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REVIEW ARTICLE

Cost-effectiveness of photobiomodulation therapy for the prevention and management of cancer treatment toxicities: a systematic review

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Abstract

Purpose To identify and summarize the evidence on the cost-effectiveness of photobiomodulation (PBM) therapy for the prevention and treatment of cancer treatment-related toxicities.

Methods This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) and Meta-analysis Of Observational Studies in Epidemiology (MOOSE). Scopus, MEDLINE/PubMed, and Embase were searched electronically.

Results A total of 1490 studies were identified, and after a two-step review, 4 articles met the inclusion criteria. The included studies analyzed the cost-effectiveness of PBM therapy used in the context of lymphedema for breast cancer and oral mucositis (OM) induced by chemotherapy and radiotherapy. Better outcomes were associated with PBM therapy. The incremental cost-effectiveness ratio ranged from 3050.75 USD to 5592.10 USD per grade 3–4 OM case prevented. PBM therapy cost 21.47 USD per percentage point reduction in lymphedema in comparison with 80.51 USD for manual lymph drainage and physical therapy.

Conclusion There is limited evidence that PBM therapy is cost-effective in the prevention and treatment of specific cancer treatment-related toxicities, namely, OM and breast cancer-related lymphedema. Studies may have underreported the benefits due to a lack of a comprehensive cost evaluation. This suggests a wider acceptance of PBM therapy at cancer treatment centers, which has thus far been limited by the number of robust clinical studies that demonstrate cost-effectiveness for the prevention and treatment of toxicities.

Keywords Photobiomodulation · Cancer toxicities · Cost · Systematic review

Introduction

Economic evaluation of the management of health conditions is essential in supporting decision-making by clinicians, policymakers, and planners to shape healthcare policy and health services delivery [1–4]. Cancer treatment toxicities consist of several adverse consequences that often affect quality of life and may result in increased medical consultations,

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emergency room visits, new or prolonged hospitalizations, the need for nutritional support, and the use of opioids for pain management, all of which are drivers of healthcare costs [4–8]. Management of these toxicities is an ongoing challenge, but therapeutic interventions can potentially improve outcomes and reduce costs [7, 9, 10]. Even though most reported cancer costs are related to direct medical expenditures for the treatment of malignant disease, it is crucial to understand the overall cost, which encompasses both the direct treatment costs and the incremental costs associated with high rates of acute and chronic treatment toxicities [1].

Photobiomodulation (PBM) therapy is used in cancer care to prevent or manage treatment-related toxicities such as oral mucositis (OM), lymphedema, peripheral neuropathy, radiodermatitis, dysphagia, radiation fibrosis, radionecrosis, bisphosphonate-related osteonecrosis of the jaw, trismus, and graft-versus-host disease [11–16]. PBM includes a broad range of nonionizing light sources that lead to anti-inflammatory effects, promote wound healing and tissue repair, improve neural function, and exert an analgesic effect [11, 13, 17–21]. Moreover, the Multinational Association of Supportive Care in Cancer/International Society of Oral Oncology (MASCC/ISOO) has recommended PBM for oral mucositis (OM) [21]. Despite PBM therapy being accessible, implementation requires trained staff and specific equipment [21, 22]. To our knowledge, the present systematic review is the first to evaluate the evidence on the cost-effectiveness of PBM therapy in the prevention and treatment of complications related to cancer treatment.

Materials and methods

A systematic literature review was carried out according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [23] and Meta-analysis Of Observational Studies in Epidemiology (MOOSE) [24] guidelines. The protocol for this systematic review was registered in the International Prospective Register of Systematic Review (PROSPERO) database (registration number CRD42019133695—https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=133695) to avoid potential duplication and to enable comparison among methods as they are reported in the review protocol.

