Society of Medical Education & Research

2025, Volume 5, Page No: 87-99
ISSN: 3108-4850

Annals of Pharmacy Education, Safety, and Public Health Advocacy

The Evolution of Simulation as a Teaching Strategy in Oncology: Global Bibliometric Insights

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Abstract

Simulation-based medical education (SBME) represents a transformative approach to teaching, enabling learners to replicate realistic patient scenarios and acquire skills in a safe environment that does not compromise patient safety. Despite its increasing adoption, there is limited information regarding its perceived impact and value, specifically in oncology education. To address this gap, we conducted a bibliometric analysis to examine global trends and potential directions for SBME in oncology. Publications from January 2010 to April 2024 were systematically analyzed using bibliometric indicators across various databases, including PubMed, SpringerLink, Google Scholar, EM-Consulte, and ScienceDirect. A total of 428 articles focusing on oncology-related simulation were included. The United States led the field with 164 publications (38.3%). Original research predominated (n = 357, 83.4%), and the vast majority of articles (n = 413, 96.5%) were published in English. Research outputs were concentrated in surgical oncology (n = 165, 38.6%), medical oncology (n = 130, 30.4%), and radiation oncology (n = 77, 18.0%). Most studies were indexed in PubMed and the Web of Science core collections, appearing across 232 journals with a median impact factor of 2.6 [range 0.3–81.1]. Authors demonstrated a median H-index of 10, a median i-10 index of 12, and the maximum publications by a single author was three. SBME is recognized as a vital educational tool in oncology, supporting undergraduate curricula, ongoing professional development, and recertification processes. It effectively enhances technical, procedural, and communication competencies. Future research is likely to focus on integrating advanced technologies and innovative simulation techniques across oncology education.

Keywords: Simulation, Learning tool, Medical education, Oncology, Bibliometric analysis

Introduction

Simulation-based medical education (SBME) represents a significant evolution in teaching strategies, providing an interactive learning approach that allows students to practice and refine skills through realistic patient scenarios without risk to actual patients. The effectiveness of SBME in enhancing clinical learning has been well-documented in medical and nursing education [1]. By offering immersive, lifelike experiences, SBME enables learners to develop both technical and interpersonal competencies within a controlled environment, thereby improving readiness for real-world clinical practice [2].

SBME is widely promoted as a strategy to enhance patient safety. It can be delivered in various formats and settings, targeting individual learners, teams, or both, with the choice of method determined by educational goals and curricular integration [3]. Advances in simulation technology have broadened the available modalities, including high-fidelity mannequins, virtual reality (VR) and augmented reality (AR), standardized patients, and hybrid simulations, allowing practice across a broad spectrum of clinical procedures—from basic skills to complex surgical techniques. Evidence indicates that SBME leads to superior acquisition of clinical and

Access this article online https://smerpub.com/

Received: 05 June 2025; **Accepted:** 24 September 2025

How to cite this article: Ba H, Zhang L, He X, Li S. The Evolution of Simulation as a Teaching Strategy in Oncology: Global Bibliometric Insights. Ann Pharm Educ Saf Public Health Advocacy. 2025;5:87-99. https://doi.org/10.51847/DP7gqM8vsZ

procedural competencies compared with traditional teaching methods [4, 5].

Enhancing medical education through SBME has direct implications for patient outcomes and healthcare efficiency [6]. However, several challenges limit its widespread adoption, including high costs for equipment and facilities, as well as the need for trained personnel to operate simulations and facilitate debriefings [7, 8]. Combining SBME with other pedagogical strategies, such as problem-based learning or interdisciplinary training, has been shown to create richer, more comprehensive educational experiences [9, 10]. Despite its broad acceptance as an educational tool, SBME has seen limited implementation in oncology, where it has the potential to strengthen teamwork, communication, and identify knowledge gaps. A significant barrier is the scarcity of simulation resources tailored explicitly for oncology [11].

Bibliometric analysis offers a quantitative framework to evaluate scholarly literature over time, providing insights into publication trends, research impact, funding patterns, international collaborations, and citation dynamics [12, 13]. This method has become a standard tool for mapping scientific progress across medical disciplines [14]. In oncology, simulations have emerged as an effective approach to bridge theoretical knowledge with practical skill development, enabling learners to navigate complex clinical scenarios and enhance problem-solving, communication, patient education, and critical thinking skills [15]. SBME thus holds broad potential for incorporation into oncology curricula.

