high alopecic tendencies, like anthracyclines.

One of the other practical concerns and limitations in the patient's tolerance. Some of the most common side-effects of scalp cooling include headaches, discomfort to the scalp, cold intolerance and overall chills. Though typically mild and transient, such symptoms could potentially reduce the acceptance of treatment, especially when some patients experience migraines or peripheral vascular disorders [10, 11].

Based on the reduced access of cytotoxic agents to the scalp skin during cooling and a potential for scalp metastases, there is a frequently debated theoretical safety concern for that method. Nonetheless, long-term retrospective and observational studies have not proven an increased risk of scalp metastases in groups of patients that have undergone scalp cooling, compared with a control group of standard treatment [8, 10]. Existing evidence suggests a strong oncological safety in patients, if appropriately selected, although it is advisable to continue surveillance.

Beyond safety concerns, there are also some ethical considerations. There is a wide variability of access to scalp cooling across healthcare systems, depending on resources, insurance, ability of patients to pay on their own. Those differences raise concerns in regard to equality in supportive treatments during cancer care. Uneven access to medical innovations that improve the quality of life may lead to further healthcare disparities [5].

While scalp cooling became a well-documented and innovative supportive medical intervention, its routine integration into oncological treatment practice should be followed by policies focused on promoting equal access and fully informed patient's decision.

## 7. Psychosocial impact of hair preservation

Chemotherapy-induced alopecia carries a substantial psychosocial impact. The loss of hair can affect self-image, emotional health, relationships and fulfilling social roles. Numerous studies suggest that alopecia is one of the most concerning side effects during chemotherapy, sometimes even as or more severe than nausea and fatigue [3, 4].

These effects are strongly mitigated by preserving hair during chemotherapy. Those patients who maintain hair report to having a higher self-esteem, retain their body image and feel less stigmatized. Overall, hair preservation allows for maintaining the feeling of normality and enables the patients to engage in social, professional and familial activities [3].

Hair loss is a visible sign of illness, often leading to unintentional diagnosis disclosure.

There may also be an indirect influence of psychosocial benefits on clinical results. The fear of experiencing CIA contributes to heightened reluctance to undergo and complete cancer treatment. Scalp cooling may indirectly improve the acceptance and the adherence to chemotherapy treatment by alleviating the fear of hair loss [7].

From a psychosocial viewpoint, scalp cooling technology allows for not only appearance preservation but also with maintenance of social roles and identity which further extends to familial and workplace relations along with other social networks.

## 8. Discussion

This paper highlights the multifaceted nature of scalp cooling beyond simple clinical effectiveness with measurable results. Standardized trials may provide evidence of reduced chemotherapy induced alopecia but lived experience is required for broader interpretation of social and ethical frameworks.

Hair loss is a key aspect altering one's self-perception and how we are perceived by others when battling cancer, which makes it the symbolic central theme of this article. Mitigation of this visible illness marker which may be provided by scalp cooling, allows for greater privacy and control over the patients' social identity [3, 4]. The ability to manage disclosure is an often underappreciated feature of supportive treatment.

Scalp cooling technique represents the importance of integrating patient's values with technological innovation. Certain technologies that do not affect survival rate can, nonetheless, influence the treatment experience, adherence, emotional resources and support a more holistic approach of therapeutic success.

Given all these benefits, they are unevenly distributed. Social, institutional and economic differences in medical care raise concerns about equality. To address these disparities, reimbursement strategies and inclusion of supportive medical technologies in guidelines must be included in policy interventions [10].

When looked upon from a social sciences perspective, scalp cooling is a psychosocial innovation that redefines standards of oncology care which align with broader popular movements of patient-centered standards in healthcare.

Further research is required to examine long-term psychosocial effects that include the time of return to work, social relations, post-treatment identity well-being, across cultural contexts, using qualitative data.

### **8.1 Global and sociological context of chemotherapy-induced alopecia**

From a perspective of global issues, CIA reflects medical, socio-cultural and economic dimensions of oncological care. There are millions of patients undergoing cancer treatment every year, with hair loss being one of the most feared side effects across cultures and populations [1, 2].