Search strategy

A systematic electronic search for scientific studies evaluating the cost-effectiveness of PBM therapy in cancer patients for the prevention and/or treatment of toxicities induced by antineoplastic therapies was conducted without restriction on the publication year (the last search was performed on July 17th, 2020). To this end, Medline/PubMed (https://www.ncbi.nlm.nih.gov/pubmed), EMBASE (https://www.embase.com/login), and Scopus (https://www.scopus.com) were screened with the following keywords: "low-level laser therapy," "photobiomodulation," "cost-effectiveness," "oral mucositis," "lymphedema," "esophagitis," "radiodermatitis," "peripheral neuropathy," "hyposalivation," "xerostomia," "dysphagia," "radiation fibrosis," "radionecrosis," "bisphosphonate osteonecrosis of the jaw," "dysgeusia," "graft-versus-host disease," "trismus," "postsurgical wound healing," "tinnitus," "dyshidrotic eczema," and "cancer toxicities." Synonyms, abbreviations, and related keywords for each of these terms were used for the search, linked in independent strategies by the Boolean operator "AND." We retrieved all publications containing a combination of controlled, predefined medical subject headings (MeSH) and free terms related to PBM therapy using Boolean operators (OR, AND) to combine searches. The process was repeated in each database to ensure that relevant results were not missed during the identification phase, which was adapted to the syntax rules of each electronic database. Additional manual searches were conducted by reading the reference lists from all selected studies to detect other potentially eligible reports meeting the inclusion criteria. Key authors/coauthors were identified among the included studies, allowing for the verification of additional database searches filtered by author/coauthor name.

Inclusion criteria

The inclusion criteria for this systematic review were based on the PICOS approach [Population (P), Intervention (I), Comparison (C), Outcome (O), and Study design (S)]. We included (S) clinical trials, regardless of randomization, and retrospective clinical studies that evaluated (O) the cost-effectiveness of preventive and therapeutic (I) PBM therapy compared with a (C) placebo group or any other therapy for cancer treatment toxicity management in (P) cancer patients undergoing oncological treatment.

Exclusion criteria

We excluded case reports, case series, animal studies, in vitro studies, letters to editors, editorials, review articles, guidelines, study protocols, commentaries, monographs, conference papers, unpublished data, studies published in a language other than English, and studies lacking information on the cost-effectiveness analysis of PBM therapy in the treatment of toxicities induced by antineoplastic therapies.

Study selection

The study selection was completed using Rayyan QCRI [25] reference manager software for the initial screening phase. After duplicates were excluded, a screening of titles and

abstracts was independently performed by two authors (EKF, ARSS) for possible inclusion in the qualitative synthesis of this review. Subsequently, studies assessed for eligibility were reviewed independently in full-text versions by two reviewers (EKF, ARSS). A final decision was made by a third reviewer (LRO) to achieve consensus when discrepant ratings occurred between the two reviewers.

Data extraction

Study characteristics

Study characteristics extracted from the included studies were as follows: (1) first author, (2) year of publication, (3) cancer toxicity, (4) study type, (5) patient condition, (6) sample size, (7) study groups, (8) cost-effectiveness based on authors' considerations, and (9) PBM therapy parameters.

Cost-effectiveness and cost analysis

PBM therapy was defined as cost-effective when there was an improvement in the relative costs of cancer toxicity outcomes compared with the corresponding costs related to placebo or an alternative treatment. To evaluate cost-effectiveness, we extracted information on the (10) toxicity prevalence, (11) basis for the cost analysis, and (12) cost analysis procedures.

The costs reported in the systematic review were converted to 2020 US dollars (USD) by applying the gross domestic product deflator index (GDP values) and purchasing power parity conversion rates (PPP values) using the Campbell and Cochrane Economics Methods Group-the Evidence for Policy and Practice Information (CCEMG–EPPI)-Centre Cost Converter software (V1.6) [26, 27], which automatically adjusts estimates for costs and price year. This conversion methodology is meant to provide a way to compare data from articles that are written at different times and that use currencies other than USD. In situations where a reference year was not provided, we used the last year in which patients were included, or when this was unknown, the costs were calculated based on one year before the publication year.

Risk of bias assessment

The risk of bias for selected studies was evaluated using the standardized critical appraisal instrument for risk of bias assessed by the Meta-Analysis of Statistics Assessment and Review Instrument (MAStARI) critical appraisal tool [28]. Higher scores denote a lower risk of bias. The risk of bias was categorized as high when the study scored less than 50% on the MAStARI scale, moderate when the study scored 50% to 69%, and low when the study scored 70% or higher. Both reviewers scored each item as "yes," "no," "unclear," or "not applicable" and assessed the quality of each included study independently. A third reviewer resolved disagreements.