Although prior research has described simulation experiences in oncology, no bibliometric analysis has comprehensively evaluated global trends in this field. The primary aim of this study is to provide a systematic overview of SBME research in oncology from January 2010 to April 2024, highlighting publication trends and identifying opportunities for future innovation. This report is structured into four main sections: Methodology, Results, Discussion, and Conclusion. The methodology outlines data collection, inclusion criteria, and analytical approaches; the results section summarizes findings and examines their implications for oncology education and patient care; and the conclusion synthesizes the key insights and potential directions for future research.

Materials and Methods

This bibliometric study involved a systematic review of the literature to identify research on simulation-based learning in oncology and to examine global trends. The objective was to provide a comprehensive overview of the integration of SBME into oncology education and to highlight emerging research focuses in this field.

Search strategy

A retrospective bibliometric search was performed to identify publications on medical simulation in oncology. We utilized major abstracting and indexing databases, including PubMed and Scopus, which are recognized for their extensive coverage and suitability for bibliometric analyses.

The search employed combinations of keywords such as: ((‘simulation’ OR ‘education’ OR ‘learning’) AND (‘oncology’ OR ‘tumors’ OR ‘cancer’)). In addition, a MeSH-based search was conducted using: (‘simulation training’ [MeSH]) AND ‘neoplasms’ [MeSH]. The search was executed in June 2024. This initial strategy yielded 30,327 potentially relevant records, which were then screened according to predefined criteria, including topic relevance and publication period.

To ensure comprehensive coverage, we conducted a “snowball search,” screening additional references through cross-referencing, SpringerLink (Springer Nature®), and Google Scholar using the same keywords. Francophone literature was incorporated through EM-Consulte (Elsevier Masson®) and ScienceDirect (Elsevier®) to reduce language bias.

Inclusion and exclusion criteria

Publications were included if they were published between January 1, 2010, and April 30, 2024, and focused on the application or impact of simulation techniques in oncology. Initial screening involved reviewing titles and abstracts, with uncertain cases evaluated through a full-text review. Studies not meeting the inclusion criteria were excluded. Two investigators independently conducted the screening, with discrepancies resolved through consensus.

After removing 29,428 records due to duplication or failure to meet inclusion criteria, 899 full-text articles were assessed. Of these, 471 were excluded for reasons including duplication, irrelevance to oncology or SBME, or retraction. Ultimately, 428 studies met the eligibility requirements and were included in the bibliometric analysis. **Figure 1** presents the PRISMA flow diagram illustrating the study selection process.

