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Learning to breathe for radiation therapy: A scoping review of deep inspiration breath-hold training

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ABSTRACT

Deep inspiration breath-hold (DIBH) is widely used in radiation therapy (RT) to reduce radiation exposure to organs at risk, particularly during breast cancer treatment. Successful implementation of DIBH relies on high levels of patient compliance and breath-hold reproducibility. Structured patient training has been proposed as a key component to optimise DIBH performance; however, evidence regarding training modalities and their clinical impact remains fragmented. This scoping review aims to map the available evidence on DIBH training strategies and their outcomes in RT. Literature searches were conducted using PubMed, Embase, Scopus, and Web of Science from inception to 9 October 2025. Twelve studies fulfilled the selection criteria. Most investigations focused on breast cancer patients (n = 10; 83%), with limited evidence available for other anatomical sites. Most studies were comparative, evaluating trained versus untrained patients or different training approaches. Across studies, DIBH training was associated with multidimensional benefits, including dosimetric improvements, enhanced breath-hold reproducibility, and reductions in simulation, set-up, and treatment times. Additionally, patient-reported outcomes indicated high satisfaction and increased confidence following training. Considerable heterogeneity was observed in both the endpoints assessed and the training approaches and delivery modalities. Nevertheless, most studies supported the inclusion of home-based practice following initial coaching. Available evidence suggests that structured DIBH training provides clinically relevant benefits across the RT pathway. Current evidence is limited by small sample sizes and predominantly single-centre designs, highlighting the need for standardized training methodologies and outcome measures to enable more robust comparisons across studies.

1. Introduction

Advances in radiation therapy (RT) techniques have increasingly focused on reducing radiation exposure to organs at risk (OARs) while maintaining optimal target coverage. Among these developments, the implementation of deep inspiration breath-hold (DIBH) techniques has emerged as one of the most widely adopted strategies worldwide for reducing radiation dose to the heart (Bergom et al. 2018; Latty et al. 2015). DIBH is used in clinical practice for several anatomical targets, but its application is particularly relevant in breast cancer RT, which represents the largest proportion of treatments delivered using breath-hold techniques. Although postoperative RT for breast cancer has been shown to improve both local control and overall survival (Early Breast Cancer Trialists' Collaborative Group (EBCTCG) et al., 2011; EBCTCG (Early Breast Cancer Trialists' Collaborative Group) et al., 2014; Wang et al. 2023; Steene et al. 2000), concerns have been raised

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that treatment-related adverse events, particularly those associated with increased long-term mortality, may offset some of this benefit ('Favourable and Unfavourable Effects on Long-Term Survival of Radiotherapy for Early Breast Cancer, 2000; Hooning et al. 2006). In particular, in patients with left-sided breasts, cardiac dose exposure during RT has been associated with an increased risk of coronary heart disease and cardiac mortality(Cheng et al. 2017; Rutqvist and Johansson, 1990; Henson et al. 2013). As highlighted in the literature, cardiac toxicity is influenced by both treatment- and patient-related factors. RT-related factors include the irradiated site, beam proximity to cardiac structures, total dose, and number of fractions, while patient-related factors include baseline cardiovascular risk, concurrent potentially cardiotoxic chemotherapy, age, and gender (Siaravas et al. 2023; Chin et al. 2024; Hooning et al. 2007; Harris et al. 2006). For this reason, recent advances in RT techniques have contributed to a progressive reduction in treatment-related cardiac morbidity (Bergom et al. 2018; 2021; Chan et al. 2024). Among these advancements, the implementation of DIBH has been demonstrated to play a crucial role as an alternative to free-breathing (Bergom et al. 2018; Latty et al. 2015; Bruzzaniti et al. 2013). By increasing lung volume and displacing the heart away from the treatment field, DIBH enables significant cardiac dose reduction while preserving target coverage. However, its successful clinical application depends on several factors, including the equipment available within each RT department, the need for additional hardware and software, intrafractional monitoring capabilities and patient feedback systems(Yamauchi et al. 2020; Aznar et al. 2023).

A wide range of commercially available devices can be used for DIBH delivery, often incorporating automated gating and treatment interlock systems. All DIBH approaches require a surrogate measure of the respiratory signal, which is most commonly obtained using spirometry or surface-based monitoring systems, frequently combined with visual feedback for the patient (Aznar et al. 2023). Spirometry systems monitor airflow throughout the respiratory cycle and prompt breath hold once a predefined lung volume is reached (Wong et al. 1999; Remouchamps et al. 2003; Delombaerde et al. 2021), whereas surface-guided systems rely on optical tracking to reconstruct the patient's three-dimensional surface and assess respiratory cycle by tracking the position of a predefined point or region (Rong et al. 2014; Peng et al. 2010; Al-Hallaq et al. 2022). According to the ESTRO-ACROP guidelines, each system has specific advantages and limitations, and the choice of technology is often driven by institution-specific factors such as platform compatibility, available positioning devices, and acquisition costs (Aznar et al. 2023). Accurate and reproducible delivery of DIBH in clinical practice requires not only appropriately trained staff and standardised institutional protocols, but also a high level of active patient cooperation (Aznar et al. 2023). Patient eligibility for DIBH must therefore be carefully assessed, and effective communication between healthcare professionals and patients plays a pivotal role in this process (Kefeli et al. 2025). In this context, structured patient coaching and training prior to the planning computed tomography has been shown to be essential for achieving reliable and reproducible breath holds (Aznar et al. 2023). Despite the widespread adoption of DIBH, evidence regarding how patient training is implemented within the RT care pathway, and how such training influences clinical, dosimetric, and workflow-related outcomes, remains limited. Existing reviews address this topic only partially, often within broader discussion on DIBH techniques, without systematically analysing training specific data(Latty et al. 2015; Hanczyk et al. 2024; Mayr et al. 2020). Although several approaches to DIBH patient training have been described in recent years, dedicated reviews explicitly focusing on training strategies remain limited. Given the heterogeneity of training protocols, outcome measures, and implementation contexts reported in the literature, a scoping review was considered the most appropriate methodological approach to comprehensively map the available evidence, identify key concepts, and highlight existing gaps. Accordingly, this scoping review aims to address this need by critically appraising reported DIBH training approaches and summarizing the current evidence on their implementation and associated outcomes in RT.

2. Methods

2.1. Search strategy

This study did not require formal ethical approval. Relevant literature was systematically searched across PubMed, Web of Science, SCOPUS, and Embase. The specific search strings used for each database, developed and optimised with support from the University of Florence's library system, are reported in Supplementary Table 1.

A scoping review methodology was adopted to address multiple review objectives and to provide an overview of the available evidence in an evolving research area. The review was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis extension for scoping reviews (PRISMA-ScR)(Tricco et al. 2018) and the Arksey and O'Malley framework(Arksey et al., 2005).

2.2. Inclusion and exclusion criteria

An electronic literature search was performed to identify full-text original studies reporting training protocols or procedures for cancer patients receiving RT with DIBH, without the use of invasive tools or technologies, across different anatomical sites. Studies were eligible if they described the clinical implementation and application of patient training strategies for DIBH techniques. No publication date restrictions were applied.