To critically appraise the quality of studies, we completed the Consensus on Health Economic Criteria (CHEC) list for each publication that mentioned a cost evaluation [29]. The CHEC-list consists of 19 yes-or-no questions, one for each category. Higher scores of "yes" denote a better methodological quality of the economic evaluation.

Data analysis

It was not possible to perform a meta-analysis of the included studies due to the lack of uniformity in the presented cost-effectiveness analysis and CHEC-list items. Therefore, this systematic review presented a detailed qualitative synthesis of the results from the included studies.

Results

Study selection and study characteristics

A flow diagram that summarizes the process of selecting studies is shown in Fig. 1. In total, 1490 studies were identified through the aforementioned search strategies. No additional studies were identified through the manual search. For the initial review process, 369 duplicates were excluded, and after a thorough evaluation of titles and abstracts, an additional 1104 articles that did not meet the inclusion criteria were excluded, resulting in 17 articles.

A full-text analysis was performed on the 17 remaining studies, and a second review process led to the further exclusion of 13 studies: 3 were conference abstracts not associated with full-text articles, 1 was excluded due to the publication language (Russian), 2 were study protocols of ongoing clinical trials, 1 full-text article was not available for evaluation, 2 were publications using the same sample but with updated data, and 4 did not conduct a cost-effectiveness analysis. Finally, 4 studies met all inclusion criteria and were included in the systematic review. All of the included studies evaluated the cost-effectiveness of PBM for the prevention and treatment of toxicities induced by cancer treatments [22, 30–32].

Table 1 presents the main characteristics of the included studies. The cost-effectiveness of PBM therapy for OM was evaluated in 3 studies. Two studies analyzed PBM therapy for OM in head and neck cancer patients receiving radiation therapy [31, 32], and one study focused on patients undergoing hematopoietic stem cell transplantation (HSCT) [22]. No uniformity of PBM parameters was observed. The fourth study assessed the cost-effectiveness of PBM therapy for lymphedema in breast cancer patients [30], specifically among patients with chronic lymphedema, and included a small sample. All