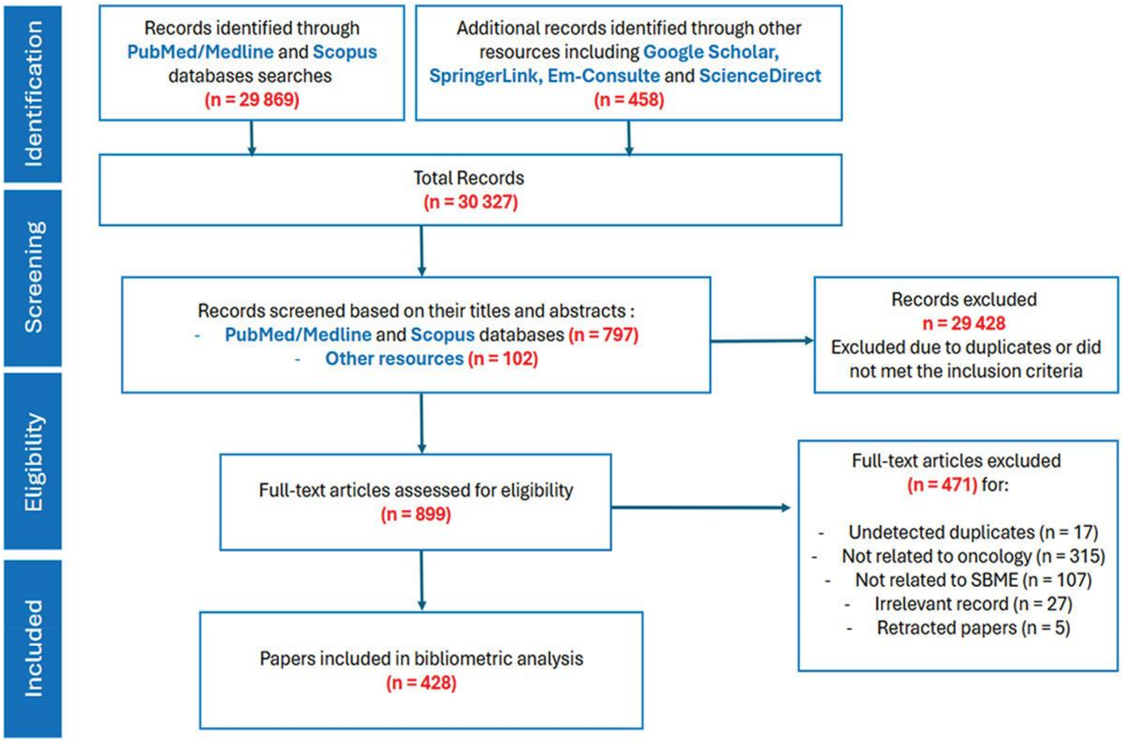

Figure 1. Flow chart of publication selection

Data analysis

Information on author and publication year, article title, article type and language, type of SBME intervention, journal access model (open access or subscription), indexing status in PubMed and Web of Science (WoS), research field, number of authors, funding, and international collaboration was collected. Journal-level metrics, including CiteScore 2023, SCImago Journal Rank (SJR), 2023 Journal Citation Report impact factors, and quartile rankings, were also recorded. Author-level metrics included first authors' H-index from Scopus (June 2024) and i-10 index from Google Scholar. All data were exported to SPSS version 22.0 software for descriptive analysis. Qualitative variables were summarized as percentages, while quantitative variables were expressed as medians along with minimum and maximum values.

Annual publication counts were analyzed to assess historical trends in SBME research within the field of oncology. To evaluate geographical distribution and research productivity, the country of the first author was recorded and analyzed. Other bibliometric characteristics—including publication and author metrics, journal information, publication type and language, funding sources, and collaborative patterns—were examined to provide a detailed profile of SBME research in oncology from 2010 to April 2024. Ethical approval was not required, as all data were drawn from publicly available publications, with no additional input collected from study authors.

Results and Discussion

Trends in annual publications

The yearly number of publications on oncology-focused SBME has fluctuated, reflecting the evolving attention to this field. From 2010 to 2014, publication output was relatively low and stable, with an average of 12 papers per year, indicating an initial stage of scholarly activity **(Figure 2)**. A second phase began in 2014, with a marked increase from 14 publications in 2014 to 49 in 2017, suggesting growing recognition of the value of simulation in oncology education. Following this period of rapid growth, the publication rate slowed, dropping to 40 papers in 2019. The field then reached its highest annual output in 2020, with 61 publications. Subsequently, the count gradually declined to 34 documents in 2023. In the first four months of 2024, approximately 17 papers were published. This trend highlights the sustained relevance of SBME in oncology and underscores the need for continued research and development to advance this educational approach.

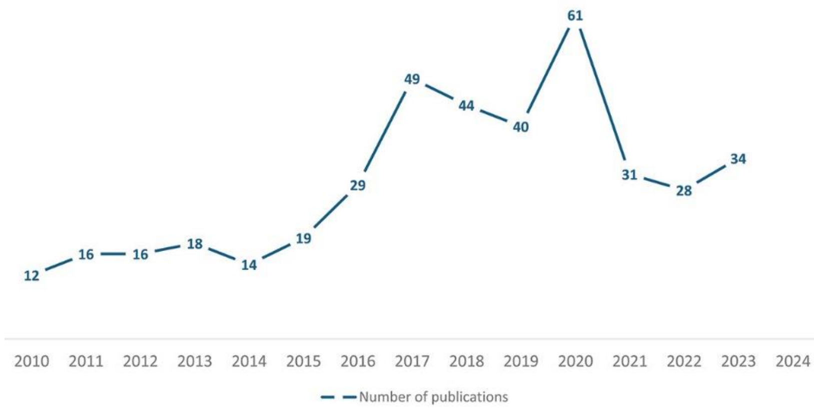

Figure 2. Annual publication pattern

Geographical distribution of research output

Analyzing the geographic distribution of scholarly publications provides essential insights into the global landscape and relative research strengths across countries or regions. In this study, a worldwide assessment was conducted to identify patterns in SBME research within oncology. The results indicated that most publications originated from North America, Western Europe, and Eastern Asia. Overall, researchers from 36 countries or territories spanning 15 regions contributed to this field. The United States emerged as the dominant contributor, producing 164 papers (38.3%), highlighting a considerable gap compared to other nations. Canada followed with 53 publications (12.4%), while the United Kingdom (24, 5.6%), Australia (22, 5.1%), and Germany (20, 4.7%) rounded out the top contributors **(Table 1)**. These findings underscore the prominent role of developed countries in advancing SBME in oncology, a trend consistent with observations in many other scientific fields. The leadership of these countries is likely linked to their advanced economic status and high levels of scientific and technological development.