The experience of alopecia is shaped by the cultural norms around hair. Many societies consider hair as a symbol of femininity or masculinity, vitality or even social status. Hair loss may therefore mean a loss of identity, more vulnerability and shattered meaning of gender roles and social structure [4].

For certain cultures, gender differences are of at most importance. Although the distress connected to CIA affects both women and men, women report greater emotional threat due to some social and cultural associations with hair, femininity and attractiveness [3]. Hair loss may affect social and professional relations and affect participation and confidence.

Further experience shaping belongs to socioeconomic factors. Wigs, therapy counseling and preventive technologies like scalp cooling have varied access globally. In low- to middle-income societies, where such resources are rare which underscores an importance of social inequality of alopecia in global cancer treatment.

The obvious, visible nature of alopecia intersects with a forced disclosure and stigma. Being a public sign of illness, hair loss can lead to unintentional reveal and reduced autonomy [4]. Therefore, hair loss reducing technologies play a big role in altering social status.

Overall, scalp cooling does not provide a cosmetic concern but rather a psychosocial target. By resolving a serious side-effect with a clear social meaning, it aligns with an effort to make cancer care more humane and to integrate social considerations into treatment strategies.

### **8.2 Future implications for social and health strategy**

Evidence that supports the effectiveness of scalp cooling sets some directions for further research. Long-term studies are required to assess the effects for quality of life, social integration and psychosocial rehabilitation after cancer treatment. Qualitative nature of the studies may show more clearly how patients perceive hair preservation across their return to normalcy [3, 4].

Further research needs expanding beyond breast cancer patients population and to become more inclusive for other various malignant tumors, other chemotherapy regimens, genders and age groups as well as aim at improving the standard of care to be more equal and commonly applied [9, 13].

As far as social sciences are considered, scalp cooling can shed light on how some technological innovations in medicine may help in retaining identity, alleviate stigma, shift social situations and enforce an interdisciplinary approach.

Despite scientific evidence, policy considerations seem to be substantial. Access to scalp cooling is limited and unequal mostly due to financing issues. Incorporation of scalp cooling into standard oncological practice could be possible if cost-effectiveness is demonstrated by the reduced need for head coverings and wigs, less psychological interventions and rarer work absences [10].

An inclusion of patient-reported data in an assessment of health technology would be useful in providing a coherent and comprehensive evaluation of supportive interventions oriented on the quality of life [5, 11].

For a broad and effective adoption, innovative medical technologies should also focus on comfort, accessibility and efficiency. As common as oncological care becomes, supportive interventions should address both medical and social concerns.

## 9. Conclusions

Scalp cooling proves to be an effective and psychosocially important intervention that helps manage chemotherapy-induced alopecia. There is strong evidence for its significant reduction in hair loss, especially in patients undergoing chemotherapy involving taxanes.

Looking further than esthetic considerations, scalp cooling technology represents a patient-centered innovative medical technology that addresses psychological and social well-being and comfort. Still some challenges remain considering equality in access, inconsistent effectiveness and limited proof for different types of chemotherapy protocols and long-term evaluation but these limitations should be treated as a motor for further deep research and not overshadow the existing demonstrated scalp-cooling results.

Ultimately, this paper shows that scalp cooling has meaningful implications in regard to medical, social and psychological implications as an innovative medical supportive technology. In the era of holistic, patient-based medical practice, this method should be seriously considered to be put into standard oncological care regimens that prioritize not only physical health successes but also maintenance and improvement of the quality of life, patients dignity and experience.

### Author contribution:

Concept and methodology - D. R. Płaza; concept and writing (review and editing) – J. Chamier-Gliszczyński; research – P. Siemiątkowski and A. Kiedik; writing (draft) – A. Boba, S. Skraińska and J. Kozłowska; data gathering and resources – Z. Pietruk and K. Zima.

**Funding Statement:** This research received no external funding.

**Conflict of Interest Statement:** The authors declare no conflicts of interest.

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