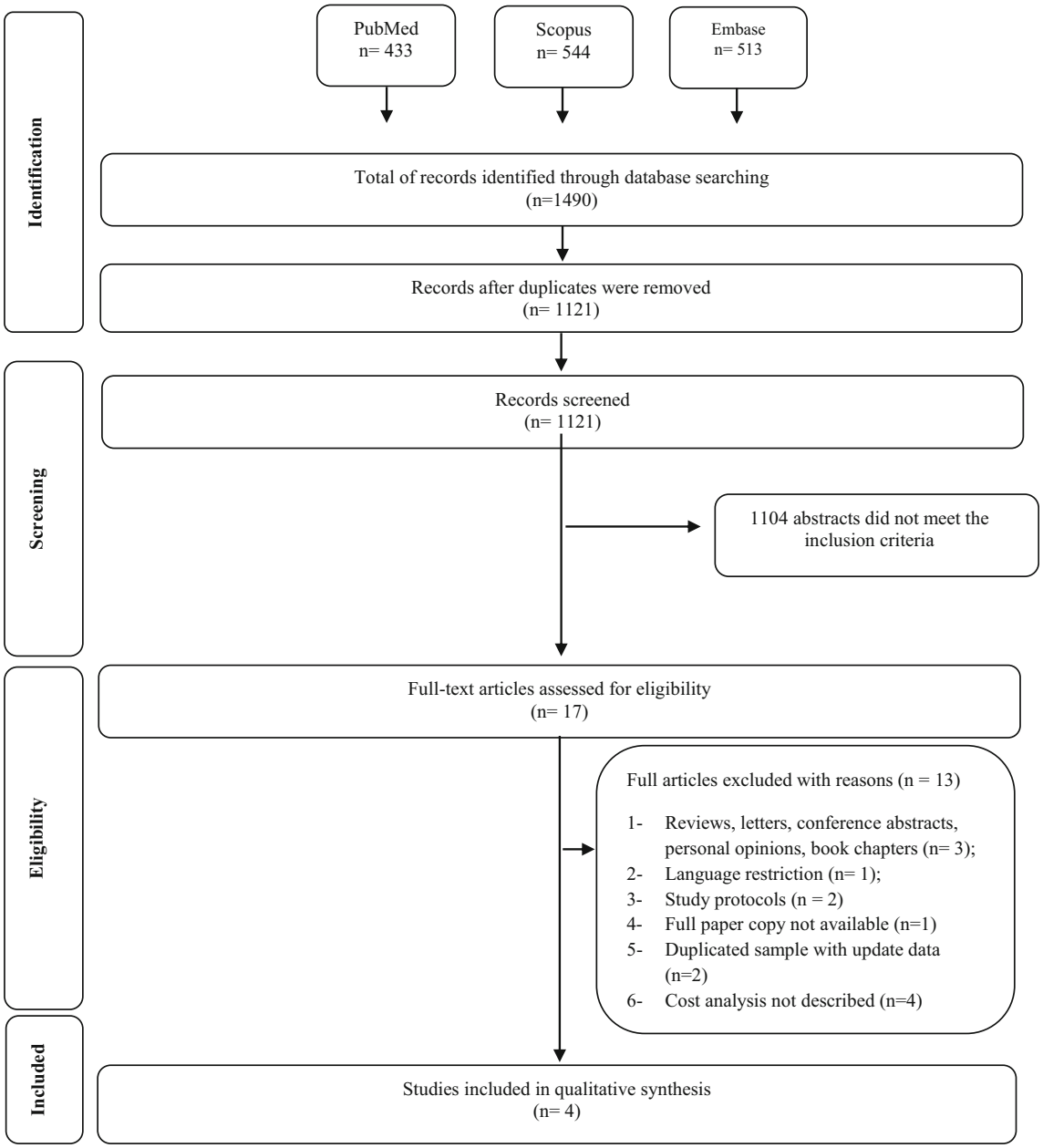

Fig. 1 Flow diagram of the literature search and selection criteria adapted from PRISMA (Moher et al., 2010)

of the included studies reported the cost-effectiveness of PBM therapy for OM and lymphedema.

Cost-effectiveness of PBM therapy for OM

Table 2 presents the prevalence of cancer toxicity and the parameters for the cost-effectiveness analysis. All included studies found PBM to be a cost-effective therapy for OM. The efficacy of PBM therapy for OM was demonstrated by the presence of higher grades (grades 3–4) of OM (World Health Organization [WHO] Oral Toxicity Score scale) [33] in the control group than in the PBM group (grades 1–2) [22, 31, 32]. For all 3 studies evaluating PBM therapy for OM, the cost analysis evaluation was performed by assessing inpatient charges limited to the period of cancer treatment (HSCT and chemoradiation), costs associated with nutritional support (parenteral nutrition, nasoenteral feeding tube, gastrostomy), and those related to opioid use. For the PBM therapy group, costs related to PBM therapy (e.g., equipment and professional wages) were also added.

Bezinelli et al. [22] evaluated the total cost of HSCT in two groups, the PBM group and a control group receiving no PBM, which included patients treated in a period before the introduction of a dental team in the transplant unit. This study evaluated the costs related to daily hospitalization fees, nutritional support, and opioid use, in addition to the costs of the

Table 1 Baseline characteristics and PBM therapy protocol of studies included in the systematic review

Study	Study type	Patient condition	Sample size	Experimental group	Control group	Cost-effectiveness	PBM protocol
Oral mucositis							
Bezinelli et al., 2014 [22]	Retrospective, case control	HSCT (transplantation)	167	PBM (n = 91)	No PBM (n = 76)	Yes, PBM contribute to minimize hospitalization costs during HSCT	Wavelength 660 nm, power 40 mW, energy density 8 J/cm^2. Daily, starting 1 day after the conditioning until marrow engraftment
Antunes et al., 2016 [31]	Randomized, double-blind, placebo controlled, clinical trial	Head and neck cancer (chemoradiation)	94	PBM (n = 47)	Placebo (n = 47)	Yes, PBM has important cost-impact per oral mucositis case prevented	Wavelength 660 nm, power 40 mW, energy density of 8 J/cm^2. Daily during radiotherapy treatment. 5 days/week during radiotherapy
Martins et al., 2020 [32]	Randomized, double-blind, placebo controlled, clinical trial	Head and neck cancer (chemoradiation)	48	PBM (n = 25)	Placebo (n = 23)	Yes, PBM is a cost-effective option in preventing severe degrees of oral mucositis and interruption of RT	Wavelength 660 nm, power 25 mW, energy density of 6.2 J/cm^2. Daily during radiotherapy treatment. 5 days/week during radiotherapy
Lymphedema							
Study	Study type	Patient condition	Sample size	Experimental group	Control group	Cost-effectiveness	PBM protocol
Piller and Thelander, 1995 [30]	Prospective, interventional, clinical trial	Breast cancer (mastectomy)	11	PBM (n = 11)	Contralateral arm (n = 11)	Yes, PBM therapy is a cost-effective strategy for the treatment of chronic lymphedema.	Wavelength 632 nm and 904 nm (4 semiconductors), average power 7 mW, energy density of 24 J/cm^2. Twice a week during 6 weeks, and single session for further 4 weeks.