Table 1. Publication distribution by regions and territories

Region (N)	Countries/territories	Number of publications N (%)
North America (218)	USA, Canada, Mexico	164 (38.3%), 53 (12.4%), 1 (0.2%)
South America (7)	Brazil	7 (1.6%)
Oceania (23)	Australia, New Zealand	22 (5.1%), 1 (0.2%)
Western Europe (61)	Germany, France, Switzerland, Belgium, Netherlands	20 (4.7%), 18 (4.2%), 9 (2.1%), 8 (1.9%), 6 (1.4%)
Northern Europe (33)	UK, Denmark, Ireland	24 (5.6%), 8 (1.9%), 1 (0.2%)
Eastern Europe (4)	Romania, Hungary, Poland	2 (0.5%), 1 (0.2%), 1 (0.2%)
Southern Europe (13)	Italy, Spain, Malta	8 (1.9%), 4 (0.9%), 1 (0.2%)
Eastern Asia (42)	China, Japan, Taiwan, Republic of Korea	18 (4.2%), 16 (3.7%), 6 (1.4%), 2 (0.5%)
South Central Asia (12)	Iran, India, Pakistan	8 (1.9%), 3 (0.7%), 1 (0.2%)
Arabian Peninsula (4)	Saudi Arabia	4 (0.9%)
South East Asia (3)	Singapore, Thailand	2 (0.5%), 1 (0.2%)
Western Asia (3)	Jordan, Lebanon, Turkey	1 (0.2%), 1 (0.2%), 1 (0.2%)
West Africa (2)	Nigeria	2 (0.5%)
Southern Africa (2)	South Africa	2 (0.5%)

Northern Africa (1)	Morocco	1 (0.2%)

Prolific productions and their research impact

A total of 428 publications were analyzed during the study period, of which 357 (83.4%) were original research articles and 57 (13.3%) were review papers **(Table 2)**. Open-access publishing accounted for 176 articles (41.1%). Most publications were indexed in major databases, with 396 papers (92.5%) listed in PubMed and 379 (88.6%) in the selective Web of Science (WoS) database. English was the predominant language, used in 413 articles (96.5%). Research outputs were distributed across surgical oncology (n=165, 38.6%), medical oncology (n=130, 30.4%), and radiation oncology (n=77, 18.0%). Funding was reported in 149 studies (34.8%), originating from both national and international sources. Regarding international collaboration, 38 publications (8.9%) included at least one author affiliated with a foreign institution.

Table 2. Characteristics of Publications, Journals, and Authors

Variables	**N (%)**
Publications type	
–	
Original articles	357 (83.4%)
Reviews	57 (13.3%)
Meta-analysis	3 (0.7%)
Others	11 (2.6%)
Publications language	
–	
English	413 (96.5%)
Chinese	6 (1.4%)
French	5 (1.2%)
Germany	2 (0.5%)
Japanese	1 (0.2%)
Spanish	1 (0.2%)
Citation counts for publications	
–	
Median	10 [0–358]
Oncology fields	
–	
Surgical oncology	165 (38.6%)
Medical oncology	130 (30.3%)
Radiation oncology	77 (18.0%)
Oncology nursing	45 (10.5%)
Oncology pharmacy	11 (2.6%)
Types of SBME interventions	
–	
Virtual reality systems	141 (32.9%)
Simulated patients	94 (22.0%)
Simulated environment	54 (12.6%)
Screen-based simulators	44 (10.3%)
Part-task trainers	39 (9.1%)
Computer-based systems with mannequins	29 (6.8%)
Hybrid simulation	27 (6.3%)
Funding	
–	
Yes	149 (34.8%)
No	279 (65.2%)
Collaboration	
–	
Yes	38 (8.9%)
No	390 (91.1%)
Free access	
–	
Yes	176 (41.1%)
No	252 (58.9%)
PubMed indexing	
–	
Yes	396 (92.5%)
No	32 (7.5%)
Web of Science indexing	
–	
Yes	379 (88.6%)
No	49 (11.4%)
CiteScore	
–	
Median	4.7 [0–99,4]
Not assigned	25 (5.8%)
SCImago journal rank (SJR)	
–	
Median	0.802 [0–21.048]
Not assigned	20 (4.7%)
Impact factor (IF)	
–	
Median	2.6 [0.30–81.10]
Not assigned	49 (11.4%)
Quartile ranking (Q)	
–	
1	222 (51.9%)
2	128 (29.9%)
3	41 (9.6%)
4	10 (2.3%)
Not assigned	27 (6.3%)
H-index	