The search was limited to English-language publications and concluded on 9 October, 2025. The following publication types were excluded: conference abstracts, proceedings, conference papers, and clinical trial protocols.

In line with Kapoor's classification of medical research (Kapoor, 2016), the search strategy included both primary research (clinical and experimental studies) and secondary research (reviews, systematic reviews, and meta-analyses) indexed in the selected databases.

2.3. Study selection

The titles and abstracts of articles retrieved from the search were uploaded to Rayyan (Rayyan Systems Inc., available at https://www.rayyan.ai). The software's automatic duplicate detection function was used to identify and remove obvious duplicates. In addition, a manual screening was performed to ensure all duplicates were correctly identified. After duplicates were removed, study selection was conducted in two phases. First, titles and abstracts were independently screened by two reviewers (A.L. and L.M.). Disagreements were resolved through discussion and, when necessary, consultation with additional reviewers (N.I. and G.I.) until consensus was achieved. In the second phase, full texts were assessed collegially by all four reviewers to confirm eligibility based on methodological and content-related criteria.

2.4. Data extraction and analysis

Key data were extracted using a standardized Microsoft Excel (Microsoft Corp., Redmond, WA) form, including authors, year of publication, study aim, sample size, anatomical site, training characteristics, assessed endpoints, main findings, and reported limitations. In accordance with the Arksey and O'Malley framework, a formal quality appraisal was not performed; instead, a narrative synthesis was used to summarize and interpret the findings of the included study.

3. Results

3.1. Study inclusion and characteristic

Overall, twelve articles out of 383 screened records fulfilled the inclusion criteria and were included in this scoping review. The study selection process is detailed in the PRISMA flow diagram (Fig. 1), which also reports the distribution of studies by anatomical site.

The included studies were published between 2006 and 2025. However, three quarters of the studies (n = 9) were published after 2020, with only one study published before 2018. Only one review article was included, while the remaining publications were original studies classified as primary research. Geographically, most original studies were conducted in the United States (n = 3), while Europe and Asia accounted for the highest number of included studies overall (n = 4). An overview of different DIBH training main characteristics is reported in Fig. 2.

3.2. Study focusing on breast cancer RT

In the vast majority of breast cancer studies (n = 10; 83%), comparisons were performed either between different DIBH training approaches or between trained patients and those who did not receive specific training (Oonsiri et al. 2019; Khan et al. 2025; Kim et al. 2018; Thornley et al. 2025; Li et al. 2025; Kalet et al. 2021; Sonnhoff et al. 2025). The main findings of these primary studies are summarized in Table 1.

Although all studies investigated patient training for DIBH, substantial heterogeneity was observed in both the study objectives and the endpoints assessed. Half of the studies (n = 5; 50%) primarily evaluated the dosimetric impact of training (Kefeli et al. 2025; Mayr et al. 2020; Khan et al. 2025; Kim et al. 2018; Sonnhoff et al. 2025) but employed different dosimetric parameters to compare trained and untrained cohorts. Despite this variability, these studies consistently reported a significant reduction in cardiac exposure (Kefeli et al. 2025; Khan et al. 2025; Kim et al. 2018) and, in some cases, reduced lung doses in trained patients compared with untrained (Khan et al. 2025). One study by Sonnhoff et al. compared different training intensities, focusing on more intensive versus lighter coaching protocols. No significant differences in OARs dose exposure were observed between the two approaches (Sonnhoff et al. 2025). In contrast, the review by Mayr et al. (Mayr et al. 2020) included a study (Zhao et al. 2018) comparing thoracic and abdominal breathing manoeuvres during DIBH, demonstrating that abdominal DIBH achieved a significantly lower cardiac dose.

Beyond dosimetric outcomes, several studies (n = 4; 40%) assessed the impact of training on workflow efficiency, including the duration of CT simulation (Oonsiri et al. 2019), patient set-up (Kefeli et al. 2025; Li et al. 2025), treatment delivery (Li et al. 2025) and overall fraction time (Sonnhoff et al. 2025). In this analysis, comparisons between trained and untrained patients showed that structured training was associated with significantly reduced simulation, set-up, and treatment times (Kefeli et al. 2025; Oonsiri et al. 2019; Li et al. 2025). Only one study reported no significant difference in average daily fraction duration between groups (Sonnhoff et al. 2025).

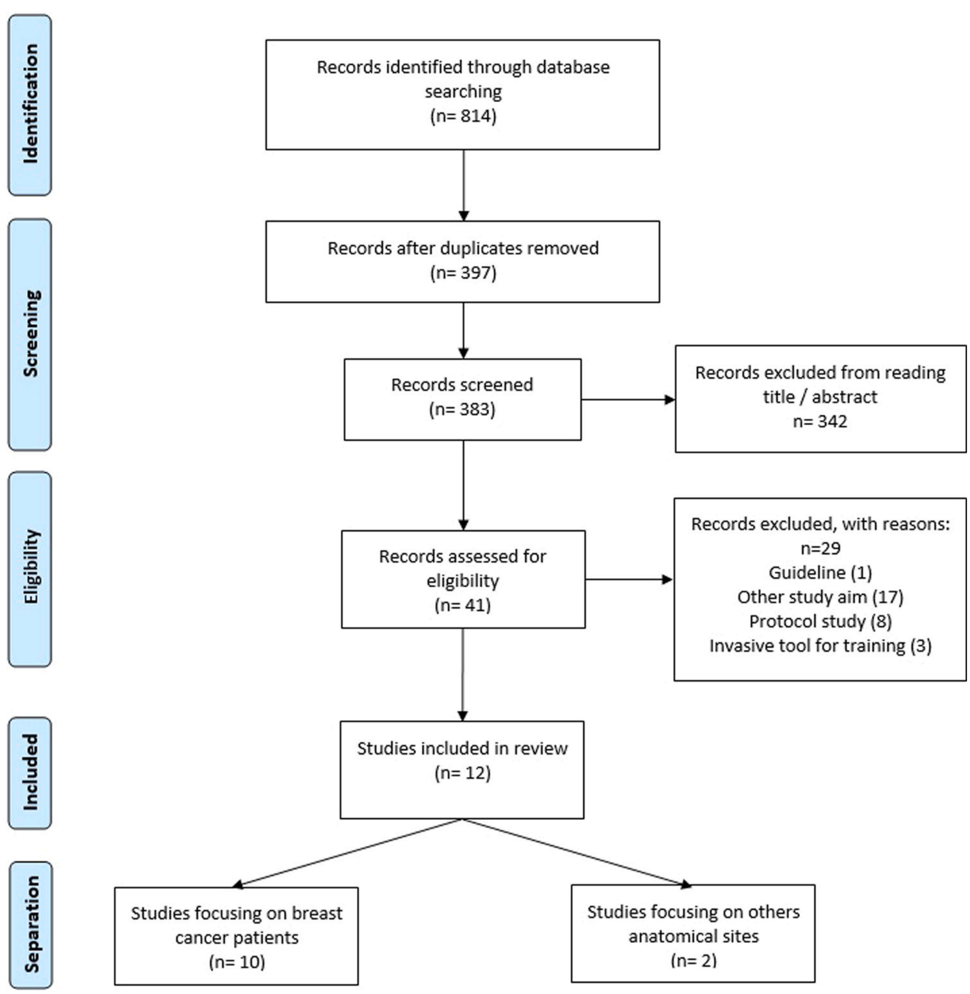

Fig. 1. Flowchart of study selection.