HSCT, hematopoietic stem cell transplantation; *PBM*, photobiomodulation

Table 2 Cost analysis of studies included in the systematic review

Study	Toxicity prevalence	Basis for cost analysis	Cost analysis PBM group (2020 USD)[1]	Cost analysis control group (2020 USD)[1]
Bezinelli et al., 2014 [22].	Grades 1–2 oral mucositis for PBM group; Grades 3–4 oral mucositis for control group. (WHO scale)	Sum of inpatient charges, costs of parenteral nutrition, opioids use, PBM (when received) and HSCT (autologous and allogenic). Limited to impatient time.	Total cost of transplantation (mean): - Without PN/opioids: 33,484.69 USD (autologous) 49,847.48 USD (allogenic) - With PN and opioids: 41,714.84 USD (autologous) 61,614.95 USD (allogenic)	Total cost of transplantation (mean): - Without PN/opioids: 33,259.34 USD (autologous) 55,661.42 USD (allogenic) - With PN and opioids: 53,614.77 USD (autologous) 79,972.65 USD (allogenic)
Antunes et al., 2016 [31].	Grades 1–2 oral mucositis for PBM group; Grades 3–4 oral mucositis for control group. (WHO scale)	Individual cost of hospitalization charges, nutrition support, opioids use, and PBM (when received). Limited to time of radiation therapy. Costs associated with cancer treatment were not considered.	Incremental cost per patients: Opioids: 10.23 USD Gastrostomy: 56.92 USD Hospitalization: 0.00 USD PBMT: 2119.64 USD ICER* to prevent oral mucositis grade 3-45592.10 USD	Incremental cost per patients: Opioids: 49.89 USD Gastrostomy: 146.37 USD Hospitalization: 86.82 USD PBM therapy: 0.00 USD
Martins et al., 2020 [32]	Grades 1–2 oral mucositis for PBM group; Grades 3–4 oral mucositis for control group. (WHO scale)	Individual cost of hospitalization charge, nutrition support (nasoenteral tube and polyvitamins), opioids use, and PBM (when received). Limited to time of radiation therapy. Costs associated with cancer treatment were not considered.	Incremental cost per patients: Opioids: 0.25 USD Nutritional support: 40.61 USD Hospitalization: 0.00 USD PBMT: 935.30 USD ICER* to prevent oral mucositis grades 3–4 3050.75 USD ICER* to prevent RT interruption due to oral mucositis 2864.37 USD	Incremental cost per patients: Opioids: 4.61 USD Nutritional support: 53.91 USD Hospitalization: 263.39 USD PBM therapy: 0.00 USD
Piller and Thelander, 1995 [30].	PBM therapy was associated with 19% of average reduction of lymphedema in 10 weeks.	Total cost of treatment per percentage reduction of lymphedema	PBM therapy cost 21.47 USD per percentage point reduction in lymphedema. 16 sessions of PBM therapy (10 weeks) cost 402.57 USD	Physical therapy of MLD cost 80.51 USD per percentage point reduction in lymphedema. One year of treatment cost up to 4025.74 USD, (~ 774.18 USD for 10 weeks)

*Incremental cost-effectiveness ratio (ICER); **Photobiomodulation (PBM); ***Parenteral nutrition (PN); ****MLD*, manual lymphatic drainage

[1] Campbell and Cochrane Economics Methods Group—the Evidence for Policy and Practice Information (CCEMG–EPPI)- Centre Cost Converter software (V1.6)

cancer treatment itself. The results were reported as overall costs of treatment separated in coordination with the autologous or allogeneic transplant modality and subdivided into patients with and without nutritional support and opioid use. The individual cost of PBM therapy was not available.