– Median	10 [0–134]
i-10 index	
– Median	12 [0–496]
Number of co-authors	
– Median	6 [1–39]

Types of SBME interventions and research metrics

The included studies documented a diverse range of simulation-based interventions, which were grouped into seven main categories: part-task trainers, computer-assisted mannequin systems, screen-based simulators, virtual reality (VR), standardized or simulated patients, simulated clinical environments, and hybrid simulation models. Among these, VR-based systems were the most frequently reported, appearing in 141 studies (32.9%), followed by simulated patients in 94 publications (22.0%) and simulated environments in 54 articles (12.6%).

Analysis of citation patterns showed that the median number of citations per paper was 10, according to Scopus data. To evaluate journal influence, the 2023 CiteScore was calculated for each journal, with a median of 4.7. The median journal impact factor across publications was 2.6, and slightly over half of the journals (222; 51.9%) belonged to the Q1 quartile. Author-level metrics indicated a median H-index of 10 and a median i-10 index of 12, reflecting moderate research productivity and influence.

Across the study period (2010–2024), a total of 232 journals published studies on simulation in oncology. Journal of Cancer Education led the field, contributing 18 articles (4.2%) to the literature. **Table 3** presents the top 10 journals in terms of the number of publications, showcasing the main publication venues for research in this area.

Table 3. Top 10 most productive journals, along with their corresponding impact factors, indexing, type, and number of publications

Journal	Impact factor	PubMed indexing	Web of Science indexing	Number of publications				Type of publications		
				Total	2010 – 2014	2015 – 2019	2020 – 2024	Original articles	Reviews	Others
Journal of Cancer Education	1.40	Yes	Yes	18	3	6	9	18	0	0
International Journal of Radiation Oncology, Biology and Physics	6.40	Yes	Yes	17	3	6	8	15	1	1
Brachytherapy	1.70	Yes	Yes	16	0	1	15	14	1	1
Patient Education and Counseling	2.90	Yes	Yes	12	4	7	1	10	1	1
BMC Medical Education	2.70	Yes	Yes	12	0	3	9	12	0	0
Journal of Surgical Education	2.60	Yes	Yes	12	0	10	2	12	0	0
World Neurosurgery	1.90	Yes	Yes	10	1	5	4	9	1	0
Clinical Journal of Oncology Nursing	1.30	Yes	Yes	10	2	7	1	7	3	0
Operative Neurosurgery (Hagerstown)	1.70	Yes	Yes	7	0	4	3	7	0	0
Strahlentherapie und Onkologie	2.70	Yes	Yes	6	0	1	5	6	0	0

Journal impact factors

Analysis of journal impact factors, as reported in the 2023 Journal Citation Reports (Clarivate Analytics®), revealed that many publications appeared in high-profile journals from well-established academic publishers. The highest impact factor was recorded for a single article in Nature Reviews Clinical Oncology (Nature; IF = 81.1), followed by two papers in Annals of Oncology (Elsevier; IF = 56.7) and two in Journal of Clinical Oncology (Lippincott; IF = 42.1) **(Table 4)**.

Table 4. Top-10 journals with the highest Impact factor

Rank	Journal	Publisher	Impact factor	Number of publications
1	Nature Reviews Clinical Oncology	Nature Publishing Group	81.1	1
2	Annals of Oncology	Elsevier	56.7	2
3	Journal of Clinical Oncology	Lippincott Williams & Wilkins	42.1	2
4	Annals of Internal Medicine	American College of Physicians	19.6	1
5	Journal of the American Academy of Dermatology	Elsevier	12.8	2
6	npj Digital Medicine	Nature Publishing Group	12.4	1
7	British Journal of Dermatology	Oxford University Press	11.0	1
8	JAMA Network Open	American Medical Association	10.5	4
9	CHEST	Elsevier	9.5	2
10	Journal of Educational Evaluation for Health Professions	Korea Health Personnel Licensing Examination Institute	9.3	1