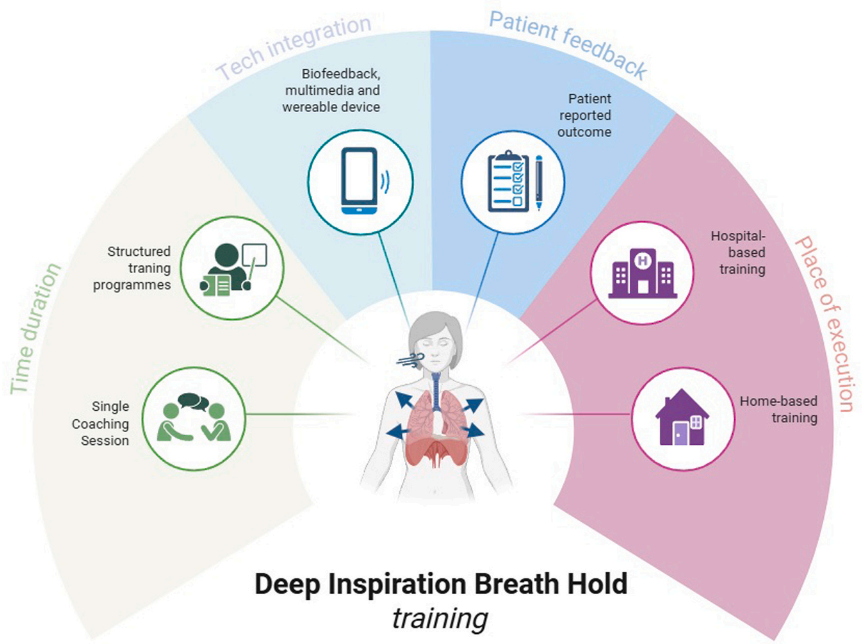

Fig. 2. Different types of training approaches and characteristics of DIBH training.

Reproducibility and stability of the DIBH technique were evaluated in three studies, each using different endpoints. Chopra et al. assessed cumulative maximum movement error by comparing planning CT and cone-beam CT images (Chopra et al. 2006). Thornley et al.(Thornley et al. 2025) evaluated positioning reproducibility using a five-point scoring system scored by two expert radiographers, by comparing planning CT and cone-beam CT images, while Kalet et al.(Kalet et al. 2021) analysed day-to-day variability in chest-wall excursion patterns during treatment. Collectively, these studies suggest that training was associated with improved breath-hold reproducibility, reduced chest.-wall and breast motion, and enhanced patient positioning accuracy compared with untrained patients (Thornley et al. 2025; Kalet et al. 2021; Chopra et al. 2006).

Patient-reported outcomes were assessed in two studies, focusing on patient perceptions and feedback related to DIBH training (Oonsiri et al. 2019; Thornley et al. 2025). Despite the use of different assessment tools, both studies reported higher satisfaction levels and improved perceived preparedness among trained patients, particularly with regard to information provision and understanding of the DIBH procedure.

Concerning the training modality, considerable heterogeneity was also observed in the timing, setting, and delivery of DIBH training. Most studies (n = 8; 80%) delivered training at least 5 days or one week before planning CT, or even earlier (Kefeli et al. 2025; Mayr et al. 2020; Oonsiri et al. 2019; Khan et al. 2025; Kim et al. 2018; Thornley et al. 2025; Kalet et al. 2021; Chopra et al. 2006). In contrast, one study (Li et al. 2025) provided training throughout the RT course, while another compared two institutional workflows in which training was performed either on the same day as planning CT or several days beforehand (Sonnhoff et al. 2025). Regarding the training setting, the majority of studies (n = 7; 70%) implemented home-based training, allowing patients to practice independently before planning CT (Kefeli et al. 2025; Khan et al. 2025; Kim et al. 2018; Thornley et al. 2025; Kalet et al. 2021; Sonnhoff et al. 2025; Chopra et al. 2006). In most of these cases, patients initially received supervised coaching from healthcare professionals, who provided guidance on correct positioning and breath-hold execution and highlighted common errors to avoid (Kefeli et al. 2025; Khan et al. 2025; Kim et al. 2018; Li et al. 2025; Kalet et al. 2021; Chopra et al. 2006). Differences were also noted in the professional background of staff delivering the initial coaching. In several studies, training was conducted by physicians (Khan et al. 2025; Kim et al. 2018; Kalet et al. 2021), whereas others involved radiation therapy technologists (RTTs) (Li et al. 2025), oncology nurses (Kefeli et al. 2025), breast specialist radiographers (Thornley et al. 2025), or occupational therapists (Chopra et al. 2006). In some cases, patients also received home-based instructions for DIBH practice (Kefeli et al. 2025; Kim et al. 2018; Kalet et al. 2021), while other studies provided educational materials such as instructional videos or written instruction sheets (Oonsiri et al. 2019), or a combination of videos and audio podcasts (Mayr et al. 2020; Thornley et al. 2025).

3.3. Study focusing on others anatomical sites

Two additional studies investigated DIBH training in anatomical sites other than the breast. The study by Gonzalez et al. (Gonzalez et al. 2024) evaluated patients with pancreatic cancer treated with magnetic resonance imaging–guided RT (MRI-gRT). This work introduced an innovative and immersive training approach using virtual reality (VR) tools. Twenty-two patients were trained using VR headsets and dedicated minigames designed to familiarise them with DIBH delivery within a simulated MRI-gRT environment. Most patients reported that the VR-based training was helpful in learning breath-hold techniques, and its use was also associated with reduced anxiety and high acceptability. The second study, by Lundgaard et al. (Lundgaard et al. 2020), was a pilot investigation exploring the feasibility of DIBH training in a paediatric population. Thirty-three children aged five years or older were enrolled, including both healthy participants and hospitalised paediatric oncology patients. Training consisted of written and verbal instructions provided to children and their parents. Coaching sessions were conducted either in the CT scanner room or in a dedicated training space. An optical surface imaging system provided visual feedback to the children during breath hold. Semi-structured interviews revealed that the vast majority of participants (n = 31, 94%) reported positive experiences, with no children reporting fear or discomfort during training.

Although limited in number, these studies suggest that DIBH training may be feasible and beneficial beyond breast cancer RT, including in technically complex settings and vulnerable patient populations.

Table 1
Summary of the main findings of the primary studies on DIBH training in breast cancer patients.