All results from Bezinelli et al. [22] presented lower costs for the PBM group than for the control group. However, the cost of the treatment for patients submitted to autologous transplantation without parenteral nutrition and opioid use was slightly increased for the PBM group. When comparing costs for patients who required nutritional support and opioid use, an additional cost of approximately 12,000 USD for autologous transplantation and 18,000 USD for allogenic transplantation was posed for the control group in comparison with the PBM group.

Antunes et al. [31] and Martins et al. [32] evaluated the mean cost per patient by including the costs of PBM, hospitalization, opioid use, and nutritional support in two distinct groups: PBM therapy and placebo. The cost analysis was presented in individual costs for each outcome assessed [31, 32], and the individual cost of PBM therapy was reported [31, 32]. Both studies assumed the cost of cancer treatment to be equivalent between groups and, therefore, did not assess the cost of chemoradiation in the cost analysis [31, 32].

For Antunes et al. [31], incremental costs were higher for the control group, except for the additional cost associated with PBM therapy, estimated at 1903.70 USD. When costs related to PBM therapy were not considered, the total incremental cost per patient was 283.07 USD higher in the control group due to OM toxicity. The incremental cost-effectiveness ratio (ICER) was assessed in this study, and 5592.10 USD was saved per grade 3–4 OM cases prevented by PBM therapy. For Martins et al. [32], all incremental costs were higher for the control group, and PBM therapy posed an additional cost per patient of 935.30 USD. The base-case ICER assessed to prevent grade 3–4 OM was 3050.75 USD. Additionally, the ICER to prevent RT interruption due to OM was 2864.37 USD.

Cost-effectiveness of PBM therapy for lymphedema

One study that evaluated the cost-effectiveness of PBM therapy for lymphedema was included [30]. The study demonstrated a positive impact of PBM therapy, which decreased the lymphedema severity. Piller and Thelander [30] evaluated the PBM therapy efficacy for lymphedema in breast cancer patients, and PBM was shown to decrease edema volumes by an average of 19% after 16 sessions (10 weeks). The cost-effectiveness analysis was based on the total cost of treatment and the percentage reduction in lymphedema as the health outcome. The patient's contralateral arm was used as the control group for volume comparison. Cost analysis compared the costs of PBM therapy with the costs of manual lymph drainage and complex physical therapy, which represented conventional lymphedema treatment. PBM cost 21.47 USD per percentage point reduction in edema volume, while conventional treatment cost 80.51 USD. For 10 weeks of treatment, PBM therapy cost 402.57 USD, and for the same period, conventional treatment cost 774.18 USD. In addition, the authors suggested that fewer PBM sessions would be necessary to achieve similar results. Thus, PBM therapy can potentially be more cost-effective than reported in the present study.

Risk of bias

The selected studies were considered at low risk of bias [22] for comparable cohort/case-control studies and at low risk of bias [31, 32] and moderate risk of bias [30] for randomized control trials.

The included articles that evaluated costs were critically appraised by the CHEC-list tool. The articles evaluating OM had more transparent, informative, and comparable quality assessments of economic evaluations, with higher scores: 73.68% [22] and 89.47% [31, 32] in comparison with the lymphedema study, at 52.63% [30].

Discussion

PBM is being increasingly utilized to prevent and treat a wide range of cancer treatment toxicities that pose an incremental economic cost to cancer treatment, such as OM, lymphedema, peripheral neuropathy, and radiodermatitis [5, 11, 13–16, 18, 20]. Understanding and evaluating the incremental costs associated with these toxicities and the impact of PBM therapy on cost savings may help increase the acceptance of PBM therapy by health care professionals and administrators [4]. To our knowledge, this is the first systematic review to address and evaluate the cost-effectiveness of PBM therapy for the prevention and treatment of cancer-related toxicities.

Several prior studies discussed the economic benefits of integrating PBM therapy into cancer care [19, 22, 30–32, 34–36], yet most studies did not conduct an economic evaluation [19, 34–36] and assumed cost-effectiveness conclusions by relying on outcomes associated with treatment time, outpatient services, pharmaceutical costs, nutritional support, and hospitalization days, which are parameters associated with the per patient costs for individual resources and cost criteria [1, 2, 37, 38]. A cost-effectiveness analysis of PBM therapy has been conducted in only a small number of studies [22, 30–32].