Authorship productivity

The H-index is commonly used to evaluate the scholarly influence and productivity of researchers. In this study, the median H-index among authors was 10. **Table 5** lists the top 10 authors with the highest H-index scores. Yuman Fong (City of Hope Medical Center, USA) ranked first with an H-index of 134, followed by J. Randall Curtis (Washington University, USA) with 85, and both James A. Tulsky (Duke University, USA) and Mark K. Ferguson (University of Chicago, USA) with an H-index of 68. While the H-index provides insight into academic productivity, it represents only one dimension of scholarly impact. Other considerations, including the significance and quality of the research contributions, are also essential for a complete assessment of a researcher's standing.

Table 5. Top-10 authors with the highest H-index.

H-index	Author	Institution	Country	Publication title	Journal	Impact factor
134	Yuman Fong	City of Hope Medical Center	USA	Using the Delphi Method to Develop a Training Curriculum for Hepatopancreaticobiliary Robotic Surgery	Surgical Endoscopy	NA*
85	J. Randall Curtis	University of Washington	USA	Impact of Communication Skills Training on Residents and Nurse Practitioners' Quality of Interaction with Seriously Ill Patients: A Randomized Trial	JAMA Network Open	10.5
68	James A. Tulsky	Duke University	USA	Improving Oncologist-Patient Communication Through a Computer-Based Training Program: A Randomized Trial	Annals of Internal Medicine	19.6
68	Mark K. Ferguson	University of Chicago	USA	Defining Key Elements of Thoracoscopic Lobectomy and Simulation Training Targets	The Annals of Thoracic Surgery	3.6
63	Anthony L. Back	University of Washington	USA	Equipping Clinicians with Communication Skills to Align Medical Treatments with Patient Values	Journal of the American Geriatrics Society	4.3
61	David W. Kissane	Memorial Sloan Kettering Cancer Center	USA	Communication Skills Training Program for Oncology Professionals	Journal of Clinical Oncology	42.1
53	Steven J. Frank	University of Texas MD Anderson Cancer Center	USA	Hands-On Prostate Brachytherapy LDR/HDR Simulation Workshops by the American Brachytherapy Society: Step-by-Step Quality Assurance Training	Brachytherapy	1.7

51	Subba R. Digumarthy	Harvard Medical School	USA	Determining Causes of Missed Lung Nodules and the Role of Reader Training: A Simulation Study Using Nodule Insertion Software	Journal of Cancer Research and Therapeutics	1.4
51	Tonya R. Kaltenbach	University of California	USA	Enhancing Endoscopy Quality in Inflammatory Bowel Disease: Surveillance and Management of Colorectal Dysplasia with Interactive Image- and Video-Based Training	Gastrointestinal Endoscopy	6.7
47	Juergen Barth	University of Bern	Switzerland	Effectiveness of Communication Skills Training in Oncology: A Systematic Review and Meta-Analysis	Annals of Oncology	56.7

* NA: not assigned.

The median number of co-authors was 6. The total number of first authors was 397, with the majority having only one paper published during the study period (n = 370, 93.2%). The most productive authors were Alexander Winkler-Schwartz, Crispen Chamunyonga, Sherry A Burrell, and Yves Libert, each of whom published four articles. 23 authors published two papers each **(Table 6)**.