Paper	Study type	Sample size	Training	Training setting	Endpoint	Main findings	Main limitations
Chopra et al., 2006	Non-comparative study	5	Short respiratory training course (8–10 days) including supervised deep-breathing exercises. Daily spirometer-guided training (15–20 min), followed by twice-daily unsupervised practice.	NA	Respiratory motion and breath-hold capacity	Non-significant reduction in skin marker motion. Significant increase in breath-hold time (31 s to 44 s) and tidal volume (560–1160 cm^3).	Very small sample size.
Kim et al., 2018	Comparative study	69 (27 coached vs 42 non-coached)	Single 10–15 min coaching session before RT. Supervised DIBH practice until reproducible maximal breath hold without visible chest wall motion. Home practice: 3 sets of 10 breath holds, $\geq$ 3 times/day. Target breath-hold $\geq$ 40 s.	Coaching pre-planning CT with home-based training	Cardiac dose	Reduced maximum cardiac dose and cardiac volume exposure in coached patients.	Non-randomised design; limited sample size.
Oonsiri et al., 2019	Comparative study	112 (25 no DIBH, 23 DIBH without material, 64 DIBH with instructions)	Written information sheet (aim, step-by-step instructions, figures) and optional QR-linked 3-min educational video, provided $\geq$ 1 week before CT simulation. Materials available in Thai and English.	Educational materials provided pre-planning CT	Simulation time	Simulation time significantly reduced with instructional guidance. No significant difference between sheet, video, or combined use.	Non-randomised allocation; limited evaluation of long-term reproducibility.
Kalet et al., 2021	Retrospective comparative study	67 (27 coached vs 40 non-coached)	Preparatory DIBH coaching by a radiation oncologist $\geq$ 1 week before CT. Home practice: 3 sets of 10 DIBHs, 3 times/day. Total coaching time 10–15 min.	Coaching pre-planning CT and home-based training	Chest wall excursion reproducibility	Mean chest wall motion similar between groups. Excursions > 3 mm were significantly less frequent in the coached group, particularly in patients with cardiopulmonary disease.	Small cohort; retrospective design.
Kefeli et al., 2025	Retrospective comparative study	64 (36 coached vs 28 non-coached)	10–15 min coaching session after RT consultation. Home training for $\geq$ 1 week before CT simulation.	Coaching pre-planning CT with home-based training	Set-up time and cardiac dose	Set-up time significantly reduced in coached patients. Lower heart and LAD doses in coached group (LAD statistically significant).	Retrospective design; limited evaluation of positioning accuracy on imaging.
Khan et al., 2025	Comparative study	40 (20 coached vs 20 non-coached)	DIBH demonstration using online images/ videos plus 10–15 min coaching. Home practice for $\geq$ 5 days before CT and throughout RT.	Coaching pre-planning CT on site with home-based training before the simulation and during RT sessions	Cardiac and lung dose	Non-significant reduction in mean and maximum cardiac doses; lower mean left lung V17 in coached patients.	Small sample size; lack of randomisation.
Li et al., 2025	Randomised self-controlled clinical trial	50 (25 trained vs 25 untrained)	Structured daily breathing training with supervised feedback: slow nasal inhalation (5–7 s), controlled posture, repeated breath holds (10/day) throughout RT. Untrained group received a single instructional session.	During RT sessions	Treatment time and breath-hold performance	Training led to progressive increase in breath-hold duration and significantly shorter treatment times. No significant differences in setup reproducibility metrics.	Single-centre study; modest sample size; patient-related factors not fully explored.
Sonnhoff et al., 2025	Retrospective multi-centre comparative study	59 (TC1 vs TC2 workflows)	TC1: separate DIBH training and planning CT with $\geq$ 2-day interval. TC2: combined training and planning CT on the same day. Identical training criteria and materials.	TC1: Coaching on-site pre-planning CT with home-based training TC2: Coaching on-site during the same day of planning CT with home-based training before the start of RT	OAR dose, positioning, workflow efficiency	No significant differences in OAR doses, positioning accuracy, or treatment time. Combined workflow reduced scheduled staff time without compromising outcomes.	Retrospective workflow comparison; not protocol-driven.
Thornley et al., 2025	Prospective mixed comparative study	12 (vs historical controls)	RESPIRE multimedia self-training tool (videos, podcasts) accessed via QR code. Telephone reinforcement and self-directed practice before CT.	Home-based training pre-planning CT and before the start of RT	PROMs, dosimetry, reproducibility	Improved patient preparedness. Increased lung volume and heart–chest wall distance. Enhanced CBCT reproducibility compared with historical controls.	Small, single-centre, non-randomised service evaluation.

Abbreviations: CBCT: Cone Beam Computed Tomography; CT: Computed Tomography; DIBH: Deep Inspiration Breath Hold; LAD: Left Anterior Descending; OAR: Organ at Risk; PROMP: Patient-Reported Outcome Measures; RT: Radiotherapy; TC: Treatment Center;

4. Discussion

This scoping review synthesised the available evidence on DIBH training delivery and implementation in patients undergoing RT, demonstrating that the integration of structured DIBH training within the RT care pathway is consistently recommended (Latty et al. 2015; Aznar et al. 2023; Parland et al. 2015). Although most of the included evidence pertains to breast cancer, the reviewed studies exhibited substantial heterogeneity in objectives, training modalities, and assessed endpoints, which limits direct cross-study comparisons. Heterogeneity was evident in multiple domains, including training settings, the healthcare professionals involved in patient coaching, the educational tools used, and the evaluated outcomes. These outcomes ranged from dosimetric parameters and workflow efficiency to breath-hold reproducibility, DIBH stability, and patient-reported satisfaction. Despite this variability, comparative studies consistently reported advantages of structured training over non training, underscoring the pivotal role of patient preparation in successful DIBH delivery (Kefeli et al. 2025; Oonsiri et al. 2019; Khan et al. 2025; Kim et al. 2018; Thornley et al. 2025; Li et al. 2025; Kalet et al. 2021). Across the reviewed literature, DIBH training demonstrated a multidimensional impact across throughout the RT pathway, extending beyond dosimetric benefits to OARs. Training was associated with improved breath-hold reproducibility and stability, enhanced patient positioning, reducing set-up errors, and shorter simulation and treatment delivery times. Importantly, these technical improvements were accompanied by greater patient confidence and preparedness, highlighting the added value of training from both a clinical and a patient-cared perspective. The only study reporting no clear benefit of training compared with standard practice was that by Sonnhoff et al.(Sonnhoff et al. 2025); however, the lack of detailed description of the coaching protocol and training content substantially limits the interpretability of these findings. This further emphasises the importance of transparent reporting of training methodologies in future studies. Regarding training modalities, nearly all studies implemented coaching before planning CT, often combined with home-based practice (Kefeli et al. 2025; Khan et al. 2025; Kim et al. 2018; Thornley et al. 2025; Kalet et al. 2021; Sonnhoff et al. 2025; Chopra et al. 2006). This approach, including an initial supervised coaching session followed by independent practice, offers several advantages, including increased flexibility for patients and reduced demand on clinical resources. Notably, this model may also contribute to environmental and social sustainability, as fewer additional hospital visits can reduce patient travel, caregiver burden, and travel-related carbon emissions, which are recognised as one of the biggest contributors to RT carbon footprint (Tanderup et al. 2026; Bedir et al. 2024; Cheung et al. 2023; Chuter et al. 2023; Votta et al. 2026).