The prevention and effective management of cancer-related toxicities can optimize care outcomes and reduce the cost of care [11], although there are costs associated with PBM therapy (e.g., equipment, highly skilled professionals, and additional consultation costs), as reviewed by Antunes et al. [31] and Martins et al. [32], these costs are likely offset

by the reduction in the costs of managing complications of cancer treatment, such as hospitalization, which is the largest driver of total costs [19, 38–40].

In terms of cancer-related toxicities, OM was the most prevalent toxicity described in the included studies [22, 31, 32]. Moreover, the costs of OM seem to be more significant than those reported for a wide range of other cancer treatment toxicities. The only toxicity that seems to be as costly as OM is neutropenia [5, 22, 31, 38]. Previous studies have shown that the presence, extension, and severity of OM are associated with incremental costs [9, 33, 38, 40, 41]. Higher costs were observed to be positively correlated with higher grades of OM, in agreement with the literature, which suggests that the presence, extension, and severity of OM are associated with an increased cost of care [5, 40]. These findings support the use of PBM as an intervention that potentially prevents or minimizes the severity of OM and leads to lower costs [9]. Interestingly, two of the included studies estimated an ICER per grade 3–4 OM case prevented by PBM therapy of 5592.10 USD [31] and 3050.75 USD [32]. Furthermore, Martins et al. [32] calculated the ICER to prevent RT interruption due to OM as equaling 2864.37 USD. Unplanned treatment interruption is not only related to incremental costs but is also associated with lower survival rates [2, 9, 32].

One clinical study evaluated the cost-effectiveness of PBM therapy for lymphedema [30]. In this study, PBM decreased edema volumes by an average of 19% after only 16 sessions over 10 weeks in comparison with a slower rate using traditional manual lymphatic drainage [30]. Lymphedema outcomes may lead to out-of-pocket expenses for many patients, as it is shown to be a chronic toxicity with a high impact on patient quality of life [3, 10]. It is important to note our definition of "systemic effects" of PBM as referring to the impact of treating one part of the body on another part through circulatory means [42]. The important implication for this study of lymphedema is that the contralateral arm used as a control may have actually been treated systemically, thereby reducing the difference in effect between the treatment and the control.

Few comprehensive evaluations of the costs of care associated with PBM therapy have been completed. Future studies should investigate the costs associated with prolonged medical visits, additional procedures and medications, and outpatient costs, including over-the-counter products and medications, as well as indirect costs, including impact on work (time off work, return to work), caregiver costs, and quality of life. Such omissions to the provision of a full account of the costs of care may have led to the underreporting of potential benefits [2, 4, 6, 37].

In addition to the published studies included in this systematic review, there was a clinical trial protocol for studying radiodermatitis in breast cancer patients receiving radiotherapy [43]. This study may strengthen the evidence in support of PBM as a potential cost-effective therapy once completed.

The clinical research community has not yet adequately characterized the protocols, costs, and benefits of PBM therapy for lymphedema, peripheral neuropathy, radiodermatitis, and other cancer toxicities [10]. The universal acceptance of PBM therapy at cancer centers has been limited to date by the paucity of data on its economic benefits. The limited number of available studies that measured the cost-effectiveness of PBM therapy was the primary limitation of this systematic review.

One underlying challenge was the limited comparability of data measures and the prevailing heterogeneity in cost comparisons and PBM protocols across studies [2]. Standard protocols for economic analysis have been designed to guide large-scale cost studies, such as the Northwestern University Costs of Cancer Program (NUCCP) [2], and guidance to evaluate specific toxicities as developed by Sonis et al. [41] for OM. Recently, new guidelines for the prevention and treatment of OM were published that suggest that future cost-effective analyses should be conducted based on the recommended PBM protocol [21, 32].

Conclusions

This systematic review found limited evidence for the cost-effectiveness of PBM therapy in the prevention and treatment of cancer treatment-related toxicities. Given the potential for PBM therapy to reduce cancer toxicities and subsequently improve health outcomes and reduce incremental costs, rigorous cost-effectiveness studies are necessary. The current review provides preliminary evidence for the use of PBM as a potentially cost-effective therapy for specific cancer therapy-related toxicities.

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Data availability The authors confirm that the data supporting the findings of the study are available within the article and supplementary materials.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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