Table 6. List of authors with the highest number of publications

Author	H-index	Institution	Country	Number of publications	Type of publication	Year of publication
Alexander Winkler-Schwartz	19	McGill University	Canada	3	Original articles	2019, 2019, 2020
Crispen Chamunyonga	7	Queensland University of Technology	Australia	3	Reviews	2017, 2018, 2020
Sherry A. Burrell	7	Villanova University	USA	3	Original articles	2023, 2023, 2023
Yves Libert	25	Université Libre de Bruxelles	Belgium	3	Original articles	2016, 2017, 2020
Ali M. Fazlollahi	4	McGill University	Canada	2	Original articles	2023, 2023
Caitlin T. Yeo	9	Queen's University	Canada	2	Original articles	2018, 2019
Chantal Baril	11	Université du Québec à Trois-Rivières	Canada	2	Original articles	2016, 2019
Eda Ozkara San	6	Lienhard School of Nursing	USA	2	Original articles	2019, 2020
Elise Deluche	18	University of Limoges	France	2	Original articles	2020, 2023
Emma C. Fields	14	Virginia Commonwealth University	USA	2	Original article, Review	2020, 2023
Eric G. Bing	25	Southern Methodist University	USA	2	Original articles	2019, 2021
Fernando A. Angarita	17	University of Toronto	Canada	2	Original articles	2018, 2020
Hamed Azarnoush	24	McGill University/Tehran Polytechnic	Canada/Iran	2	Original articles	2014, 2017
Katrine Jensen	8	University Hospital of Copenhagen	Denmark	2	Original articles	2015, 2017
Liam J. Wang	3	Johns Hopkins University	USA	2	Original articles	2022, 2024
Lisa Singer	12	Harvard Medical School	USA	2	Original articles	2019, 2020
Lukasz M. Mazur	18	University of North Carolina at Chapel Hill	USA	2	Original articles	2017, 2021
Maiko Fujimori	29	National Cancer Center Hospital East	Japan	2	Original articles	2013, 2014
Makoto Oishi	25	Niigata University	Japan	2	Original articles	2013, 2024
Nazim Haouchine	14	Brigham and Women's Hospital	USA	2	Original articles	2013, 2015
Nykan Mirchi	13	McGill University	Canada	2	Original articles	2020, 2020
Roberto Rosario Corsini	7	University of Catania	Italy	2	Original articles	2022, 2023

Sarah H. Michael	4	University of Colorado Anschutz	USA	2	Original article, Review	2019, 2019
Samaneh Siyar	4	McGill University/Tehran Polytechnic	Canada/Iran	2	Original articles	2020, 2020
Sergio Eduardo Alonso Araujo	20	University of São Paulo Medical School	Brazil	2	Original articles	2014, 2015
Shlomi Laufer	12	University of Wisconsin School of Medicine and Public Health	USA	2	Original articles	2015, 2016
Vernissia Tam	13	University of Pittsburgh Medical Center	USA	2	Original articles	2017, 2019

Enhancing oncology education through innovative pedagogical approaches remains a critical challenge. In this context, simulation-based medical education (SBME) has gained considerable attention as an effective teaching methodology across numerous medical specialties, including oncology [16, 17]. This study employed bibliometric analysis to examine the evolution of SBME in oncology over 14 years (2010–2024).

The findings indicate that the adoption of simulation in oncology has progressed gradually. Peaks in publication output occurred in 2017 (49 papers) and 2020 (61 papers), reflecting periods of heightened scholarly interest. The surge in 2017 coincided with broader recognition of SBME's effectiveness in medical training, while the peak in 2020 corresponded with the increased reliance on virtual and web-based learning during the COVID-19 pandemic, which necessitated innovative approaches to maintain rigorous medical education despite physical distancing.

Geographically, research output is heavily concentrated in high-income countries, with the United States leading with 38.3% of all publications. Other major contributors include Canada, the United Kingdom, Australia, Germany, China, France, and Japan, highlighting a notable disparity between developed and developing nations. This concentration is likely related to the substantial financial and infrastructural resources required to conduct SBME research, suggesting that economic capacity strongly influences research activity in this field.

Original research articles accounted for the majority of publications (357, 83.4%), covering various oncology subspecialties, with surgical oncology (38.6%), medical oncology (30.3%), and radiation oncology (18.0%) most frequently represented. Regarding simulation modalities, VR systems (32.9%), standardized patients (22.0%), and simulated clinical environments (12.6%) were the most commonly employed tools.

SBME has demonstrated particular effectiveness in onco-surgical training, including specialties such as neurosurgery, urology, and gynecology, by enabling trainees to practice surgical techniques safely and repeatedly [18, 19]. Traditional cadaver-based dissection models, while valuable, are limited by factors such as the absence of vascular turgidity and intraoperative bleeding. Recent innovations, such as cadaver models with pulsatile vascularization and simulated blood flow, have addressed these limitations and shown promising results in areas like head and neck surgery [20, 21]. These advances suggest that SBME can meaningfully shape surgical curricula in oncology and improve hands-on training experiences.

Beyond technical skills, SBME has also shown positive impacts on soft skills, attitudes, and learner perceptions. For instance, high-fidelity simulations have been used to train oncology fellows in delivering bad news, resulting in improved communication, self-confidence, and comfort levels [22]. Combining SBME with art-based teaching methods may further enhance communication competencies within oncology curricula [23]. Additionally, simulation has been applied to improve chemotherapy safety by training learners in the handling and administration of cytotoxic agents, reducing risks such as extravasation incidents [24]. SBME has also proven effective in teaching complex concepts such as cancer genomics and precision medicine to undergraduate students, using simulated patient cases that illustrate therapeutic targets and associated treatments [25].