While traditional educational tools such as written instructions, videos, and audio podcasts remain widely used, emerging evidence highlights the potential role of immersive technologies in improving patient engagement and reducing anxiety (Lastrucci et al. 2025; Chen et al. 2026; Zhao et al. 2023). The use of innovative tools based on immersive environments, such as the development of specific applications on VR- and AR-based platforms, has the potential to introduce interactive and gamified elements that may enhance learning and motivation, particularly in complex treatment settings or among populations requiring additional support (Gonzalez et al. 2024; Martin-Gomez et al. 2021).

An additional and often overlooked other aspect is the potential role of structured DIBH training in promoting equitable access to advanced RT techniques. Standard DIBH coaching relies heavily on real-time verbal communication, which may pose challenges for patients with hearing impairments, language barriers, or communication difficulties.

Disparities in the execution and successful implementation of DIBH among patients with communication barriers have been reported in the literature (Shukla et al. 2022; Saby et al. 2025). The adoption of multimodal training tools, such as multilingual written materials, visual aids, instructional videos, and immersive environments, could help mitigate these disparities and support more inclusive implementation of DIBH across diverse patient populations. Specifically, leaflets translated into multiple languages, combined with visual aids, instructional videos, or step-by-step animations, may help patients familiarise themselves with the DIBH procedure before planning CT. In addition, patients with hearing impairments could particularly benefit from immersive approaches such as video-based instruction or VR environments. Overall, integrating multimodal and accessible DIBH training tools into clinical workflows has the potential to eliminate communication-related barriers, improve treatment accuracy, and promote equitable access to DIBH across diverse patient populations.

Finally, several studies demonstrated (Kefeli et al. 2025; Oonsiri et al. 2019; Li et al. 2025) that structured DIBH training can reduce CT simulation and treatment delivery times. This workflow may translate into shorter waiting lists and improved departmental throughput, further supporting the integration of training into routine clinical practice. Fig. 3 presents a schematic overview of the scoping review findings on DIBH patient training, summarizing the main findings and limitations of the included studies, as well as the reported advantages and limitations of the training approaches.

4.1. Study limitations

This scoping review provides a comprehensive and explorative overview of the existing literature on DIBH training in RT; however, several limitations should be acknowledged. First, the inclusion criteria were intentionally specific, which may have resulted in the exclusion of studies that addressed DIBH training only indirectly or were published in languages other than English. Second, consistent with the scoping review methodology, no formal quality assessment or quantitative synthesis was performed. The included studies involved heterogeneous populations, interventions, and outcome measures, limiting the possibility of direct comparison or meta-analysis.

5. Conclusions

Training patients undergoing DIBH RT has demonstrated consistent and clinically meaningful benefits across multiple phases of the treatment pathway. The available evidence suggests that structured training can reduce radiation exposure to OARs, decrease planning and set-up times, and improve the reproducibility and stability of the DIBH technique. Beyond technical advantages, DIBH training also supports a more patient-centred approach, enhancing patient engagement, confidence and understanding of the treatment process. At present, DIBH training is predominantly implemented in breast cancer RT, with limited evidence available for other anatomical sites.

The existing literature is constrained by small sample sizes, predominantly single-centre designs, and substantial heterogeneity in training protocols and reported endpoints. Standardisation of training approaches, outcome measures, and reporting methodologies is therefore essential to enable robust comparisons across studies and institutions. Future multicentre investigations with clinically relevant sample sizes are needed to better define the role of DIBH training and support its systematic integration into routine RT practice.

Critical view

This scoping review was undertaken to delineate and critically examine the role of structured patient training in the implementation of

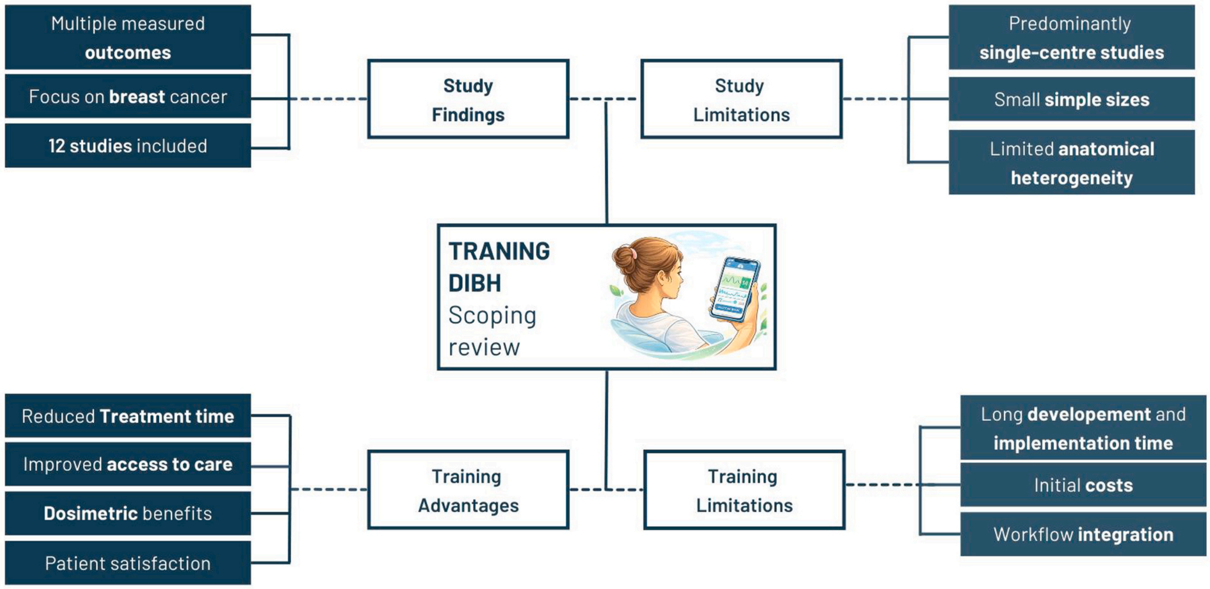

Fig. 3. Summary of evidence from the scoping review on DIBH patient training, including study findings, methodological limitations, and reported training-related advantages and challenges.

deep inspiration breath-hold (DIBH) radiotherapy. While DIBH has been extensively investigated from a technical and dosimetric standpoint, the patient training component has received comparatively limited and fragmented attention. Existing reviews typically address DIBH within broader discussions of cardiac sparing techniques, without isolating training as a discrete and potentially modifiable intervention within the radiotherapy pathway.

Our review distinguishes itself by explicitly reframing DIBH training as an independent clinical process rather than a procedural adjunct. By systematically mapping how training is delivered, who delivers it, when it is introduced within the care pathway, and which outcomes are assessed, we move beyond the question of whether DIBH reduces cardiac dose and instead examine how structured preparation may influence reproducibility, workflow efficiency, patient-reported experience, and treatment equity. This multidimensional perspective allows a more comprehensive understanding of training as a determinant of both technical quality and patient-centred care.

Importantly, our findings reveal marked heterogeneity in training protocols, educational tools, timing, and outcome measures. This variability underscores a critical gap in the field: although DIBH training appears consistently beneficial, it is rarely standardised, and its evaluation lacks harmonised metrics. By documenting these discrepancies, our review highlights the urgent need for consensus-driven frameworks that define minimum training requirements, core outcome sets, and reporting standards.

The scope of this review was intentionally broad, encompassing non-invasive DIBH training strategies across anatomical sites and without temporal restriction, in order to capture the full evolution of practice. At the same time, the depth of analysis extends beyond descriptive reporting, providing detailed examination of training modalities, implementation models (in-clinic versus home-based), professional roles, and reported clinical, operational, and patient-related outcomes. Consistent with scoping review methodology, we did not conduct a formal quality appraisal or quantitative synthesis, as our objective was to map the landscape of evidence and identify conceptual and methodological gaps.

From a broader oncological perspective, structured DIBH training represents more than a technical refinement: it may serve as a model for integrating behavioural preparation into advanced radiation techniques. As radiotherapy becomes increasingly sophisticated and technology-driven, patient-dependent components such as breath control require equal methodological rigor. Moreover, the incorporation of multimodal and immersive educational tools may support more equitable access to complex treatments, particularly for patients facing communication barriers or limited health literacy.

In conclusion, this review contributes to the current body of knowledge by positioning DIBH training as a measurable, optimisable, and standardisable element of contemporary radiotherapy practice. By identifying heterogeneity, unmet needs, and future research priorities, we aim to stimulate methodological harmonisation and prospective multicentre investigations capable of defining the true clinical value of structured DIBH training within oncology care.

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Declaration of Competing Interest

An author declares occasional fees or honoraria from Eli Lilly, Novartis, Astra Zeneca, Daiichi Sankyo, Gilead, Pfizer, Menarini Stem-Line, MSD, Exact Sciences, TEMA Sinergie.

All other authors declare no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.critrevonc.2026.105313.

References

Al-Hallaq, Hania A., Cerviño, Laura, Gutierrez, Alonso N., et al., 2022. AAPM Task Group Report 302: Surface-Guided Radiotherapy. Med. Phys. 49 (4), e82–e112. https://doi.org/10.1002/mp.15532.

Arksey, Hilary, Lisa, O'Malley, 2005. Scoping Studies: Towards a Methodological Framework. Int. J. Soc. Res. Methodol. 8 (1), 19–32. https://doi.org/10.1080/1364557032000119616.

Aznar, Marianne Camille, carrasco de Fez, Pablo, Corradini, Stefanie, et al., 2023. ESTRO-ACROP Guideline: Recommendations on Implementation of Breath-Hold Techniques in Radiotherapy. Radiother. Oncol. 185 (August). https://doi.org/10.1016/j.radonc.2023.109734.

Bedir, Ahmed, Maximilian Grohmann, Sebastian Schäfer, et al. 2024. 'Sustainability in Radiation Oncology: Opportunities for Enhancing Patient Care and Reducing CO2 Emissions in Breast Cancer Radiotherapy at Selected German Centers'.

Strahlentherapie Und Onkologie: Organ Der Deutschen Rontgengesellschaft … [et Al], ahead of print, September 24. https://doi.org/10.1007/s00066-024-02303-w.

Bergom, Carmen, Bradley, Julie A., Ng, Andrea K., et al., 2021. Past, Present, and Future of Radiation-Induced Cardiotoxicity: Refinements in Targeting, Surveillance, and Risk Stratification. '. Jacc. CardioOncology 3 (3), 343–359. https://doi.org/10.1016/j.jaccao.2021.06.007.

Bergom, Carmen, Currey, Adam, Desai, Nina, Tai, An, Strauss, Jonathan B., 2018. Deep Inspiration Breath Hold: Techniques and Advantages for Cardiac Sparing During Breast Cancer Irradiation. Front. Oncol. 8, 87. https://doi.org/10.3389/fonc.2018.00087.

Bruzzaniti, Vicente, Abate, Armando, Pinnarò, Paola, et al., 2013. Dosimetric and Clinical Advantages of Deep Inspiration Breath-Hold (DIBH) during Radiotherapy of Breast Cancer. J. Exp. & Clin. Cancer Res. 32 (1), 88. https://doi.org/10.1186/1756-9966-32-88.

Chan, Maria F., Parikh, Dhwani, Shi, Chengyu, 2024. Narrative Review: Cardiotoxicities and Cardiac-Sparing Techniques in Radiotherapy. Technol. Cancer Res. & Treat. 23 (October), 15330338241301211. https://doi.org/10.1177/15330338241301211.

Chen, Fangping, Guo, Xingyue, Wei, Dingyuan, et al., 2026. The Use of Virtual Reality in Cancer Patient Health Education: A Scoping Review. Int. J. Nurs. Sci. 13 (1), 27–35. https://doi.org/10.1016/j.ijnss.2025.12.013.

Cheng, Yun-Jiu, Xiao-Ying, Nie, Cheng-Cheng, Ji, et al., 2017. Long-Term Cardiovascular Risk After Radiotherapy in Women With Breast Cancer. J. Am. Heart Assoc. 6 (5), e005633. https://doi.org/10.1161/JAHA.117.005633.

Cheung, Ronald, Ito, Emma, Lopez, Marianela, et al., 2023. Evaluating the Short-Term Environmental and Clinical Effects of a Radiation Oncology Department's Response to the COVID-19 Pandemic. Int. J. Radiat. Oncol. Biol. Phys. 115 (1), 39–47. https://doi.org/10.1016/j.ijrobp.2022.04.054.

Chin, Vicky, Finnegan, Robert N., Keall, Paul, Otton, James, Delaney, Geoff P., Vinod, Shalini K., 2024. Overview of Cardiac Toxicity from Radiation Therapy. J. Med. Imaging Radiat. Oncol. 68 (8), 987–1000. https://doi.org/10.1111/1754-9485.13757.

Chopra, S., Dinshaw, K.A., Kamble, R., Sarin, R., 2006. Breast Movement during Normal and Deep Breathing, Respiratory Training and Set up Errors: Implications for External Beam Partial Breast Irradiation. Br. J. Radiol. 79 (945), 766–773. https://doi.org/10.1259/bjr/98024704.

Chuter, Robert, Stanford-Edwards, Catherine, Cummings, James, et al., 2023. Towards Estimating the Carbon Footprint of External Beam Radiotherapy. Phys. Med. PM Int. J. Devoted Appl. Phys. Med. Biol. Off. J. Ital. Assoc. Biomed. Phys. (AIFB) 112 (August), 102652. https://doi.org/10.1016/j.ejmp.2023.102652.

Delombaerde, Laurence, Petillion, Saskia, Weltens, Caroline, Depuydt, Tom, 2021. Spirometer-Guided Breath-Hold Breast VMAT Verified with Portal Images and Surface Tracking. Radiother. Oncol. 157 (April), 78–84. https://doi.org/10.1016/j.radonc.2021.01.016.