Simulation-based education has been increasingly applied within radiation oncology training to achieve a variety of educational goals [26–28]. For instance, screen-based simulators have been used to teach contouring skills. At the same time, high-fidelity simulations that replicate complex clinical scenarios support the acquisition of competencies such as brachytherapy techniques and team-based communication [29, 30]. Evidence suggests that SBME is more effective than conventional teaching methods in developing these specialized skills [31, 32]. Although SBME demands greater time and financial investment, its adoption may be justified by long-term improvements in patient care quality and potential reductions in healthcare costs [33]. Overall, SBME functions as a valuable adjunct for teaching a wide range of radiation oncology competencies, underscoring the need to expand its use to encompass even broader skill sets.

In pharmacy education, oncology-focused SBME has shown promise in improving students' understanding of oncology pharmacy practice and clarifying the responsibilities of oncology pharmacists [34]. Simulation-based approaches facilitate learning in multiple areas, including crafting evidence-based, patient-specific therapeutic plans, applying empathetic counseling techniques, performing precise pharmaceutical calculations, and verifying prescriptions efficiently [35]. Incorporating interactive oncology simulations can enhance pharmacy students' knowledge and practical skills, while also serving as a tool for faculty to evaluate and refine oncology curricula [36, 37].

Globally, SBME in oncology represents an educational strategy that emphasizes patient safety, mitigates the limitations of traditional apprenticeship models, and allows learners unlimited opportunities for risk-free practice. Beyond improving psychomotor and procedural competencies, SBME enhances interpersonal communication, builds confidence, and reduces anxiety in high-stakes clinical and emergency oncology scenarios [38]. It is also a powerful tool for improving the skills of oncology professionals, ultimately contributing to higher-quality care and patient safety [39]. Additionally, simulation models have been utilized to optimize patient flow in oncology departments, with configurable agent-based models developed to decrease waiting times and enhance the patient care experience [40–43].

Artificial intelligence (AI) has emerged as a transformative technology in medical education, offering advanced tools for simulation, diagnostics, and personalized training. By leveraging sophisticated algorithms and data-processing capabilities, AI can generate highly realistic simulations, improve VR fidelity, and optimize surgical skills training [44–46]. AI also enhances 3D printing applications in medical education by accurately modeling internal organ structures and producing precise anatomical replicas [47].

Several limitations of this study should be acknowledged. The dataset was derived primarily from PubMed and Scopus, which, while comprehensive, may not capture all relevant publications. Although efforts were made to include Francophone literature and reduce language bias, studies published in other languages were not systematically searched. Furthermore, the dataset excluded specific sources, including medical theses, conference proceedings, and patents, which may limit completeness. Finally, bibliometric analyses are inherently influenced by the choice of search terms, which can affect the scope and results of the study.

Limitations

As research and technology continue to advance, variations in terminology used by authors can complicate comprehensive literature retrieval, potentially leading to underrepresentation of relevant studies. Additionally, the manual extraction of data in this analysis introduces the possibility of human error, which could influence the accuracy and consistency of the results. Future improvements in bibliometric software and automated data-mining tools may help address these challenges. Nevertheless, despite these constraints, this study offers meaningful insights into the global scope, trends, and impact of SBME in oncology, providing a reliable overview of the current research landscape.

Conclusion

This bibliometric review confirms that simulation-based medical education (SBME) is a highly effective instructional strategy in oncology training. SBME facilitates the development of essential competencies, including clinical knowledge, procedural skills, interprofessional collaboration, and communication between healthcare providers and patients. By allowing learners to engage in realistic, risk-free practice, SBME enhances both technical and cognitive skills while promoting confidence and decision-making in clinical settings.

The majority of publications on this topic are original research, predominantly focusing on surgical and medical oncology. These findings underscore the growing recognition and adoption of SBME as a valuable educational approach. Given its capacity to improve performance without compromising patient safety, SBME should be integrated as a core or complementary component of oncology curricula, as well as in professional development and recertification programs. Future research should prioritize methodologically rigorous and innovative studies that explore the full potential of SBME, evaluate its long-term educational impact, and optimize its implementation across diverse oncology training environments.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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