Early Breast Cancer Trialists' Collaborative Group (EBCTCG), Darby, S., McGale, P., et al., 2011. Effect of Radiotherapy after Breast-Conserving Surgery on 10-Year Recurrence and 15-Year Breast Cancer Death: Meta-Analysis of Individual Patient Data for 10,801 Women in 17 Randomised Trials. Lancet (Lond. Engl.) 378 (9804), 1707–1716. https://doi.org/10.1016/S0140-6736(11)61629-2.

EBCTCG (Early Breast Cancer Trialists' Collaborative Group), McGale, P., Taylor, C., et al., 2014. Effect of Radiotherapy after Mastectomy and Axillary Surgery on 10-Year Recurrence and 20-Year Breast Cancer Mortality: Meta-Analysis of Individual Patient Data for 8135 Women in 22 Randomised Trials. Lancet (Lond. Engl.) 383 (9935), 2127–2135. https://doi.org/10.1016/S0140-6736(14)60488-8.

Favourable and Unfavourable Effects on Long-Term Survival of Radiotherapy for Early Breast Cancer, 2000. An Overview of the Randomised Trials, 1757–70 Lancet 355 (9217). https://doi.org/10.1016/S0140-6736(00)02263-7.

Gonzalez, Brian D., Choo, Sylvia, Janssen, Joseph J., et al., 2024. Novel Virtual Reality App for Training Patients on MRI-Guided Radiation Therapy. Adv. Radiat. Oncol. 9 (6), 101477. https://doi.org/10.1016/j.adro.2024.101477.

Hanczyk, Edyta, Piecuch, Dawid, Kopcial, Szymon, Jonska-Gmyrek, Joanna, 2024. Factors Affecting the Effectiveness of DIBH (Deep Inspiratory Breath Hold) in Patients with Left Breast Cancer: A Narrative Review. Appl. Sci. 14 (16). https://doi.org/10.3390/app14167287.

Harris, Eleanor E.R., Correa, Candace, Hwang, Wei-Ting, et al., 2006. Late Cardiac Mortality and Morbidity in Early-Stage Breast Cancer Patients after Breast-Conservation Treatment. J. Clin. Oncol. Off. J. Am. Soc. Clin. Oncol. 24 (25), 4100–4106. https://doi.org/10.1200/JCO.2005.05.1037.

Henson, K.E., McGale, P., Taylor, C., Darby, S.C., 2013. Radiation-Related Mortality from Heart Disease and Lung Cancer More than 20 Years after Radiotherapy for Breast Cancer. Br. J. Cancer 108 (1), 179–182. https://doi.org/10.1038/bjc.2012.575.

Hooning, Maartje J., Aleman, Berthe M.P., van Rosmalen, Agnes J.M., Kuenen, Marianne A., Klijn, Jan G.M., van Leeuwen, Flora E., 2006. Cause-Specific Mortality in Long-Term Survivors of Breast Cancer: A 25-Year Follow-up Study. Int. J. Radiat. Oncol. Biol. Phys. 64 (4), 1081–1091. https://doi.org/10.1016/j.ijrobp.2005.10.022.

Hooning, Maartje J., Botma, Akke, Aleman, Berthe M.P., et al., 2007. Long-Term Risk of Cardiovascular Disease in 10-Year Survivors of Breast Cancer. J. Natl. Cancer Inst. 99 (5), 365–375. https://doi.org/10.1093/jnci/djk064.

Kalet, Alan M., Kim, Aileen, Hippe, Daniel S., et al., 2021. The Dosimetric Benefit of In-Advance Respiratory Training for Deep Inspiration Breath Holding Is Realized during Daily Treatment in Left Breast Radiotherapy: A Comparative Retrospective Study of Serial Surface Motion Tracking. J. Med. Imaging Radiat. Oncol. 65 (3), 354–364. https://doi.org/10.1111/1754-9485.13181.

Kapoor, Mukul Chandra, 2016. Types of Studies and Research Design. Indian J. Anaesth. 60 (9), 626–630. https://doi.org/10.4103/0019-5049.190616.

Kefeli, Aysegul Ucuncu, Diremsizoglu, Umut, Erdogan, Sevda, et al., 2025. Patient Coaching for Deep Inspiration Breath Hold Decreases Set-up Duration and Left Anterior Descending Artery Dose for Left-Sided Breast Cancer Radiotherapy. Supportive Care Cancer Official Journal Multinational Association Supportive Care Cancer 33 (5), 387. https://doi.org/10.1007/s00520-025-09446-1.

Khan, Laraib, Khan, Maham, Shakeel, Fabiha, et al., 2025. Effect of DIBH Coaching on Dosimetric Parameters of Heart and Lung Doses in Patients Undergoing Adjuvant Breast Radiotherapy. Asian Pac. J. Cancer Prev. 26 (5), 1809–1813. https://doi.org/10.31557/APJCP.2025.26.5.1809.

Kim, A., Kalet, A.M., Cao, N., et al., 2018. Effects of Preparatory Coaching and Home Practice for Deep Inspiration Breath Hold on Cardiac Dose for Left Breast Radiation Therapy. Clin. Oncol. 30 (9), 571–577. https://doi.org/10.1016/j.clon.2018.04.009.

Lastrucci, Andrea, Iosca, Nicola, Busto, Giorgio, et al., 2025. A Mixed Scoping and Narrative Review of Immersive Technologies Applied to Patients for Pain, Anxiety, and Distress in Radiology and Radiotherapy. Diagnostics 15 (17). https://doi.org/10.3390/diagnostics15172174.

Latty, Drew, Stuart, Kirsty E., Wang, Wei, Ahern, Verity, 2015. Review of Deep Inspiration Breath-Hold Techniques for the Treatment of Breast Cancer. J. Med. Radiat. Sci. 62 (1), 74–81. https://doi.org/10.1002/jmrs.96.

Li, Hongming, Miao, Zheng, Shen, Jie, et al., 2025. Investigation of the Clinical Benefits of Regular Breath-Holding Training Utilizing Surface Guided Radiation Therapy Technology for Patients with Left Breast Cancer. J. Radiat. Res. Appl. Sci. 18 (2), 101393. https://doi.org/10.1016/j.jrras.2025.101393.

Lundgaard, Anni Young, Josipovic, Mirjana, Rechner, Laura Ann, et al., 2020. The Feasibility of Implementing Deep Inspiration Breath-Hold for Pediatric Radiation Therapy. Int. J. Radiat. Oncol. Biol. Phys. 106 (5), 977–984. https://doi.org/10.1016/j.ijrobp.2019.12.025.

Martin-Gomez, A., Hill, C., Lin, H.Y., et al., 2021. Towards Exploring the Benefits of Augmented Reality for Patient Support During Radiation Oncology Interventions. Comput. Methods Biomech. Biomed. Eng. Imaging & Vis. 9 (3), 322–329. https://doi.org/10.1080/21681163.2020.1835547.

Mayr, Nina A., Borm, Kai J., Kalet, Alan M., et al., 2020. Reducing Cardiac Radiation Dose From Breast Cancer Radiation Therapy With Breath Hold Training and Cognitive Behavioral Therapy. Top. Magn. Reson. Imaging. TMRI 29 (3), 135–148. https://doi.org/10.1097/RMR.0000000000000241.

Oonsiri, Puntiwa, Wisetrinthong, Metinee, Chitnok, Manatchanok, Saksornchai, Kitwadee, Suriyapee, Sivalee, 2019. An Effective Patient Training for Deep Inspiration Breath Hold Technique of Left-Sided Breast on Computed Tomography Simulation Procedure at King Chulalongkorn Memorial Hospital. Radiat. Oncol. J. 37 (3), 201–206. https://doi.org/10.3857/roj.2019.00290.

Parland, Neil Mc, Nica, Luminita, Soo, Jenny, Menna, Tara, 2015. Deep Inspiration Breath Hold for Left-Sided Breast Cancer: Experience from the Patient's Perspective. J. Radiother. Pract. 14 (3), 228–235. https://doi.org/10.1017/S146039691500028X.

Peng, Jean L., Kahler, Darren, Li, Jonathan G., et al., 2010. Characterization of a Real-Time Surface Image-Guided Stereotactic Positioning System. Med. Phys. 37 (10), 5421–5433. https://doi.org/10.1118/1.3483783.

Remouchamps, Vincent M., Letts, Nicola, Vicini, Frank A., et al., 2003. Initial Clinical Experience with Moderate Deep-Inspiration Breath Hold Using an Active Breathing Control Device in the Treatment of Patients with Left-Sided Breast Cancer Using External Beam Radiation Therapy. Int. J. Radiat. Oncol. Biol. Phys. 56 (3), 704–715. https://doi.org/10.1016/s0360-3016(03)00010-5.

Rong, Yi, Walston, Steve, Welliver, Meng Xu, Chakravarti, Arnab, Quick, Allison M., 2014. Improving Intra-Fractional Target Position Accuracy Using a 3D Surface Surrogate for Left Breast Irradiation Using the Respiratory-Gated Deep-Inspiration Breath-Hold Technique. PloS One 9 (5), e97933. https://doi.org/10.1371/journal.pone.0097933.

Rutqvist, L.E., Johansson, H., 1990. Mortality by Laterality of the Primary Tumour among 55,000 Breast Cancer Patients from the Swedish Cancer Registry. Br. J. Cancer 61 (6), 866–868. https://doi.org/10.1038/bjc.1990.193.

Saby, Tamryn, Cardy, Caitlyn, Grant, Zoe, 2025. Are Patients with a Hearing Impairment or Other Language Barriers Getting Equitable Access to Deep Inspiration Breath Hold (DIBH) Techniques for Breast Cancer Radiotherapy? J. Radiother. Pract. 24 (January), e35. https://doi.org/10.1017/S1460396925100216.

Shukla, Utkarsh, Sueyoshi, Mark, Diamond, Brett, et al., 2022. Disparities in Radiation Therapy: Practice Patterns Analysis of Deep Inspiratory Breath Hold Use in Non-English Speakers. Int. J. Radiat. Oncol. Biol. Phys. 113 (1), 21–25. https://doi.org/10.1016/j.ijrobp.2021.12.171.

Siaravas, Konstantinos C., Katsouras, Christos S., Sioka, Chrissa, 2023. Radiation Treatment Mechanisms of Cardiotoxicity: A Systematic Review. Int. J. Mol. Sci. 24 (7). https://doi.org/10.3390/ijms24076272.

Sonnhoff, M., R.-M. Hermann, K. Aust, et al. 2025. 'Is Intensive Training with a Time Interval between Instruction and Planning CT Necessary for Deep Inspiration Breath-Hold Radiotherapy in Breast Cancer?' Strahlentherapie Und Onkologie: Organ Der Deutschen Rontgengesellschaft … [et Al] 201 (2): 185–90. https://doi.org/10.1007/s00066-024-02295-7.

Steene, Jan Van de, Guy, Soete, Storme, Guy, 2000. 'Adjuvant Radiotherapy for Breast Cancer Significantly Improves Overall Survival: The Missing Link'. Radiother. Oncol. 55 (3), 263–272. https://doi.org/10.1016/S0167-8140(00)00204-8.

Tanderup, Kari, Kirby, Anna M., Eriksen, Jesper Grau, et al., 2026. ESTRO's Principles for Environmental Sustainability in the Radiation Oncology Community. Radiother. Oncol. J. Eur. Soc. Ther. Radiol. Oncol. 217 (January), 111384. https://doi.org/10.1016/j.radonc.2026.111384.

Thornley, A., Taylor, K., Goldsworthy, S., 2025. Improving Patient Preparation and Comfort in Voluntary DIBH – Single-Centre Quality Improvement Evaluation. Radiography 31 (6). https://doi.org/10.1016/j.radi.2025.103162.

Tricco, Andrea C., Lillie, Erin, Zarin, Wasifa, et al., 2018. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann. Intern. Med. 169 (7), 467–473. https://doi.org/10.7326/M18-0850.

Votta, Claudio, Lastrucci, Andrea, Iosca, Nicola, et al., 2026. Green Radiotherapy: AITRO Survey on Sustainability Awareness among Italian Radiation Therapists. Tech. Innov. & Patient Support Radiat. Oncol. 37 (March), 100360. https://doi.org/10.1016/j.tipsro.2025.100360.

Wang, Yun, Shen, Jingjing, Gu, Peihua, Wang, Zhongming, 2023. Recent Advances Progress in Radiotherapy for Breast Cancer after Breast-Conserving Surgery: A Review. Front. Oncol. 13, 1195266. https://doi.org/10.3389/fonc.2023.1195266.

Wong, J.W., Sharpe, M.B., Jaffray, D.A., et al., 1999. The Use of Active Breathing Control (ABC) to Reduce Margin for Breathing Motion. Int. J. Radiat. Oncol. Biol. Phys. 44 (4), 911–919. https://doi.org/10.1016/s0360-3016(99)00056-5.

Yamauchi, Ryohei, Mizuno, Norifumi, Itazawa, Tomoko, Saitoh, Hidetoshi, Kawamori, Jiro, 2020. Dosimetric Evaluation of Deep Inspiration Breath Hold for Left-Sided Breast Cancer: Analysis of Patient-Specific Parameters Related to Heart Dose Reduction. J. Radiat. Res. 61 (3), 447–456. https://doi.org/10.1093/jrr/rraa006.

Zhao, Feng, Shen, Jiayan, Lu, Zhongjie, et al., 2018. Abdominal DIBH Reduces the Cardiac Dose Even Further: A Prospective Analysis. Radiat. Oncol. (Lond. Engl.) 13 (1), 116. https://doi.org/10.1186/s13014-018-1062-6.

Zhao, Qianfeng, Liu, Bo, Sun, Qiushi, Jin, Yiqiang, 2023. Development and Validation of a Cost-Effective Virtual Reality Educational Tool to Reduce Anxiety and Improve Set-up Accuracy in Radiotherapy Patients. Cancer Med. 12 (5), 6161–6169. https://doi.org/10.1002/cam4.5348.

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